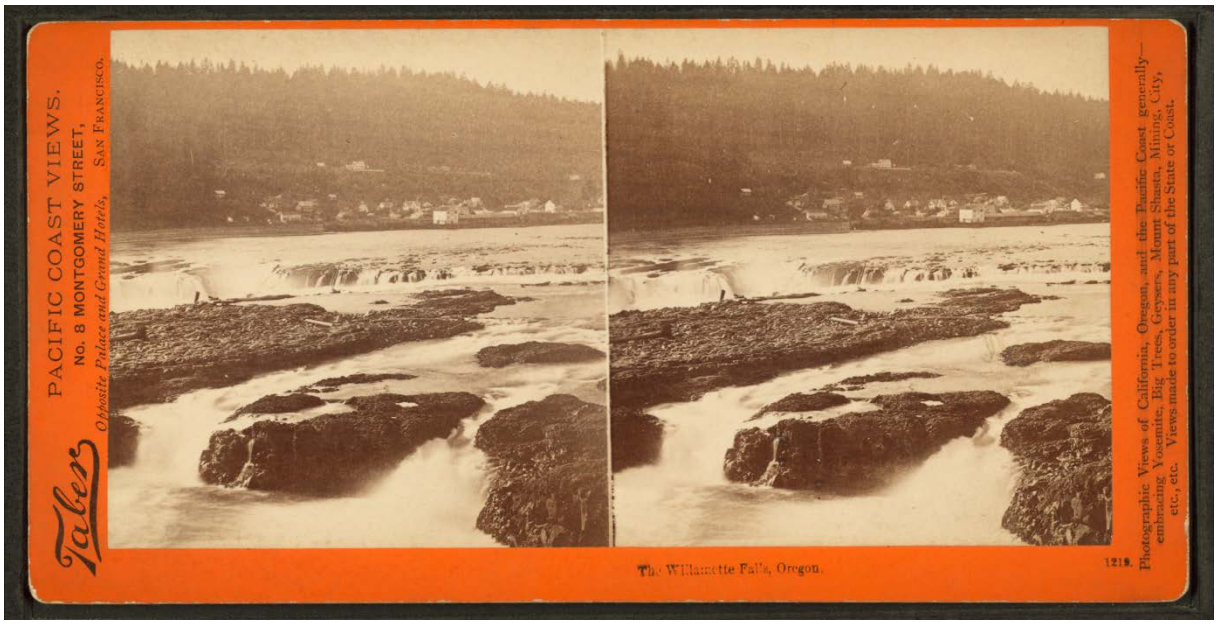
APPENDIX C

Detailed Biological Analysis

Viable Salmonid Population (VSP) Modeling of Willamette River Spring Chinook and Steelhead Populations



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Viable Salmonid Population (VSP) Modeling Of Willamette River Spring Chinook and Steelhead Populations

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Viable Salmonid Population (VSP) Modeling Of Willamette River Spring Chinook and Steelhead Populations

CHAPTER 1. INTRODUCTION AND OVERVIEW

1.1. Introduction

Due to substantial declines in adult returns, the Upper Willamette River (UWR) spring Chinook salmon Evolutionary Significant Unit and UWR steelhead Distinct Population Segment were listed as threatened under the U.S. Endangered Species Act (NMFS 1999a, 1999b, NMFS 2005). Among the potential factors for decline,13 Federally operated dams and reservoirs exist within the Willamette River Basin that are managed for flood control, recreation, irrigation, fish and wildlife management, and power generation. In response to the National Marine Fisheries Service's (NMFS) 2008 Biological Opinion, the U.S. Army Corps of Engineers (Portland District) and regional partners have developed a suite of proposed actions designed to enhance Chinook salmon and steelhead population abundance. The actions are focused primarily on fish passage at dams, but also address other issues such as water temperature control and supplementation with hatchery fish.

The goal of the effort described in this document is to assess the biological benefit to listed Chinook salmon and steelhead of the proposed actions within the basin. We have not attempted to model the effect of modified fish passage on populations of Bull trout (*Salvelinus confluentus*). In developing an approach to do this, we have relied on precedents established by previous efforts to assess population performance within the Willamette River basin. In particular, the Willamette Lower Columbia River Technical Recovery Team (WLC-TRT), developed methods to assess population performance using the Viable Salmonid Population approach (VSP; (McElhany et al. 2000). McElhany et al. (2006, 2007) present the relevant viability approach as applied to Willamette River populations. Further, the ODFW recovery plan for Upper Willamette spring Chinook and steelhead (ODFW and NMFS 2011) adopted a life-cycle modeling approach using Species Life-cycle Analysis Modules (SLAM; developed by NOAA's Northwest Fisheries Science Center - NWFSC). Our modeling efforts build upon these previous analyses.

In this report, we address modeling of the following populations (Figure 1.1):

> Spring Chinook salmon in the McKenzie, North Santiam South Santiam and Middle Fork Rivers;
>
> Steelhead in the North and South Santiam Rivers.

1.2. Modeling Strategy and Data

Modeling Willamette River anadromous salmonid populations presents several challenges. Life-history diversity is an important component of population dynamics, and hatchery influence is widespread. Other factors such as pre-spawn mortality and gas bubble disease are strong sources mortality. Further, each population has several production areas and habitat conditions are influenced by large structures that either block potential spawning and rearing areas or modify river conditions downstream. Thus an accurate portrayal of population dynamics must include these factors.

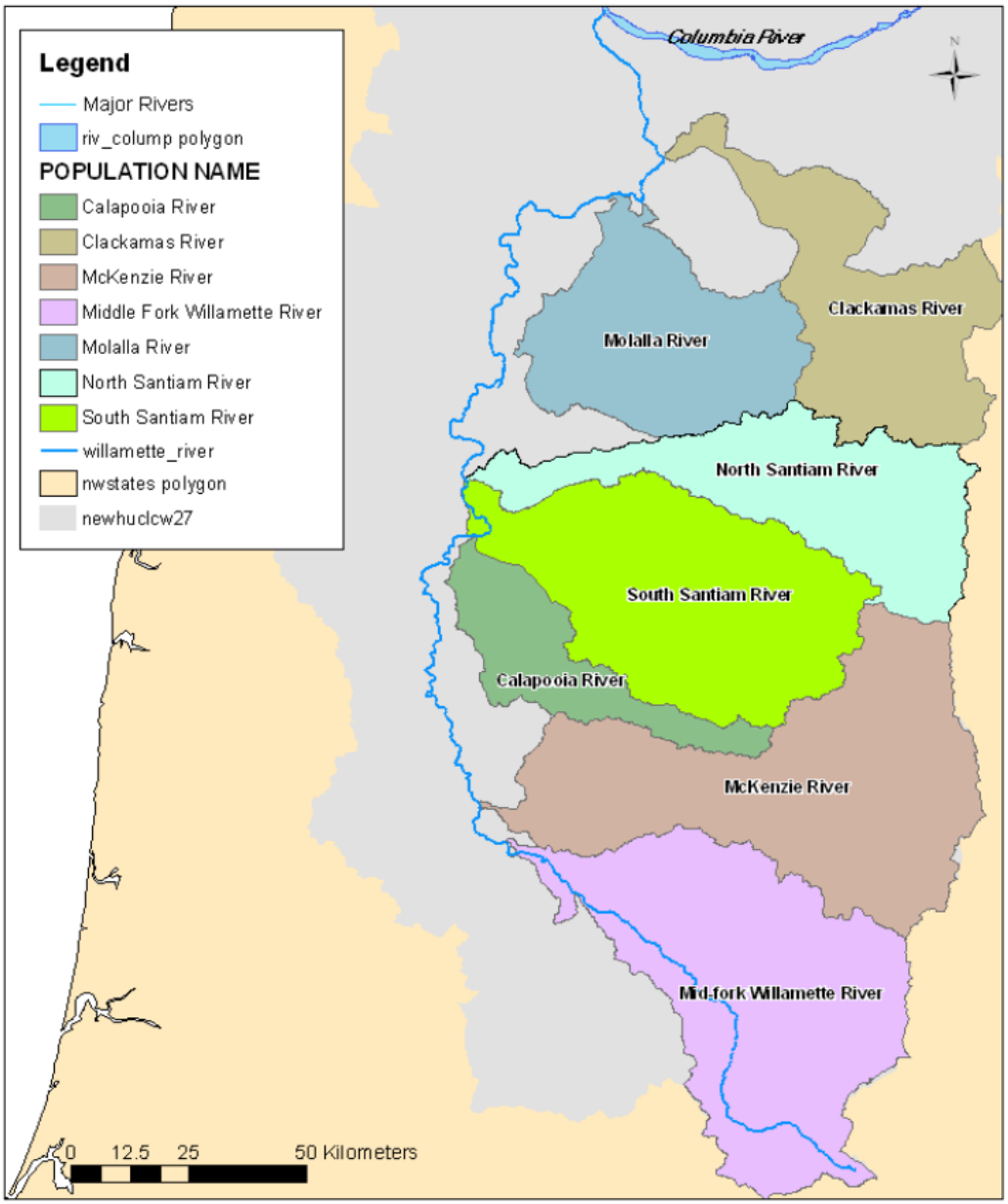


Figure 1.1: Populations of Spring Chinook in the Upper Willamette River Basin.

To populate model parameters, we relied on several types of data. The most desirable types of data are those derived from native studies. Fortunately, a strong research and monitoring program exists in the Willamette River, and data derived from local studies form the cornerstone of our analyses. In cases where local data were not available, we used information from the literature on other salmon populations. A critical component of the model is the survival and migration of juveniles in reservoirs. Establishing populations above high-head dams is primary feature of the mitigation strategies, but few data are available to determine what will happen as populations build in these new habitats. In particular, survival in the reservoirs and distribution of life-history strategies that determine migration timing are relatively unknown. For this important component of the life-cycle models, we conducted a series of workshops with local experts to estimate parameters and their ranges (see Chapter 3 for a fuller description). We found this activity to be

very successful because it forced regional experts to confront key uncertainties within the confines of a model structure that constrained ranges of estimates to be consistent with broader scale data.

Our approach was to populate the model with parameter estimates that were reasonable. After we compiled all the estimates into the model, we needed to adjust a few key parameters such that we represented recent baseline data (described in Chapter 3). Thus our Baseline alternative reflects current conditions and is consistent with recent adult returns and assessments of population viability. Our prospective modeling of management alternatives, then, can be looked upon as modeling effects of actions in terms of improvements to baseline conditions.

This modeling effort is an ongoing process where we will update the models as more information becomes available. Indeed, over the next few years, much more data will become available with the expansion of PIT-tag and telemetry studies and the construction of adult handling facilities. Finally, we see the sensitivity analyses as a critical component in the feedback loop between modeling and research and monitoring activities. Our sensitivity analyses identify model parameters that are influential and uncertain and thus important targets for future research.

1.3. TRT Population-Level Status

The VSP conceptual approach (McElhany et al. 2000) to identifying and evaluating the status of salmon and steelhead population relies on the assessment of four population parameters: (1) abundance, (2) population growth rate, (3) population spatial structure, and (4) diversity. Technical Recovery Teams (TRTs) in each of the Recovery Domains developed metrics for these parameters, metrics that are often specific to the life history characteristics of each species and quantity and quality of information available. For listed salmonids in the Upper Willamette River Basin, McElhany et al. (2006, 2007) present the relevant viability approach; however, it should be emphasized that, where new information has come to light, modifications in the viability criteria may be necessary.

1.4. Population Abundance and Productivity Criteria

In the 2003 viability report for the Willamette and Lower Columbia TRT (WLC TRT), McElhany et al. (2003) provided the following guidelines for abundance and productivity criteria:

ADULT POPULATION PRODUCTIVITY AND ABUNDANCE CRITERIA GUIDELINES
1. In general, viable populations should demonstrate a combination of population growth rate, productivity, and abundance that produces an acceptable probability of population persistence. Various approaches for evaluating population productivity and abundance combinations may be acceptable, but must meet reasonable standards of statistical rigor.
2. A population with a non-negative growth rate and an average abundance approximately equivalent to estimated historical average abundance should be considered to be in the highest persistence category. The estimate of historical abundance should be credible, the estimate of current abundance should be averaged over several generations, and the growth rate should be estimated with an adequate level of statistical confidence. This criterion takes precedence over criterion 1.

These guidelines recognize that a variety of approaches may be taken to evaluating abundance and productivity and several methods were discussed in the 2003 report. McElhany et al. (2006) more fully explored the types of analyses and metrics that are useful for estimating a population's

probability of persistence with reasonable statistical rigor and provide guidance on when each approach would be appropriate.

In the 2006 report, a generalized viability curve approach was presented. The "viability curve" approach utilized a combination of population abundance and productivity. This can be shown as an extinction risk iso-cline on a graph plotting population abundance against population productivity. Applying the viability curve approach requires two separate, but closely related analyses. The first analysis is describing the functional relationship between abundance, productivity, and extinction risk (i.e. drawing the curve). The second, related, analysis is determining the best metric for evaluating a given population relative to the viability curve. Chapter 2 presents our method for conducting such an analysis.

1.5. Diversity and Spatial Structure and Overall VSP

The VSP approach also considers population diversity and spatial structure. In essence, high total VSP scores correspond to properly functioning populations that are not only abundant, but also represent historical life-history diversity and occupy the historical range. We provide details of how we scored the Diversity and Spatial Structure criteria in Chapter 3.

Our overall approach was to develop a Life Cycle Model (LCM) for each population (Figure 1.2). We developed parameter sets that represented current (Baseline) conditions and future management scenarios. We used the LCM to estimate VSP component scores, and to then compute a total VSP scores. These VSP scores, then, were used to compare the performance of the various management alternatives (Figure 1.2).

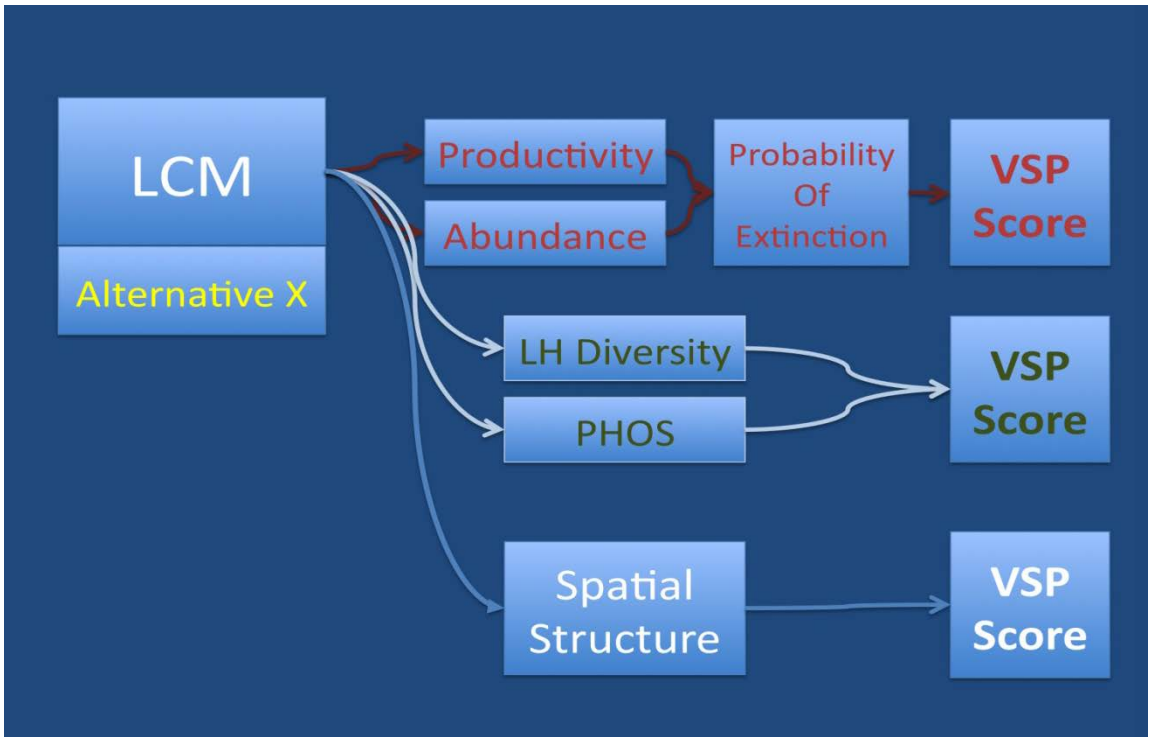


Figure 1.2: Schematic of how the Life-Cycle Model (LCM) feeds outputs for the VSP scoring. LH Diversity is Life-History Diversity and PHOS is Proportion of Hatchery Origin Spawners.

1.6. Overview of Life-Cycle Modeling

We used Species Life Cycle Analysis Modules (SLAM), a free software application developed by (McElhany et al. 2012)), to model life-cycle dynamics, and ultimately to estimate the benefits of dam operational and structural alternatives to populations of spring run Chinook salmon in the Willamette Basin. The SLAM model has had several applications to Willamette River spring Chinook populations. Oregon Department of Fish and Wildlife (ODFW) developed SLAM life cycle models for McKenzie and North Santiam Rivers as part of the Upper Willamette Basin Conservation and Recovery Plan (ODFW and NMFS 2011). R2 Resource Consultants, Inc. used the ODFW model structure and parameters as a starting point, and then used the models to begin to address proposed actions at projects (Hendrix et al. 2012a, b). In 2012, Northwest Fisheries Science Center (NWFSC) conducted a review of existing models, and then proposed modifications such as explicitly including life history diversity. NWFSC then continued with model development to meet the USACE and regional partners' objectives of understanding the implications of different alternatives for downstream passage, water quality, and habitat improvement on the life cycle of spring Chinook.

This section provides an overview of the life-cycle modeling we conducted. Chapter 4 provides specific parameter values for the McKenzie River Chinook model, and Chapter 5 provides parameter estimates for the North Santiam model. The results presented in Chapters 4 through 9 are based on simulations run with SLAM. We are currently developing a version of the model in R code (R_Core_Team 2013), and the results of the sensitivity analyses used this version. We plan to convert all of our modeling to R version because of its flexibility.

1.7. Overview of SLAM Modeling

SLAM moves fish through their life cycle (Figure 1.3) by means of splits (which preserve the number of fish and routes them into different pathways and river reaches) or transitions (which alter fish numbers by either removing fish due to mortality or adding fish due to reproduction). What follows is a description of SLAM model parameters and values used in each of five categories: 1) Productivity, capacity, and survivals; 2) Splits; 3) Data files; 4) Dynamic drivers and influencers; and 5) Initial Values.

All parameter values listed in chapters 4 through 9 correspond to the baseline scenario in SLAM. The baseline scenario represents current conditions and natural origin abundances. Alternative scenarios to the baseline scenario are also modeled in SLAM and are listed at the end of chapter 4 through 9 in a section named Alternative Scenarios. These alternative scenarios are operational or structural modifications that change the survival of fish (e.g., improvements to downstream dam passage).

The SLAM Chinook salmon models (Figure 1.3) can be summarized as follows. Natural and hatchery origin adults return to the river of interest (for example, McKenzie River) and are allocated to one of various reaches, based on the proportion of juveniles that exited each reach four years earlier, or to the hatchery broodstock program. A proportion of surviving hatchery origin adults either spawns in the wild or returns to the hatchery. Within each reach, some adults (natural and hatchery origin) experience pre-spawn mortality (PSM) while others successfully spawn. A proportion of the eggs (now considered natural origin) survive to emergent fry stage, and those fry that survive are assigned to one of three life history strategies (spring sub-yearling, fall sub-yearling, and 2nd spring yearling).

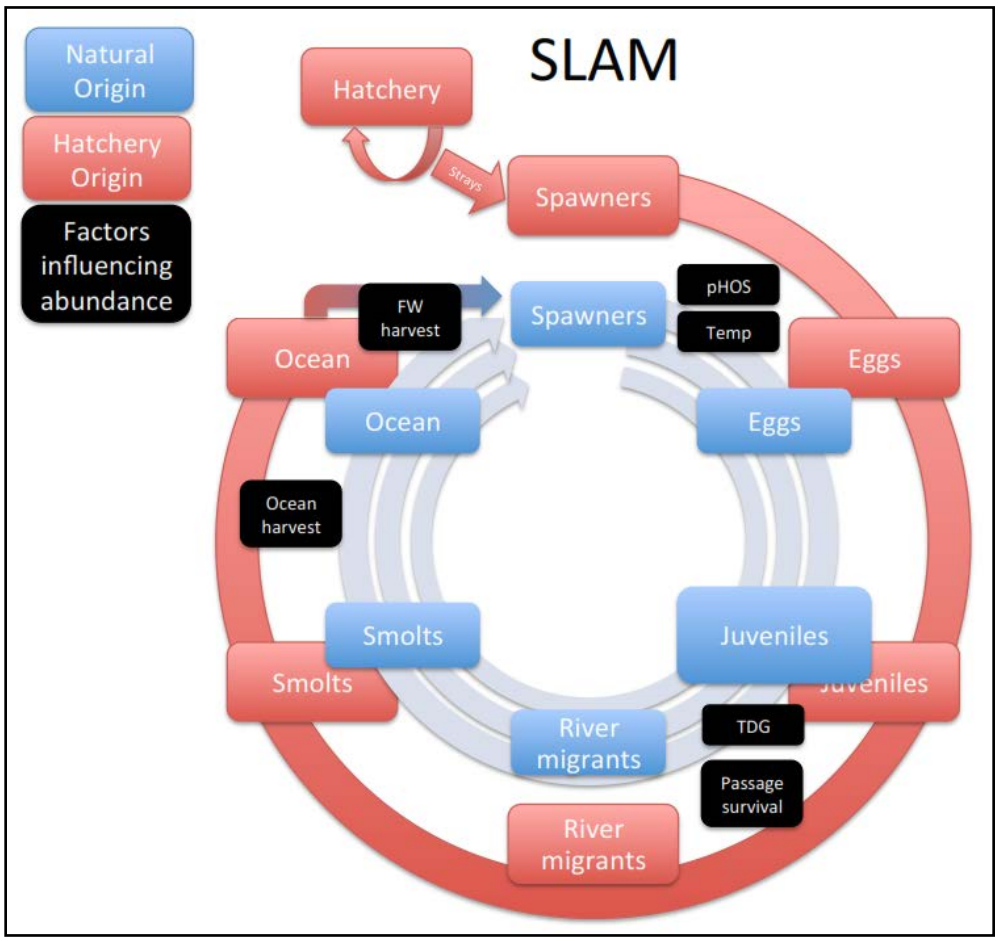


Figure 1.3: Representation of the life cycle of spring Chinook salmon used in Species Life Cycle Analysis Module (SLAM). Red and blue parts of the figure correspond to the life cycle of hatchery origin and natural origin, respectively. Black boxes represent a selection of anthropogenic impacts to survival; proportion of hatchery origin spawners in the wild (pHOS), total dissolved gas (TDG), dam passage survival, and ocean and freshwater (FW) harvest. The three blue circular arrows in the middle represent three life history strategies (spring sub-yearlings, fall sub-yearlings, and 2nd spring yearlings, (Mattson 1962) that are modeled.

Juveniles emigrating through dams or incubating and rearing in the reach immediately below the dam may be subject to gas bubble disease and mortality when total dissolved gas (TDG) exceeds specific supersaturation thresholds. Surviving juveniles from each reach are pooled and move out past Willamette Falls and become smolts. Following the smolt stage, they enter the ocean as two-year-olds. A proportion of three-year-old fish are either harvested, return to the river, or remain in the ocean to become three-year-olds, and this is repeated for four-, five, and six-year-olds in the ocean.

The SLAM model also simulates the hatchery program. Specifically, juveniles produced from the hatchery are released, and a proportion of those survive to the smolt stage. Hatchery origin fish also enter the ocean as two-year-olds, and like natural origin fish they are either harvested, return to the river, or remain in the ocean to become three-, four-, five-, and six-year-olds. Hatchery origin fish that return to the river will also experience freshwater harvest, and those that survive will return to the hatchery or to a reach to potentially spawn in the wild.

The SLAM models of steelhead can be summarized as follows (see Figure 1.4). First time spawner adults return to their natal river (for example, North Santiam River) and are allocated to one of various reaches based on the proportion of juveniles that exited each reach four years earlier. Within each reach some adults successfully spawn and die, while others outmigrate to the ocean following spawning (kelts). A proportion of these kelts may return in subsequent years to become repeat spawners. A proportion of the eggs survive to the emergent fry stage, and those that survive are assigned to one of three age trajectories (age 0, age 1, and age 2). Juveniles emigrating through dams or incubating and rearing in the reach immediately below the dam may be subject to gas bubble disease and mortality when total dissolved gas (TDG) exceeds specific supersaturation thresholds. Surviving juveniles from each reach are pooled and move out past Willamette Falls and become smolts. Following the smolt stage, they enter the ocean as two-year-olds. A proportion of two-year-old fish are either harvested, return to the river, or remain in the ocean to become three-year-olds, and this is repeated for four- and five-year-olds.

SLAM simulations consist of 500 runs and each run is 105 years (including a 5-year burn-in period). Presently, we are using SLAM version 1.1.beta.32 found at http://conserver.iugo-cafe.org/user/SLAM/SLAM.

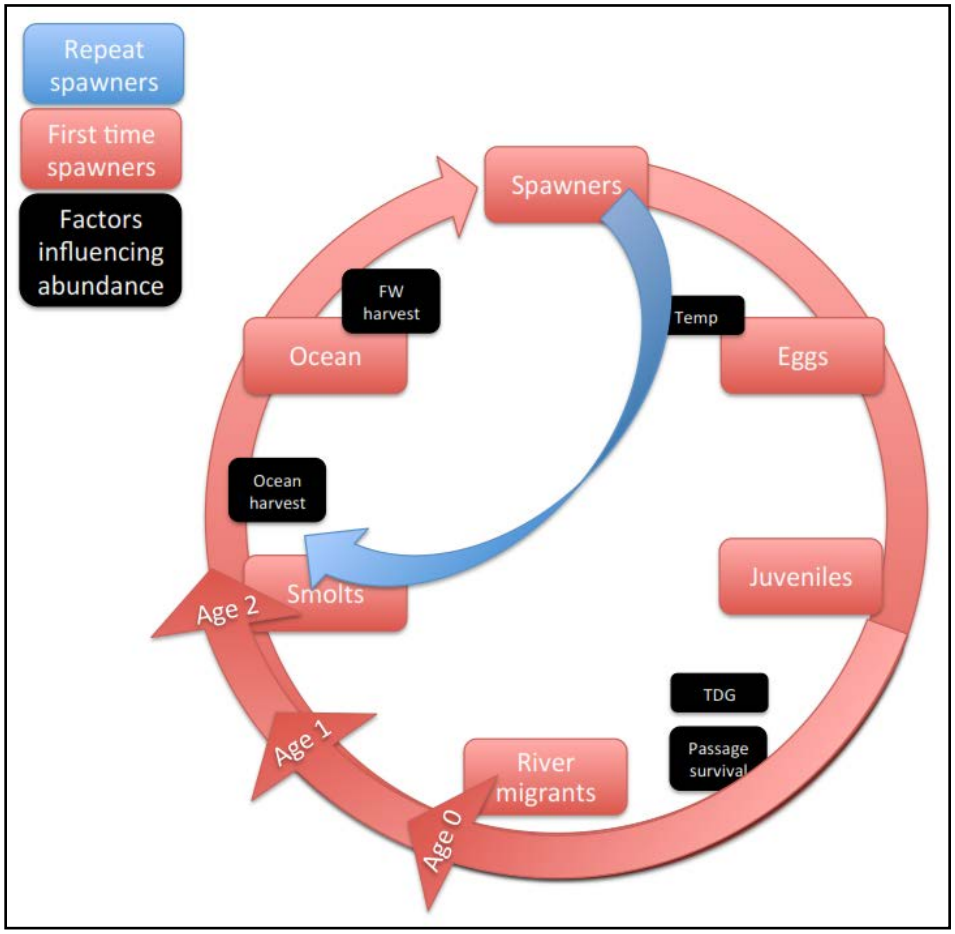


Figure 1.4: Representation of the life cycle of winter steelhead used in Species Life Cycle Analysis Module (SLAM). Red and blue parts of the figure correspond to the life cycle of first time and repeat spawners, respectively. Black boxes represent a selection of anthropogenic impacts to survival; total dissolved gas (TDG), dam passage survival, and ocean and freshwater (FW) harvest. The three red circular arrows represent three age classes (age 0, age 1, and age 2) that are modeled.

1.8. Estimating VSP Scores and Uncertainty from Productivity and Abundance Model Results

Before we describe our approach to estimating VSP based on productivity and abundance, we provide some definitions:

Run: A single iteration of the model with a given set of parameters for a set number of years (usually a hundred years). For each run we keep track of the population trajectory so we can calculate a suite of model metrics.

Alternative: A specific set parameters that represent a particular management scenario. The "Baseline" alternative represent current conditions. All other alternatives represent a proposed future management scenario.

For each alternative, we run the model 500 times to capture the variability in model outputs. To represent productivity and abundance, we produce the following outputs:

Productivity: In keeping with previous analyses (e.g., Interior Columbia Technical Recovery Team and Zabel, 2007), we calculate productivity as recruits (measured as returning spawners) per spawner measured at relatively low abundance. This represents the ability of a population to rebound at low abundance. At higher abundances, populations tend to hover about an equilibrium level, so recruits per spawner approaches unity, and does not distinguish among alternatives. Here we captured low abundance by taking the geometric mean of recruits per spawner for the first twenty years of each run (Note that we ignore the first 5 years, or one generation, because the model is quite variable during this initialization period). We chose this because we observed that this is a typical amount of time for a population to reach an equilibrium level from current conditions.

Abundance: With this measure, we are capturing population abundance at equilibrium. Accordingly, we measure abundance for years 26-105. In keeping with precedent (e.g., Interior Columbia Technical Recovery Team and Zabel, 2007), we calculated the geometric mean of abundance across each run. Geometric mean was used because population abundances tend to have a logarithmic distribution, characterized by peaks in abundance, and the geometric mean down-weights the peaks.

1.8.1. VSP Score for Abundance and Productivity

Consistent with the WLC TRT, we calculated the abundance and productivity VSP score as measure of risk, as defined as probability of following below extinction thresholds. Below we describe the methods to do this.

Probability extinction: We adopted the definition of quasi-extinction that was established by the WLC TRT as applied to the Willamette River populations. P(QET) is the probability of falling below the quasi-extinction threshold (QET) within T years, where T = 100. A population is considered to have fallen below the threshold if it drops below the QET threshold, on average per year, over a four-year period. We computed P(QET) for each alternative by compiling the proportion of 500 runs that fell below the QET threshold. We chose 500 runs because our estimates of P(QET) stabilized after that number of runs.

The quasi-extinction threshold is determined for a population based on its historical size and complexity of subpopulations. The WLC-TRT set a QET of 250 spawners per year for the McKenzie spring Chinook population, and a QET of 150 for the North Santiam spring Chinook population.

McElhany et al. (2000) provide guidelines on how to convert P(QET) into VSP scores (Table 1), with 0 indicating a population is either extinct or at a very high risk of extinction, and 4 indicating a population is at very low risk of extinction.

Table 1 Population persistence probabilities associated with persistence categories (copied from 2003 viability report).

Population Persistence Category	Probability of Population Persistence in 100 Years	Description
0	0–40%	Either extinct or very high risk of extinction.
1	40–75%	Relatively high risk of extinction in 100 years.
2	75–95%	Moderate risk of extinction in 100 years.
3	95–99%	Low ("negligible") risk of extinction in 100 years (viable salmonid population).
4	>99%	Very low risk of extinction in 100 years.

Based on the Table 1, we developed a piecewise linear translation between VSP score and probability of extinction (Figure 1.5). Thus, to estimate VSP scores for productivity and abundance $VSP_{P\&A}$, we first calculated P(QET) based on 500 runs of a specified alternative. We then used the piecewise linear equation to convert P(QET) to $VSP_{P\&A}$.

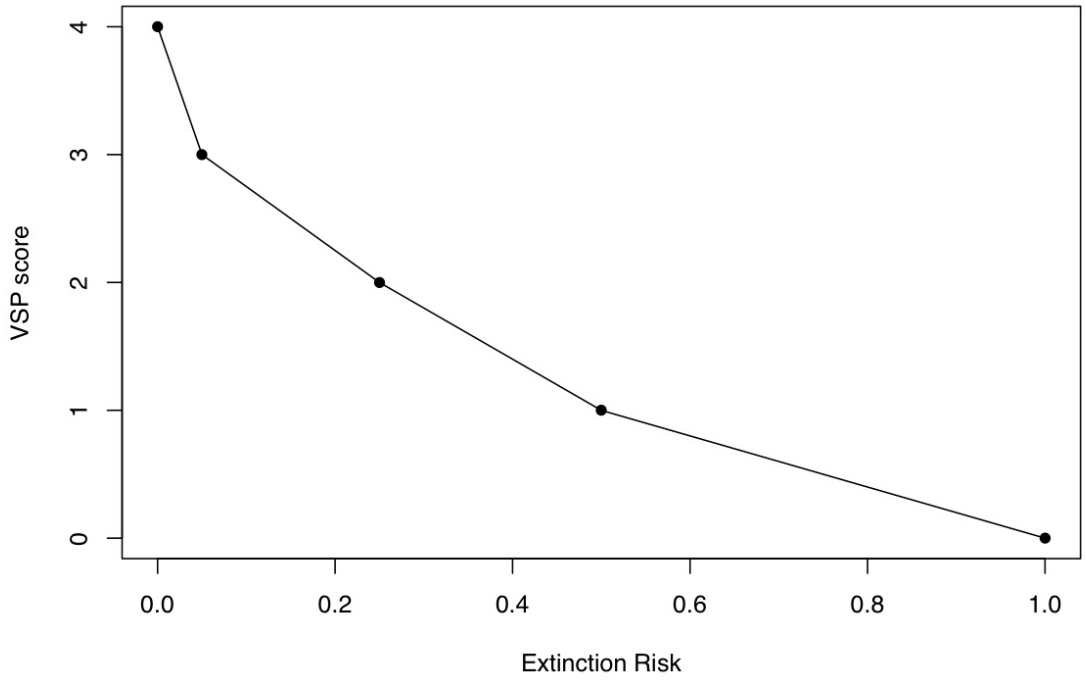


Figure 1.5: Relationship between VSP score for productivity and abundance and P(QET).

1.8.2. Calculating Uncertainty in VSP Scores for Productivity and Abundance

In addition to calculating $VSP_{P\&A}$ from life-cycle model output, we also estimated uncertainty about the scores. To do this, we adopted the following several step approach. First we defined the response surface that related P(QET) to productivity and abundance. Then we converted this surface to $VSP_{P\&A}$ scores. Then we plotted the 500 runs per alternative on this surface to generate the distribution of VSP scores for an alternative. From this distribution of $VSP_{P\&A}$ scores, we could then produce estimates of variance and confidence intervals for $VSP_{P\&A}$ scores for a given alternative.

To generate the response surface, we used logistic regression to relate P(QET) to the Productivity and Abundance metrics, described above. For each of the 500 runs within an alternative, we determined whether the individual run fell below QET. If it did, we designated it as 1; otherwise it was designated as 0. We did this across all alternatives to create a data file with each line indicting whether the run fell below QET or not, and also the mean Productivity and Abundance for the run. We then performed a logistic regression to develop a response surface for probability of extinction versus Productivity and Abundance using the following equation:

$$P(QET) = \beta_0 + \beta_P \cdot P^a + \beta_N \cdot N^b$$

where *P* is Productivity and *N* is abundance. Figure 1.6 demonstrates a response surface based on McKenzie River spring Chinook.

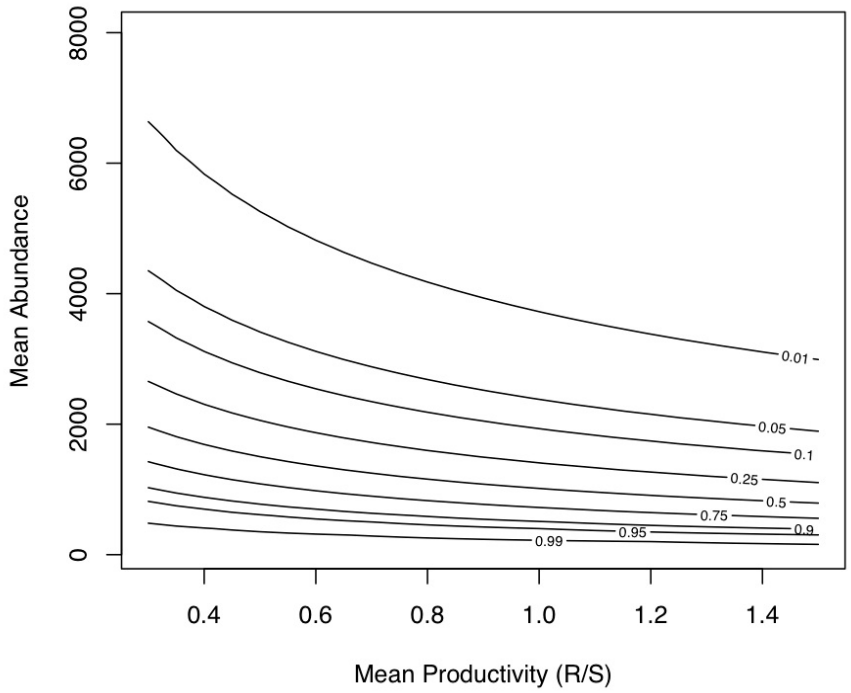


Figure 1.6. Isoclines of extinction probability on a plot of mean abundance versus mean productivity for the McKenzie spring Chinook population.

Next, we translate the response surface for P(QET) to $VSP_{P\&A}$ scores using the equation depicted in Figure 1.6. Figure 1.7 demonstrates a response surface for McKenzie spring Chinook.

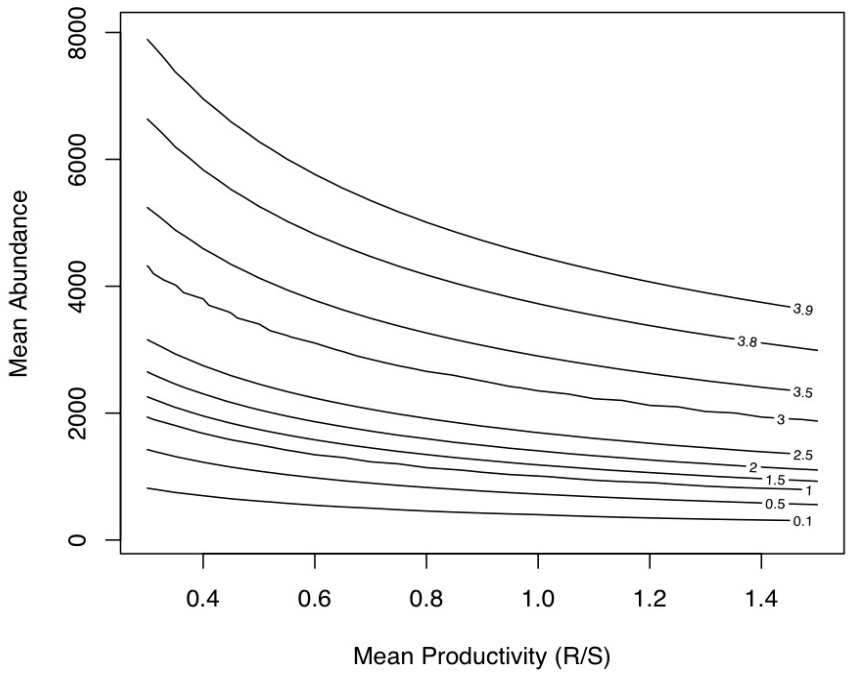


Figure 1.7: Response surface of VSP score for productivity and abundance versus mean productivity and abundance for the McKenzie spring Chinook population.

For a single alternative, we can then plot mean productivity and abundance for individual runs on the response surface, along with the grand mean for all runs.

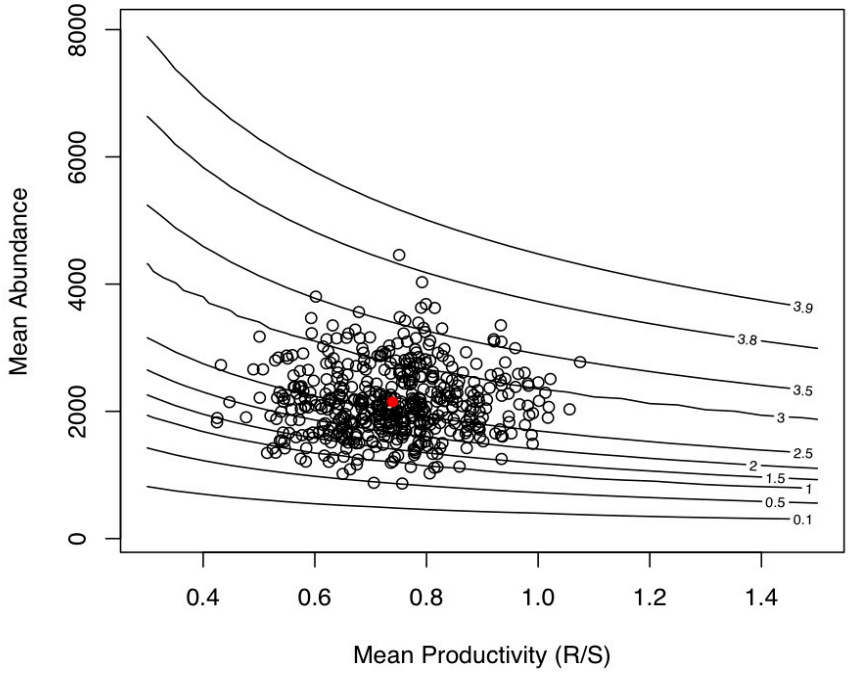


Figure 1.8: Mean abundance versus mean productivity for individual model runs under baseline conditions. The solid red point is the grand mean across all runs. The isoclines represent VSP scores for productivity and abundance.

Based on Figure 1.8, we can then determine a $VSP_{P\&A}$ score for each run, and then determine the distribution of these scores (Figure 1.9). From this distribution of scores, we can derive uncertainty measures (variance, confidence intervals) for each alternative, and we present the uncertainty in model outputs in the results presented in Chapter 4 through 9.

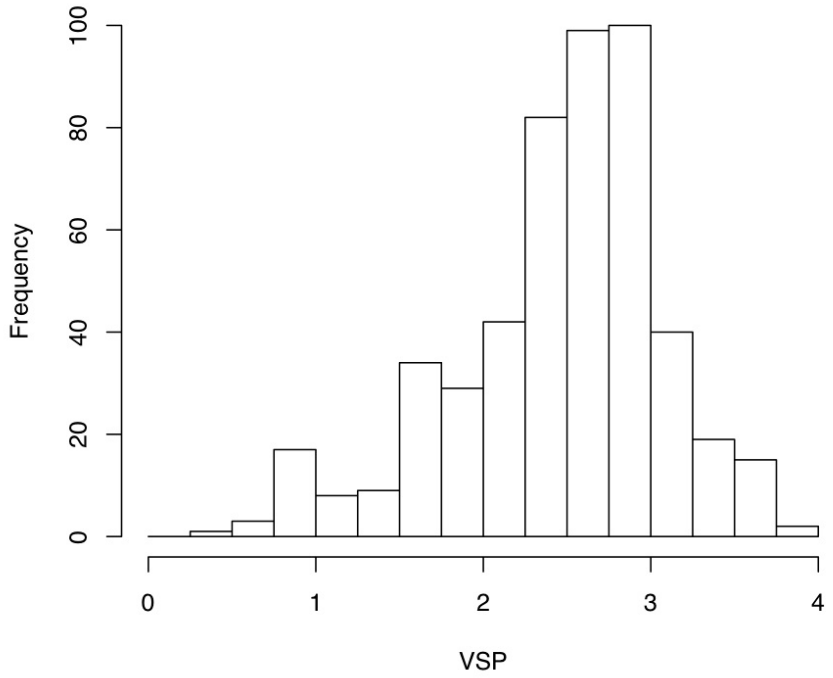


Figure 1.9: Distribution of VSP scores (productivity and abundance) for McKenzie River spring Chinook under baseline conditions.

1.8.3. Weighting of VSP Scores

We also calculate VSP scores for Diversity (VSP_D) and spatial structure (VSP_S) as described in Chapter 3. To combine scores, we use the following weighting:

$$VSP_T = \frac{4 \cdot VSP_{P\&A} + VSP_D + VSP_S}{6}$$

Each VSP component has an associated variance. To estimate variance about the combined score, we use the following formula (Mood et al. 1974), and assume independence across components:

$$\mathrm{var}_T = \sum_1^3 w_i^2 \cdot \mathrm{var}_i$$

1.9. Comparison of VSP Scoring and NOR Abundance

In assessing the performance of passage/operations alternatives there has been some discussion of the relative merits of using the total VSP score or NOR abundance as the comparative metric of choice. Both metrics provide useful indicators of how Chinook salmon and steelhead respond to the passage alternatives and while there is general agreement in alternative ranking, there are important differences between the two.

The VSP parameter includes multiple measures of population performance based on the definition of a viable salmonid population (McElhany et al 2000) and the criteria developed by the Lower Columbia and Upper Willamette River Technical Recovery Team (McElhany et al. 2007). The three components of the VSP score include: persistence probability (1 – extinction risk), diversity, and spatial structure. Persistence is measured as the probability of a population falling below the quasi-extinction threshold (QET) for one generation, as set by the TRT, and not the absolute abundance (falling to zero). This is one of the principle distinctions between VSP and abundance. Additionally, the VSP persistence score is not linear but sensitive to changes especially near the threshold 95% persistence level, 5% probability of extinction (Figure 1.10). Persistence calculations account for the absolute abundance, population variability, and QET, effectively asking the question, how many fish are enough to guarantee sustainability?

Diversity and spatial structure considerations together influence a third of the VSP score. These parameters are also related to NOR abundance, but as with persistence probability the correlation weakens as abundance increases. Spatial structure scores related to accessibility and for the SLAM model this was directly related to passage survival and above dam reach capacity. The spatial structure score is maximized as river reaches occupied by the population become self-sustaining; because of other impassable man-made barriers and highly degraded reaches this maximum is not necessarily 4.0. Diversity scores can be varied by a number of operational changes in hatchery/harvest operations or life history selectivity in passage alternatives. Diversity scores were influenced by relative NOR/HOR abundance and juvenile life history variation. We did not explore the full range of hatchery options and instead utilized manipulations that least deviated from status quo; maintaining existing hatchery juvenile production levels and hatchery harvest levels. Other hatchery alternatives may result in larger changes in the modeled VSP diversity score, and with input and agreement from co-managing agencies in selecting appropriate changes in hatchery operations those option could be explored further.

Of the three VSP parameters, diversity is least correlated to absolute NOR abundance. Together the VSP parameters provide a more broadly based measure of the population performance than absolute NOR abundance. The basis for the VSP score is sustainability.

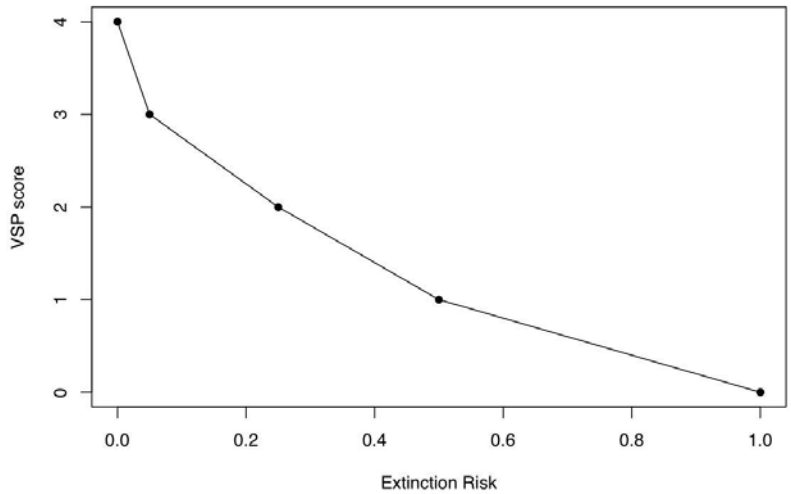


Figure 1.10: Relationship between VSP persistence score (productivity and abundance) and p(QET).

In contrast, abundance relates simply the number of NORs and is ultimately limited by the capacity of the reaches. While increasing abundance decreases the risk of extinction and more fish are

better than fewer, the abundance parameter alone will not indicate how many NORs is enough to sustain the population into the foreseeable future. There will be some diminishing net benefit with additional NORs as the extinction risk approaches zero. Ultimately, abundance will plateau as the river reaches approach capacity (Figure 1.11). In all but the lowest capacity estimates, NOR abundance will likely plateau long after the VSP persistence score is maximized.

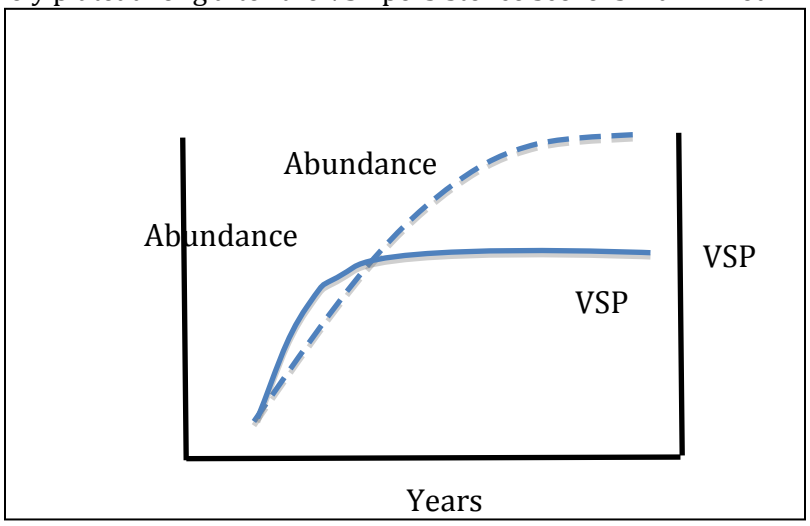


Figure 1.11. Changes in abundance and overall VSP score in a hypothetical growing population over time.

Some considerations should be given to estimate accuracy. The relative complexity of VSP scoring may be more sensitive to input uncertainty than abundance, although this has not be explicitly tested. QET and parameter variability for populations strongly influence the overall VSP score, but have little influence on median NOR abundance. Figure 2 gives a simplification of how VSP scores and abundance relate, with VSP scores reaching a plateau as the population reaches a high probability of persistence. It may be useful to consider abundance as relating more to broad-sense recovery than simply sustainability.

In this section we have underscored the differences between abundance-based and VSP-based metrics to compare passage alternatives for Chinook salmon and steelhead at Upper Willamette River federal dams. It is not our intention to recommend one metric over the other, but to simply relate their strengths and weaknesses given the existing available data.

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CHAPTER 2. OVERALL CONCLUSIONS

2.1. McKenzie River Spring-Run Chinook Salmon

2.1.1. Overview

Developing the SLAM model for McKenzie River spring-run Chinook salmon was relatively simple compared to the other basins. Currently, upstream adult access is provided via trap and haul and downstream juvenile passage is provided through existing dam structure outlets, rather than a dedicated fish passage structure. Returning adults are enumerated at both Leaburg Dam and Cougar Dam, and juvenile outmigrants have been monitored both above and below Cougar Dam (Figure 2.1). Furthermore, the installation of a temperature control structure has reduced downstream incubation and temperature anomalies. Of the four basins to be considered in this SLAM analysis, the McKenzie River is the most intensely studied and operationally the simplest (with control structures in place and a single reach above a single dam). In contrast to the other basins, SLAM outputs vary predominately according to passage survival and DPE, with other parameters being similarly shared in common.

A number of potential alternatives, including both structural and operational modifications to Cougar Dam, were analyzed using the McKenzie River SLAM model. Based on preliminary results, the Floating Screen Structure (FSS) and Floating Screen Structure with Tower (FSS-T) alternatives were the most effective at supporting naturally-produced spring-run Chinook salmon above Cougar Dam, with the FSS-T alternative resulting in the highest median natural origin recruit (NOR) spawner abundance (12,954). These alternatives were further analyzed with slight modifications in passage conditions to determine thresholds for population persistence.

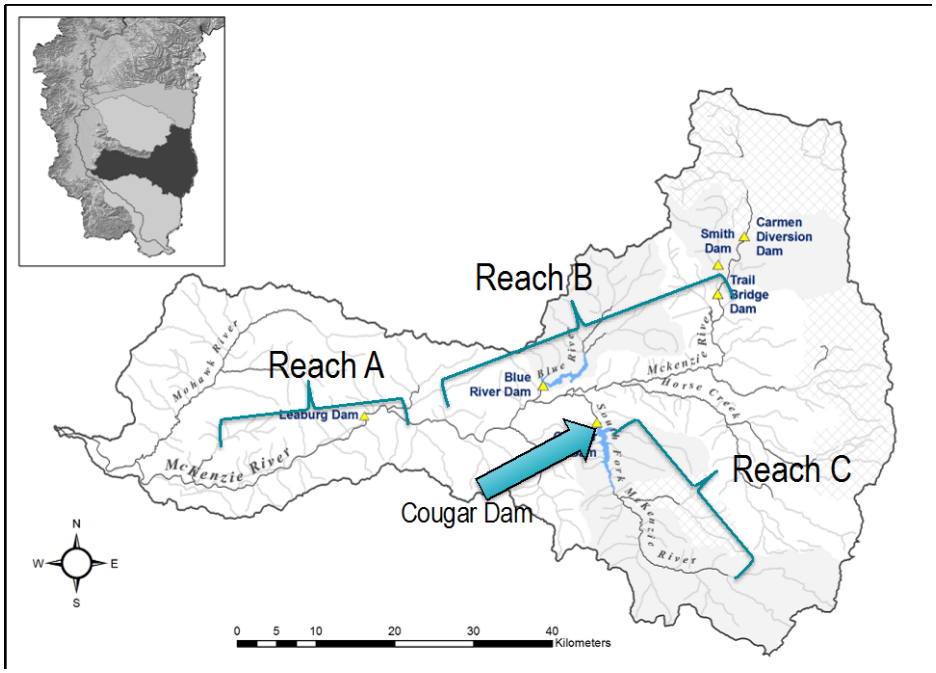


Figure 2.1: Map showing McKenzie River Basin and the three reaches (A, B, and C) that are modeled in SLAM; Reach A corresponds to mainstem McKenzie River downstream of Leaburg Dam, Reach B corresponds to mainstem McKenzie River upstream of Leaburg Dam excluding South Fork McKenzie River upstream of

Cougar Dam, and Reach C corresponds to South Fork McKenzie River upstream of Cougar Dam. Map provided by M. Sheer.

2.1.2. Abundance and Productivity

The projected NOR spawner median abundance of 12,954, and more so the upper bound of this estimate of over 20,000 adults, was considered by some, but not all, reviewers as being too high. Median abundance was related to capacity estimates, primarily for Reach C, above Cougar Dam. SLAM output for the FSS alternative using greatly reduced capacities did lower the absolute abundance, but did not appreciably change the extinction risk scores. We do not believe that a capacity of nearly 8,000 spawners for Reach C is unrealistic (this is approximately half of the Parkhurst et al. 1950 estimate), and some, but not all, reviewers agreed. The upper and lower bounds are related to the confidence intervals bounding a number of survival parameters and reflects uncertainty. In contrast to Reach C, the capacity of Reach B (the mainstem McKenzie above Leaburg Dam) is relatively low. This reach is currently accessible and geographically quite extensive, yet based on current monitoring is at a fraction of its historical capacity. It is unclear to what degree habitat is limiting production in Reach B and what, if any, restoration actions are possible. Additionally, we cannot predict to what extent NOR adults returning to Reach C might instead stray into the adjacent Reach B, especially when Reach C is near or at capacity. Finally, a number of parameters including: harvest, mainstem mortalities, prespawning mortalities; were held static or influenced by set environmental time series. Management changes in harvest or shifts in climatic conditions would likely alter the SLAM abundance and productivity output.

When we look across all alternatives for McKenzie River spring Chinook we see that there is a strong (nonlinear) relationship between mean productivity and abundance, as defined in Chapter 1 (Figure 2.1). This suggests that alternatives that increase abundance also increase productivity. Further, there was also a nonlinear relationship between VSP score and abundance (Figure 2.2). As expected, as abundance increases, a threshold is approached, above which there is little to no increase in VSP scores with increasing abundance.

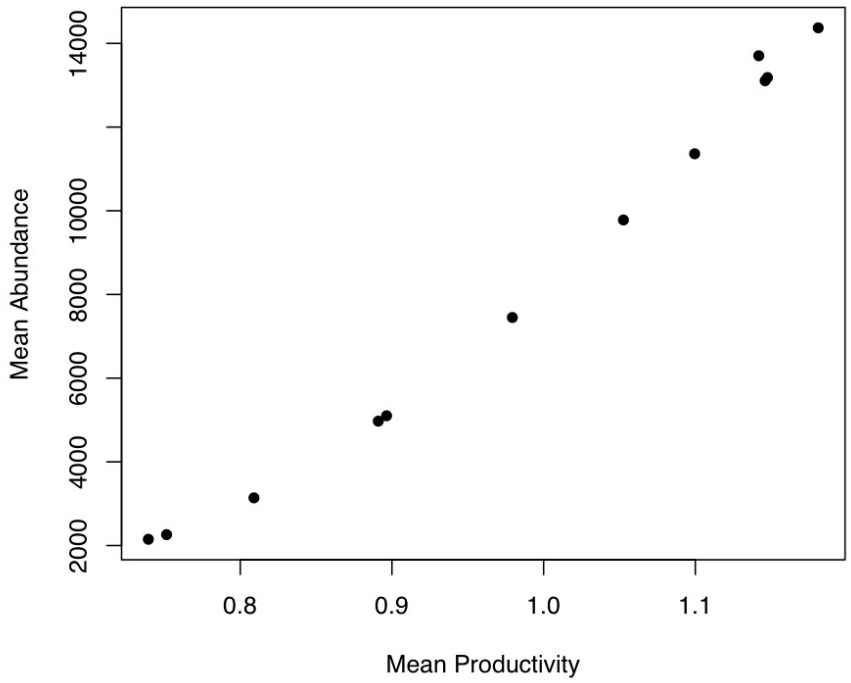


Figure 2.1: Relationship between mean Abundance and Productivity across alternatives for McKenzie River spring Chinook.

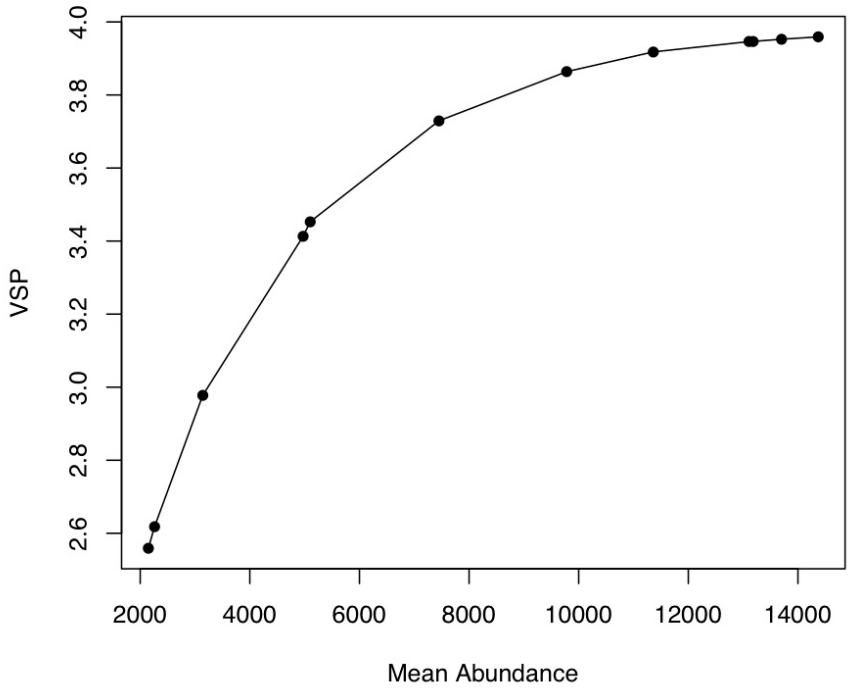


Figure 2.2: Relationship between VSP score (Productivity and Abundance) and Mean Abundance across alternatives.

2.1.3. Diversity

In most of the SLAM model alternatives, where Reach C (above Cougar Dam) was near replacement, sufficient numbers of juvenile life-history types were produced throughout the basin. For the FSS-T and FSS alternatives, the abundance of all three life histories emigrating from McKenzie was more than adequate to ensure the persistence of the life-history trajectories. It should be noted that model output does not adjust for potential changes in stream and reservoir habitat below or above Cougar Dam as a result of the operational differences among alternatives and how those changes might influence the life-history trajectories of outmigrating juveniles.

The proportion of hatchery-origin spawners (pHOS) varied among the alternatives. Changes in pHOS were primarily driven by increases in the number of NORs either by directly altering the ratio of the two, or by influencing the proportion of adults retained at the hatchery rack, the number of hatchery-origin recruits (HORs) passed above the dam, or the proportion of NOR fish retained for hatchery broodstock use (pNOB). Reductions in pHOS or increases in pNOB, in turn, reduce the level of domestication in the population, and improves the reproductive fitness of both NORs and HORs with a cascading effect on overall NOR abundance. The SLAM model allocated NORs to hatchery broodstock on a proportional basis, so as NOR abundance increase so did the number of NORs utilized in the broodstock, increasing pNOB. Reduction in pHOS also improves the hatchery portion of the diversity VSP score. Of the assessed alternatives, only Drawdown with Regulating Outlet did not reduce median pHOS to less than 10% (a management goal). It should be noted that a "no hatchery" option was not assessed; the hatchery retention approach was utilized to achieve hatchery reduction benefits while retaining hatchery harvest social benefit.

Both the life history diversity and hatchery effects criteria are based on simplified outputs and do not capture the complex interactions that occur in the river. For example, how factors such as "juvenile life-history stage at dam passage" can alter the life history trajectory of juvenile salmonids is unknown. Similarly, it is not clear how juvenile life history trajectories will respond in higher densities in an increasing population. Other life history traits have not been studied extensively enough in the Upper Willamette River Basin to develop even simple relationships. Additionally, while recent studies have focused on the reproductive fitness of hatchery-origin spawners, little is known regarding the re-adaption of hatchery propagated fish to natural conditions.

2.1.4. Spatial Structure

The simple spatial structure criteria used in the SLAM model was very useful in evaluating the productivity of Reach C. While the metric (achieving replacement above the Dam) was not specifically identified by the TRT, it did capture the essence of the Spatial Structure component – the ability of habitat to contribute to long-term population persistence.

Population performance above the dam in the McKenzie SLAM model is almost directly correlated to differences in the Fish Benefit Workbook. The model does assume that colonizing adults can find appropriate habitat, and that the presence of spawning adults does not change habitat quality over several generations.

2.1.5. VSP Scores for McKenzie River Chinook

For each alternative run in SLAM, four categories of model output are produced; abundance and productivity, proportion of hatchery origin spawners, life history diversity, and spatial structure (see Chapter 1, Parameterization of VSP Criteria). We generated VSP scores for each of these categories and a Total VSP score. Overall, three alternatives FSS-T, FSS 1571, and FSS 1571 80,

yielded the highest Total VSP Score (median of 3.8), while Baseline conditions yielded a median score of 2.7 (Table 2.1).

Table 2.1: McKenzie River Chinook salmon median VSP scores for each alternative. 95% confidence limits are noted in parentheses for each of the four categories (abundance and productivity, pHOS, life history, and spatial structure), while standard deviations are in parentheses for total VSP score.

	VSP Abundance and Productivity	VSP pHOS	VSP Life History	VSP Spatial Structure	Total VSP Score
FSS-T	4.0 (3.8-4.0)	3.9 (3.7-3.9)	4.0 (-)	3.0 (2.7-3.0)	3.8 (1.2)
FSS 1571 80	4.0 (3.7-4.0)	3.9 (3.9-4.0)	4.0 (-)	3.0 (2.7-3.0)	3.8 (1.1)
FSS 1571	3.9 (3.6-4.0)	3.9 (3.5-4.0)	4.0 (-)	3.0 (2.7-3.0)	3.8 (0.9)
FSS 1571 40	3.5 (2.5-3.9)	3.8 (2.1-3.9)	4.0 (-)	3.0 (2.7-3.0)	3.5 (0.2)
Delay Refill	3.4 (2.4-3.9)	3.7 (2.0-3.9)	4.0 (-)	3.0 (2.7-3.0)	3.4 (0.2)
Drawdown RO	2.8 (1.9-3.4)	2.5 (1.8-3.9)	4.0 (3.5-4.0)	2.0 (2.0-3.0)	2.7 (0.4)
Baseline	2.6 (1.6-3.0)	2.4 (1.5-2.8)	4.0 (3.5-4.0)	2.0 (-)	2.6 (0.4)

2.2. North Santiam River Spring-Run Chinook Salmon

2.2.1. Overview

Conditions in the North Santiam River are substantially different from those found in the McKenzie River, and the resulting SLAM model version for the spring-run Chinook salmon population reflected this difference. Firstly, demographic information regarding the status of spring-run Chinook salmon is relatively poor prior to recent improvements in adult counts at Bennett Dam. In addition, adults (hatchery origin only) have been transported above the dams only recently, so there is little empirical information on upstream productivity and passage survival. Secondly, there have been a number of major operational changes at Detroit Dam[1] related to downstream temperature control and at Bennett Dam related to adult passage. As a result, population data prior to BY 2007 is of little use in forecasting future performance. Thirdly, environmental conditions in the basin are such that non-passage factors, such as prespawning temperatures and gas supersaturation were significant sources of mortality. Finally, Detroit Dam is structurally different from Cougar Dam in that it does not have a temperature control structure, but does have regulating outlets located at varying heights in the dam face (this offers a number of different passage options).

A number of potential alternatives, including both structural and operational modifications to Detroit Dam, were analyzed using the North Santiam River SLAM model. Based on preliminary results, three alternatives were most effective at supporting naturally-produced spring-run Chinook salmon above Detroit Dam with a (NOR) spawner abundance from 10,000 to 13,000; Selective Withdrawal Structure with Floating Screen Structure (SWS-FSS and SWS-FSS 80) and Floating Screen Structure with different temperature timing (FSS-Temp Alts). Almost all of this natural production was from the Breitenbush and North Santiam River reaches above Detroit Dam. Conditions below the dam, even with improvements in water temperature and fish handling, were not predicted to be capable of contributing much more than a 1,000 NORs to spawner abundance.

[1] Alternatives may include passage effects at both Detroit and Big Cliff dams depending on the method of downstream juvenile passage.

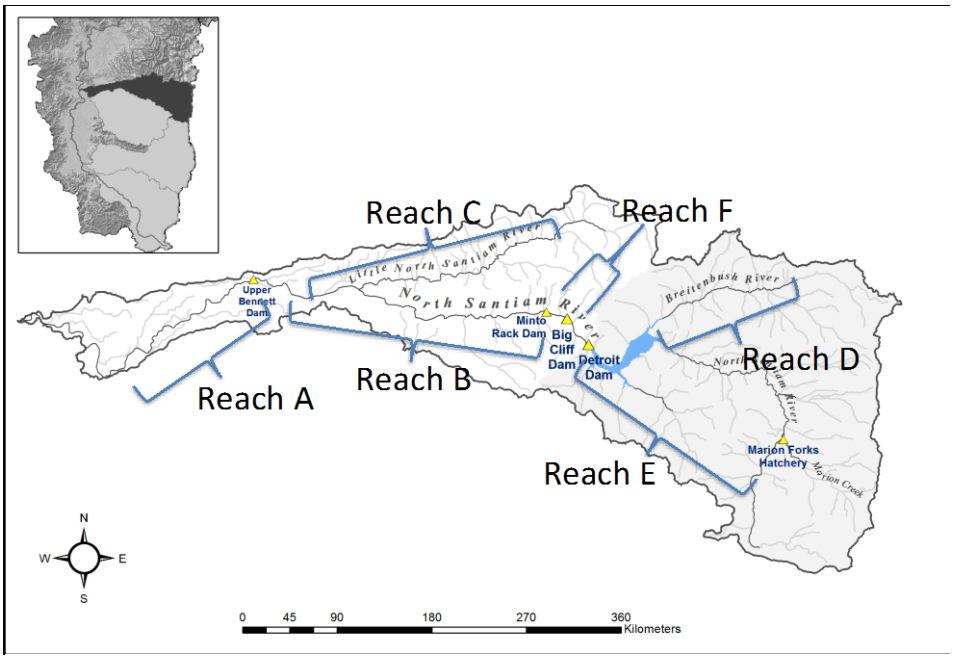


Figure 2.x: Map showing North Santiam River and the six reaches (A-F) that are modeled in SLAM; Reach A corresponds to mainstem North Santiam River downstream of Upper Bennett Dam, Reach B corresponds to mainstem North Santiam River between Upper Bennett Dam and the Minto Collection Facility, Reach C corresponds to Little North Santiam River, Reach D corresponds to Breitenbush River, Reach E corresponds to North Santiam River upstream of Detroit Dam, and Reach F corresponds to maintstem North Santiam River from Minto Collection Facility to Big Cliff Dam.

2.2.2. Abundance and Productivity

Of the alternatives investigated the highest projected NOR spawner median abundance of 12,175, and more so, the upper bound of this estimate of over 20,000 adults, was the source of some concern. Median abundance was related to capacity estimates, primarily for Reaches D and E, above Detroit Dam. Mattson (1948) had estimated that 70% of the spawning capacity existed above the then proposed dam site, and given habitat degradation below the Big Cliff/Detroit Dam complex, it is not surprising that most of the production should come from above the dams. As with the McKenzie River spring-run Chinook salmon population, the range of NOR spawner trajectory outcomes is quite large, reflected uncertainty in a number of parameters. In addition, in calibrating the model to baseline conditions it was assumed that recent improvements in NOR spawner abundance were related to beneficial changes in adult handling at Bennett Dam and incubation conditions downstream of Detroit Dam, and that these conditions would continue into the foreseeable future. Estimation of adult prespawning mortality as part of the baseline calibration was somewhat problematic. In many cases temperature gauges were not available for reaches or were badly sited (far downstream of any spawning habitat). Improvements in fish handling at Bennett Dam and at the Minto Fish Collection Facility have lead to, or will likely result in, lower prespawning mortalities in transported adults that are either recycled downstream or relocated above Detroit Dam. In some cases these modifications, especially those to PSM, improved some alternatives sufficiently to allow upstream reaches to exceed the replacement threshold. In addition to the potential direct survival effects from changes in temperature, there are a number of potential indirect effects (behavioral, growth, life history) that cannot be predicted with any

certainty. Overall, passage survival and DPE (from the fish benefit workbook) were still the primary factors influence the performance of any alternative.

2.2.3. Diversity

In most of the SLAM model alternatives, where Reaches D and E were near replacement, sufficient numbers of juvenile life-history types were produced throughout the basin. For the alternatives and baseline, the abundances for all three life histories emigrating from North Santiam were adequate enough to ensure the persistence of the life-history trajectories. It should be noted that model output does not adjust for potential changes in habitat above or below Detroit Dam and how those changes might influence the life-history trajectories of outmigrating juveniles.

The proportion of hatchery-origin spawners (pHOS) varied considerably among the alternatives. Under baseline conditions median pHOS was near 45%, reflecting the relatively poor productivity of reaches below the Big Cliff/Detroit dams. Changes in pHOS were primarily driven by increases in the number of NORs either by directly altering the ratio of the two, or by influencing the proportion of adults retained at the hatchery rack, the number of hatchery-origin recruits (HORs) passed above the dam, or the proportion of NOR fish retained for hatchery broodstock use (pNOB). Reductions in pHOS or increases in pNOB, in turn, reduce the level of domestication in the population, and improves the reproductive fitness of both NORs and HORs with a cascading effect on overall NOR abundance. Reduction in pHOS also increases the hatchery domestication portion of the diversity VSP score. Of the alternatives assessed, six alternatives reduced pHOS to less than 10% (a management goal); SWS-FSS, SWS-FSS-40, SWS-FSS-80, FSS Temp Alts, FSC 750, and FSC 1000. It should be noted that a "no hatchery" option was not assessed; the hatchery retention approach was utilized to achieve hatchery reduction benefits while retaining hatchery harvest social benefit.

Both the life history diversity and hatchery effects criteria are based on simplified outputs and do not capture the complex interactions that occur in the river. The relative scarcity of information related to the life-history of naturally-produced juveniles produced from the Breitenbush and North Santiam rivers (Reaches E and F) limits our ability to predict the life history composition of juveniles emigrating past the dams. Additionally, while recent studies have focused on the reproductive fitness of hatchery-origin spawners, little is known regarding the re-adaption of hatchery propagated fish to natural conditions. As a result VSP scores for diversity, especially life history, should likely include wider confidence limits.

2.2.4. Spatial Structure

The simple spatial structure criteria used in the SLAM model was very useful in evaluating the productivity of Reaches D and E. While the metric (achieving replacement above the Dam) was not specifically identified by the TRT, it did capture the essence of the Spatial Structure component – the ability of habitat to contribute to long-term population persistence.

Given the poor productivity of reaches below the Big Cliff/Detroit dams, the spatial structure VSP scores are closely correlated with the overall VSP score. Of the alternatives, five achieved self-sufficiency (SWS-FSS, SWS-FSS-80, FSS Temp Alts, FSC 750, and FSC 1000); however, as mentioned previously there is considerable uncertainty in the parameters for Reaches D and E.

2.2.5. VSP Scores for North Santiam River Chinook

For each alternative run in SLAM, four categories of model output are produced; abundance and productivity, proportion of hatchery origin spawners, life history diversity, and spatial structure

(see Chapter 3, Parameterization of VSP Criteria). We generated VSP scores for each of these categories and a Total VSP score. Overall, North Santiam River alternatives SWS-FSS-80 and FSC-750-Weir produced the highest Total VSP Score (median of 3.9), while Baseline conditions yielded a median score of 2.6 (Table 2.2).

Table 2.2: North Santiam River Chinook salmon median VSP scores for each alternative. 95% confidence limits are noted in parentheses for each of the four categories (abundance and productivity, pHOS, life history, and spatial structure), while standard deviations are in parentheses for total VSP score.

Alternatives	VSP Abundance and Productivity	VSP pHOS	VSP Life History	VSP Spatial Structure	Total VSP Score
SWS-FSS 80	4.0 (-)	3.9 (-)	4.0 (3.5-4.0)	3.5 (2.8-3.5)	3.9 (1.3)
SWS-FSS	4.0 (-)	3.9 (2.9-3.9)	4.0 (-)	3.5 (2.8-3.5)	3.9 (1.3)
FSS Temp Alts	4.0 (-)	3.9 (2.9-3.9)	4.0 (-)	3.5 (2.8-3.5)	3.9 (1.3)
FSC 1000	4.0 (-)	3.9 (2.8-3.9)	4.0 (-)	3.5 (2.8-3.5)	3.9 (1.3)
FSC 750	4.0 (-)	3.9 (2.8-3.9)	4.0 (-)	3.5 (2.8-3.5)	3.9 (1.3)
FSC 220	4.0 (3.7-4.0)	3.7 (2.3-3.7)	4.0 (-)	2.8 (1.5-3.5)	3.8 (1.1)
SWS-FSS 40	4.0 (3.7-4.0)	3.7 (2.3-3.7)	4.0 (-)	2.8 (1.5-3.5)	3.8 (1.1)
FSO	4.0 (3.5-4.0)	2.5 (2.1-3.7)	4.0 (-)	2.8 (1.5-3.5)	3.7 (0.9)
SWS-Weir	3.9 (2.9-4.0)	2.3 (1.8-3.5)	4.0 (-)	1.5 (1.5-2.8)	3.4 (0.4)
SWS	3.8 (2.7-4.0)	2.1 (1.6-3.3)	4.0 (-)	1.5 (1.5-2.8)	3.3 (0.2)
RoR	3.3 (2.1-3.9)	1.9 (1.4-3.1)	4.0 (3.5-4.0)	1.5 (-)	3.0 (0.6)
Baseline	2.8 (1.5-3.8)	1.7 (1.1-2.1)	4.0 (3.5-4.0)	1.5 (-)	2.6 (1.0)

2.3. South Santiam River Spring-Run Chinook Salmon

2.3.1. Overview

The South Santiam Basin SLAM model was relatively complex. It contains two major mainstem dams in series, only one of which (Foster Dam) currently provides limited adult and juvenile fish passage (Figure 2.5). The other dam (Green Peter Dam) was built with fish passage structures, but due to low passage success trap and haul operations for adults have been suspended. Additionally, a number of tributaries to the South Santiam River, such as Thomas, Crabtree, and Wiley creeks, provide additional spawning habitat, although not substantially.

Under baseline conditions passage survival at Foster Dam was relatively good[2]; however, alternatives at Green Peter Dam offered a wide range of passage survivals and modes of juvenile collection and passage. Both temperature effects (PSM and incubation alteration) and dissolved gas supersaturation can influence modeled abundance, more so than in other basins. Alternatives that provided high passage survival and ameliorated or by-passed temperature and TDG effects resulted in the highest VSP scores.

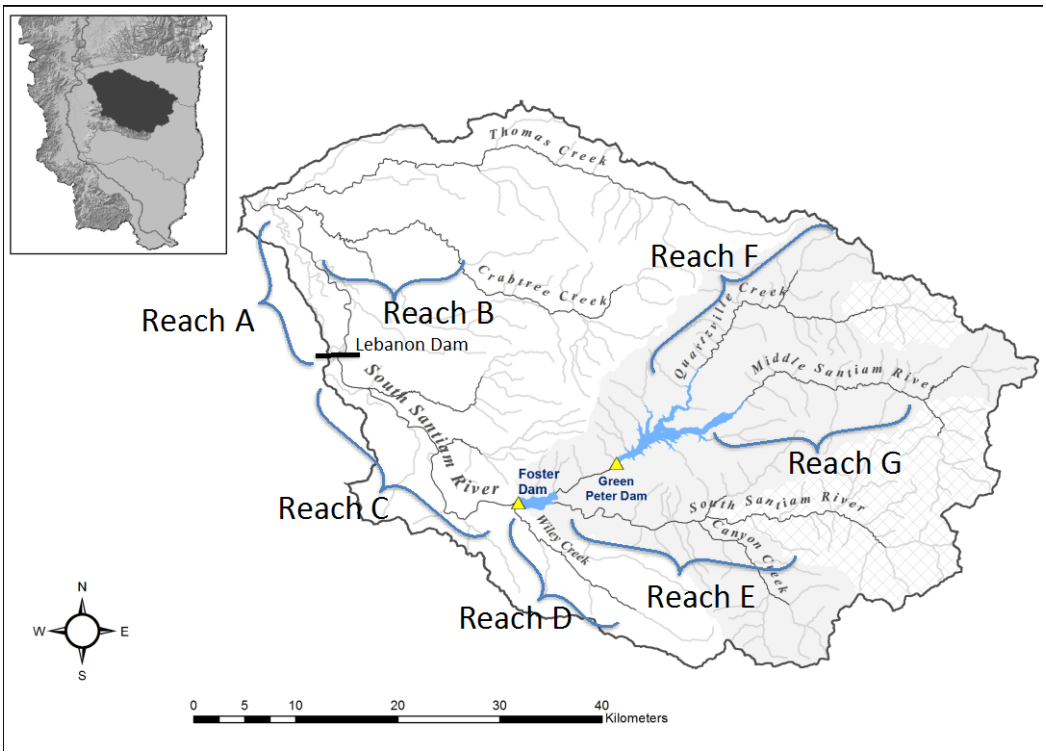


Figure 2.5: Map showing South Santiam River and the seven reaches (A-G) that are modeled in SLAM; Reach A includes the mainstem South Santiam River downstream of Lebanon Diversion Dam, Reach B includes tributaries off of the mainstem, including Thomas and Crabtree creeks, Reach C includes mainstem South Santiam River between Lebanon Diversion Dam and Foster Dam, Reach D includes Wiley Creek, Reach E includes South Santiam River upstream of Foster Reservoir, and upstream of Green Peter Dam are Reach F and G that include to Quartzville Creek and Middle Santiam River, respectively.

[2] In contrast to Green Peter Dam, Foster Dam is a low head dam and dedicated juvenile passage structures (such as FSS or FSC) were not considered among the alternatives.

Demographic information for baseline conditions was developed from redd count expansions and carcass recoveries. Only for Reach E, the South Santiam above Foster Dam, is adult count information available. For Reaches F and G, above Green Peter Dam, there is no fish abundance data.

2.3.2. Abundance and Productivity

Baseline conditions were established using recent estimates from redd and dam counts. There have been recent improvements in the adult trap at Foster Dam, but there is no data available to predict how these improvements will benefit fish transported above Foster. Most alternatives resulted in modest improvements in NOR abundance despite substantial improvements in passage survivals, especially at Green Peter Dam. In addition, it was assumed that fish passing through Green Peter Dam would migrate quickly through Foster Reservoir and not suffer additional predation mortality. Analysis of the SLAM output indicated that conditions below Foster Dam, specifically high TDG level resulted in periodic episodes of high mortality. Only in those passage alternatives at Green Peter Dam where juveniles were collected and transported below Foster Dam (into an area without high TDG) did abundances rise dramatically. Even in those cases; however, high PSM levels in Reaches E,F, and G were still limiting.

2.3.3. Diversity

In most of the SLAM model alternatives, where Reaches E, F, and G were near replacement, sufficient numbers of juvenile life-history types were produced throughout the basin. For the alternatives and baseline, the abundances for all three life histories emigrating from South Santiam were adequate enough to ensure the persistence of the life-history trajectories. It should be noted that model output does not adjust for potential changes in habitat above or below Foster and Green Peter dams and how those changes might influence the life-history trajectories of outmigrating juveniles.

The proportion of hatchery-origin spawners (pHOS) varied considerably among the alternatives. Under baseline conditions median pHOS was near 50%, reflecting the relatively poor productivity of reaches below the Foster Dam. Changes in pHOS were primarily driven by increases in the number of NORs either by directly altering the ratio of the two, or by influencing the proportion of adults retained at the hatchery rack, the number of hatchery-origin recruits (HORs) passed above the dam, or the proportion of NOR fish retained for hatchery broodstock use (pNOB). Reductions in pHOS or increases in pNOB, in turn, reduce the level of domestication in the population, and improves the reproductive fitness of both NORs and HORs with a cascading effect on overall NOR abundance. Reduction in pHOS also increases the hatchery domestication portion of the diversity VSP score. Of the alternatives assessed, only one reduced pHOS to less than 10% (a management goal); Fish Friendly Turbine at Foster Dam in combination with the Selective Withdrawal Structure with Floating Screen Structure (FOS-FriendTurb-GPD_SWS-FSS) at Green Peter Dam. It should be noted that a "no hatchery" option was not assessed; the hatchery retention approach was utilized to achieve hatchery reduction benefits while retaining hatchery harvest social benefit.

Both the life history diversity and hatchery effects criteria are based on simplified outputs and do not capture the complex interactions that occur in the river. The relative scarcity of information related to the life-history of naturally-produced juveniles produced from above Foster and Green Peter Dam (Reaches E, F and G) limits our ability to predict the life history composition of juveniles emigrating past the dams. Additionally, while recent studies have focused on the reproductive fitness of hatchery-origin spawners, little is known regarding the re-adaption of hatchery

propagated fish to natural conditions. As a result VSP scores for diversity, especially life history, should likely include wider confidence limits.

2.3.4. Spatial Structure

Because the spawning areas above Foster and Green Peter dams were treated independently for the purposes of spatial structure, the scoring was somewhat complicated. Reach E, above Foster was self-sustaining under baseline conditions, so any difference in spatial structure score would be due to an improved S/S ratio in the reaches above Green Peter Dam. In general, those alternatives that provided high survival passage at Green Peter Dam and collected and transported juveniles to be released below Foster Dam had the largest Total VSP score (e.g., alternatives that included any of the following modifications at Green Peter Dam; Selective Withdrawal Structure with Floating Surface Structure, Floating Surface Collector, and Head of Reservoir with 80% DPE and 90% passage survival).

2.3.5. VSP Scores for South Santiam River Chinook

For each alternative run in SLAM, four categories of model output are produced; abundance and productivity, proportion of hatchery origin spawners, life history diversity, and spatial structure (see Chapter 3, Parameterization of VSP Criteria). We generated VSP scores for each of these categories and a Total VSP score. Overall, South Santiam River alternative Fish Friendly Turbine (FriendTurb) at Foster Dam and Selective Withdrawal Structure and Floating Screen Structure (SWS-FSS) at Green Peter Dam (FOS_FriendTurb-GPD_SWS-FSS) had the highest Total VSP Score (median of 3.2), while Baseline conditions yielded a median score of 0.9 (Table 2.3).

Table 2.3: South Santiam River Chinook salmon median VSP scores for each alternative. 95% confidence limits are noted in parentheses for each of the four categories (abundance and productivity, pHOS, life history, and spatial structure), while standard deviations are in parentheses for total VSP score.

Alternatives	VSP Abundance and Productivity	VSP pHOS	VSP Life History	VSP Spatial Structure	Total VSP Score
FOS_FriendTurb-GPD_SWS-FSS	2.9 (0.8-3.9)	3.7 (2.4-3.7)	4.0 (3.5-4.0)	3.5 (3.2-3.5)	3.2 (0.3)
FOS_Baseline-GPD_FSC	2.7 (0.6-3.8)	3.6 (2.2-3.6)	4.0 (3.5-4.0)	3.5 (2.5-3.5)	3.0 (0.2)
FOS_Baseline-GPD_SWS-FSS	2.7 (0.7-3.8)	3.6 (2.2-3.7)	4.0 (3.5-4.0)	3.5 (3.2-3.5)	3.0 (0.2)
FOS_Baseline-GPD_Baseline HoR2	2.4 (0.6-3.5)	3.5 (2.2-3.6)	4.0 (4.0-4.0)	3.5 (3.2-3.5)	2.8 (0.1)
FOS_Weir860-GPD_FishHorn	1.6 (0.1-3.4)	2.4 (1.9-3.4)	4.0 (3.5-4.0)	3.2 (2.5-3.5)	2.1 (0.6)
FOS_Baseline-GPD_FishHorn	0.6 (0.03-2.7)	2.0 (1.6-3.2)	4.0 (3.0-4.0)	2.5 (2.5-3.5)	1.3 (1.2)
FOS_FriendTurb-GPD_SWS	0.3 (0.013-2.2)	2.0 (1.2-3.3)	4.0 (2.5-4.0)	2.5 (-)	1.1 (1.2)
FOS_FriendTurb-GPD_Baseline	0.2 (0.008-2.0)	2.0 (1.1-3.2)	4.0 (2.5-4.0)	2.5 (-)	1.0 (1.1)
FOS_Weir860-GPD_Baseline	0.2 (0.006-1.9)	1.9 (1.1-3.2)	4.0 (2.5-4.0)	2.5 (-)	1.0 (1.0)
FOS_Baseline-GPD_Baseline HoR1	0.1 (0.007-1.4)	1.7 (0.9-3.0)	4.0 (2.5-4.0)	2.5 (-)	1.0 (0.8)
FOS_Baseline-GPD_SWS	0.1 (0.004-1.0)	1.7 (0.8-3.0)	3.5 (2.5-4.0)	2.5 (-)	0.9 (0.6)
FOS_ContWeir-GPD_Baseline	0.1 (0.003-1.0)	1.7 (0.8-3.0)	3.5 (2.5-4.0)	2.5 (-)	0.9 (0.6)
FOS_Baseline-GPD_SpillPwr	0.1 (0.002-1)	1.6 (0.8-3.0)	3.5 (2.5-4.0)	2.5 (-)	0.9 (0.6)
FOS_Baseline wSpill-GPD_Baseline	0.1 (0.002-0.9)	1.6 (0.8-3.0)	3.5 (2.5-4.0)	2.5 (-)	0.9 (0.6)
Baseline	0.04 (0.002-1.0)	1.6 (0.8-3.0)	3.5 (2.5-4.0)	2.5 (-)	0.9 (0.6)

2.4. Middle Fork Willamette River Spring-Run Chinook Salmon

2.4.1. Overview

The Middle Fork Willamette River contains several major dams: Fall Creek, Dexter, Lookout Point, and Hills Creek (Figure 2.6). With the exception of unmarked adults transported above Fall Creek Dam, there is little opportunity for sustained natural production in this basin. Hatchery adult spring-run Chinook salmon are transported above Lookout Point and Hills Creek dams to estimate the spawning potential of above dam habitat and to provide forage for Bull Trout; very few juveniles from these headwater areas are able to successfully reach the sea. This basin was historically one the major producers of Chinook salmon in the Willamette River Basin, yet presently the return of naturally-produced adults is limited to a few hundred individuals.

2.4.2. Abundance and Productivity

Baseline conditions reflected the limited number of NOR adults produced in Reach C (Upper Fall Creek), in addition there were a small number of first generation progeny from naturally-spawning hatchery origin adults. As with the South Santiam River Chinook salmon simulation, TDG effects limited the survival of juvenile salmon that passed through the Dexter Lookout Point Complex. Where juveniles were collected at either Lookout Point or Hills Creek Dam and transported to below Dexter Dam there was an improvement in population productivity. Fitting either Hills Creek or Lookout Point dam with a selective water withdrawal structure (SWS) and floating screen structure (FSS) produced a median NOR adults greater than 5000, and adult NORs exceeded 10,000 with SWS and FSS structures in place at one dam and Floating Surface Collector at the other dam. Head of Reservoir (HOR) collections of juveniles from Hills Creek also produced large numbers of adults, but only when the HOR system operated at relatively high collection efficiency. Both the SWS-FSS and HOR passage alternatives resulted in very low QET levels.

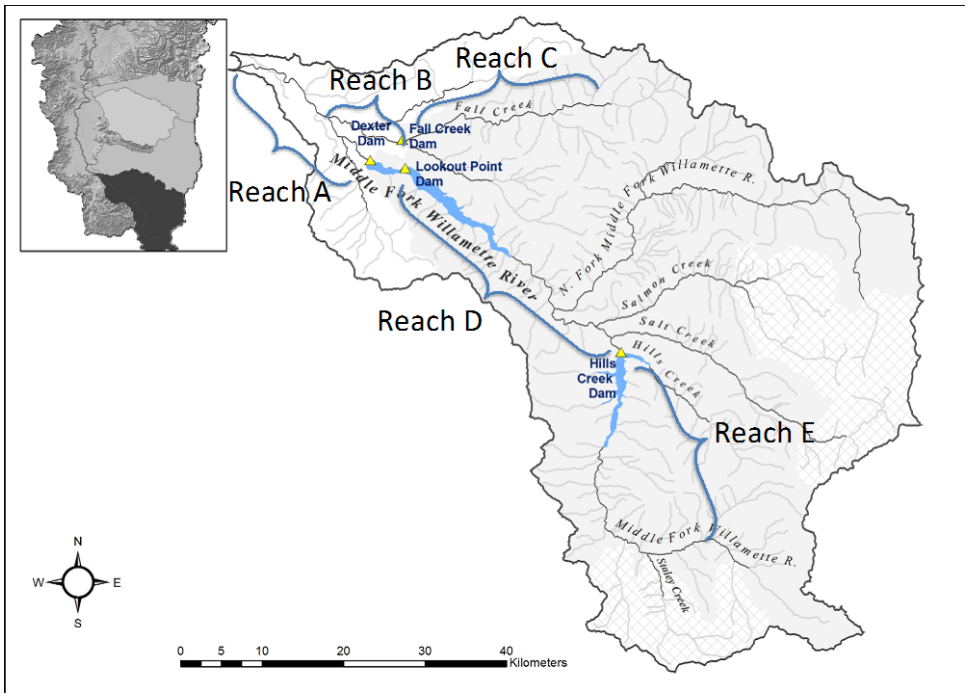


Figure 2.6: Map showing Middle Fork River and the six reaches (A-E) that are modeled in SLAM; Reach A corresponds to mainstem Middle Fork River downstream of Dexter Dam, Reach B corresponds to Fall Creek

River downstream of Fall Creek Dam, Reach C corresponds to Fall Creek River upstream of Fall Creek Dam, Reach D corresponds to Middle Fork River between Lookout Dam and Hills Creek Dam, and Reach E corresponds to Middle Fork River upstream of Hills Creek Dam.

2.4.3. Diversity

Alternatives that produced large numbers of NORs also had the lowest proportion of hatchery-origin spawners. This was due to programmed increases in the retention of returning hatchery fish at the hatchery rack and the direct result of increasing numbers of NOR adults. Similarly, juvenile production for all three life-history trajectories was poor in those alternatives with low passage survivals and those that did not collect juveniles at the forebays or head or reservoir.

2.4.4. Spatial Structure

Spatial structure was linked to the sustainability of the areas above Reaches C (Fall Creek), D (North Fork Middle Fork Willamette River), and E (Hills Creek). Under baseline conditions Reach C maintained a S/S ratio near 1, the sustainability of Reaches D and E were near 1 for those alternatives that provided high passage survival and transported collected juveniles to below Dexter Dam (e.g., SWS-FSS, FSC, and HoR). Those alternatives that provided the highest abundance did so by maintaining S/S above 1.

2.4.5. VSP Scores for Middle Fork River Chinook

For each alternative run in SLAM, four categories of model output are produced; abundance and productivity, proportion of hatchery origin spawners, life history diversity, and spatial structure (see Chapter 3, Parameterization of VSP Criteria). We generated VSP scores for each of these categories and a Total VSP score. Of the Middle Fork River alternatives, the greatest Total VSP Score of 3.7 came from the alternative that had a Selective Withdrawal Structure and Floating Screen Structure at Lookout Point Dam (SWS-FSS) and Floating Surface Collector (FSC) at Hills Creek Dam (LOP_SWS-FSS-HC_FSC), followed by 3.6 (LOP_FSC-HC_SWS-FSS), while Baseline conditions yielded a median score of 0.3 (Table 2.4).

Table 2.4: Middle Fork River Chinook salmon median VSP scores for each alternative. 95% confidence limits are noted in parentheses for each of the four categories (abundance and productivity, pHOS, life history, and spatial structure), while standard deviations are in parentheses for total VSP score.

Alternatives	VSP Abundance and Productivity	VSP pHOS	VSP Life History	VSP Spatial Structure	Total VSP Score
LOP_SWS-FSS-HC_FSC	3.6 (2.5-3.9)	3.9 (-)	3.5 (3.5-4.0)	4.0 (2.0-4.0)	3.7 (0.3)
LOP_FSC-HC_SWS-FSS	3.5 (2.6-3.9)	3.9 (-)	3.5 (3.5-4.0)	4.0 (2.0-4.0)	3.6 (0.3)
LOP_FSC-HC_Baseline HoR2	3.5 (2.9-3.8)	3.9 (-)	4.0 (-)	3.5 (2.0-3.5)	3.6 (0.4)
LOP_SWS-FSS-HC_Baseline	3.4 (1.9-3.9)	3.9 (2.9-3.9)	3.5 (3.5-4.0)	3.3 (0.5-3.3)	3.4 (0.8)
LOP_Baseline-HC_Baseline-HoR2	3.0 (2.7-3.5)	3.9 (2.8-3.9)	4.0 (-)	2.8 (2.0-2.8)	3.2 (0.4)
LOP_Baseline-HC_SWS-FSS	2.9 (1.7-3.7)	3.9 (2.8-3.8)	3.5 (3.5-4.0)	3.0 (2.0-4.0)	3.1 (0.7)
LOP_Baseline-HC_FSC	0.5 (0.1-1.95)	1.8 (1.6-2.0)	3.5 (2.0-3.5)	2.5 (0.5-3.3)	1.2 (1.2)
LOP_FSC-HC_Baseline	0.08 (0.04-2.5)	1.2 (0.9-2.8)	3.0 (2.0-3.5)	0.5 (0.5-1.0)	0.5 (1.6)
LOP_Baseline-HC_SWS	0.02 (0-0.9)	0.3 (0.3-0.7)	2.5 (1.5-3.0)	1.0 (0.5-1.0)	0.4 (0.1)
Baseline	0.02 (0-0.09)	0.3 (0.3-0.7)	2.5 (1.5-3.0)	0.5 (0.5-1.0)	0.3 (0.1)
LOP_SWS TurbRO-HC_Baseline	0.01 (0.0-0.05)	0.3 (0.2-0.5)	2.5 (1.0-3.0)	0.5 (0.5-1.0)	0.3 (0.1)
LOP_Baseline nSpill-HC_Baseline	0.01 (0.0-0.04)	0.3 (0.2-0.5)	2.5 (1.0-3.0)	0.5 (0.5-1.0)	0.3 (0.1)

2.5. North Santiam River Winter-Run Steelhead

2.5.1. Overview

The modeled demographics of steelhead are different from Chinook salmon, such that annual variability is considerably smaller. This appears to be related to a number of factors; the presence of repeat spawners tends to buffer fluctuations in first-time spawners, and the absence of PSM and temperature-related incubation effects. The absence of an artificial propagation program for winter-run steelhead eliminated the domestication reduction in reproductive success, but also eliminated the contribution of naturally-spawning hatchery-origin adults to NOR returns. The overall decrease in variability (as expressed in the small confidence intervals for NORs relative to Chinook salmon) was reflected in relatively low QET risks for alternatives with moderate abundance levels. As a result, there were a number of alternatives that produced a low risk of extinction, although the differences in NOR abundance were considerable.

2.5.2. Abundance and Productivity

Baseline conditions reflected the natural production primarily from Reaches B and C, North Santiam and Little North Santiam rivers. Passage survivals correlated strongly with NOR abundance. Additionally, alternatives that included juvenile collection (SWS-FSS and FSC) did not experience TDG effects below the Detroit and Big Cliff dams. The Selective Withdrawal Structure and Floating Screen Structure alternative (SWS-FSS) produced the highest abundance, with over 6,000 NORs, with survivals set at over 95% for all three age classes. Additionally, dam passage efficiencies were modeled as being constant across all the passage alternatives, which further emphasized the influence of passage survival.

2.5.3. Diversity

Steelhead diversity will be evaluated based on juvenile age structure alone, since no winter-run steelhead hatchery programs exist in the basin. Currently, our steelhead life cycle models are not setup to generate this output.

2.5.4. Spatial Structure

In general, those alternatives that provided passage survivals above 60% exhibited spawner to spawner above replacement. The Floating Surface Outlet alternative, with an average passage survival near 60%, was at the threshold of replacement. The SWS-FSS, FSC, and FSO alternatives all have median spatial structure scores of 4.0, although there was some uncertainty in the scores for SWS-FSS, FSC220, and FSO. Neither the baseline nor the SWS Weir alternative could sustain natural production above Detroit Dam. In both instances Reaches D and E were extirpated.

2.5.5. VSP Scores for North Santiam River Steelhead

For each alternative run in SLAM, three categories of model output are produced; abundance and productivity, age diversity, and spatial structure (see Chapter 3, Parameterization of VSP Criteria). We generated VSP scores for each of these categories and a Total VSP score. Of the North Santiam River alternatives, SWS-FSS, FSC-750, and FSC-1000 produced the highest Total VSP Score of 3.7, while Baseline conditions yielded a median score of 2.1 (Table 2.5).

Table 2.5: North Santiam River steelhead median VSP scores for each alternative. 95% confidence limits are noted in parentheses for each of the three categories (abundance and productivity, diversity, and spatial structure), while standard deviations are in parentheses for total VSP score.

Alternatives	VSP Abundance and Productivity	VSP Life History	VSP Spatial Structure	Total VSP Score
SWS-FSS	4.0 (-)	3.0 (-)	3.5(2.8-3.5)	3.7 (1.3)
FSC750	3.9 (3.9-4.0)	3.0 (-)	3.5 (3.5-3.7)	3.7 (1.2)
FSC1000	3.9 (3.9-4.0)	3.0 (-)	3.5 (3.5-3.7)	3.7 (1.2)
FSC220	3.9 (3.8-3.9)	3.0 (-)	3.5 (2.8-3.5)	3.7 (1.2)
FSO	3.0 (2.8-3.3)	3.0 (-)	3.5 (2.8-3.5)	3.1 (0.6)
SWS Weir	2.4 (1.9-2.7)	3.0 (-)	1.5 (-)	2.3 (0.1)
Baseline	2.0 (1.5-2.4)	3.0 (-)	1.5 (-)	2.0 (0.1)

2.6. South Santiam River Winter-Run Steelhead

2.6.1. Overview

The results for the steelhead SLAM model for the South Santiam Basin were generally similar to those for Chinook salmon, except that PSM did not influence the steelhead model. Alternatives that provided juvenile collection at Green Peter Dam and transportation below Foster produced the highest overall abundances. Diversity and spatial structure VSP scores were both correlated to NOR abundance.

2.6.2. Abundance and Productivity

Under baseline conditions there is some natural production in all of the reaches, except the lowermost portion of the South Santiam (Reach A) and above Green Peter Dam (Reaches F and G). Reach E, the South Santiam River above Foster Dam, is accessible through a trap and haul program and both passage survival (around 80%) and DPE (60%) are sufficient to maintain natural spawning above the Dam. Baseline conditions at Foster Dam are such that there is not much margin for improvement in overall passage and productivity in Reach E, although a number of alternatives with improvements solely at Foster Dam did produce measurable improvements in NOR abundance. Alternative improvements in passage survival and DPE at Green Peter Dam did result in relatively large increases in NOR abundance. These improvements, in combination with low trajectory variability resulted in very high median VSP scores for a number of alternatives (especially those with juvenile collection and transportation at the dam or head of reservoir, HoR).

2.6.3. Diversity

As with steelhead in the North Santiam, diversity will be evaluated based on juvenile age structure alone, since no winter-run steelhead hatchery programs exist in the basin. Currently, our steelhead life cycle models are not setup to generate this output.

2.6.4. Spatial Structure

Under baseline conditions Reach E was already at or near a spawner: spawner ratio of 1.0; therefore, any differences in the Spatial Structure VSP score would be directly related to the status of steelhead spawning above Green Peter Dam. Those alternatives that achieved a high passage survival and DPE at Green Peter Dam, had the highest VSP scores; SWS-FSS, FSC, and HoR.

2.6.5. VSP Scores for South Santiam River Steelhead

For each alternative run in SLAM, three categories of model output are produced; abundance and productivity, age diversity, and spatial structure (see Chapter 3, Parameterization of VSP Criteria). We generated VSP scores for each of these categories and a Total VSP score. Of the South Santiam River alternatives, seven produced the highest Total VSP Score of 3.7, while Baseline conditions yielded a median score of 2.6 (Table 2.6).

Table 2.6: South Santiam River steelhead median VSP scores for each alternative. 95% confidence limits are noted in parentheses for each of the three categories (abundance and productivity, diversity, and spatial structure), while standard deviations are in parentheses for total VSP score.

Alternatives	VSP Abundance and Productivity	VSP Life History	VSP Spatial Structure	Total VSP Score
FOS_FriendTurb-GPD_SWS-FSS	4.0 (-)	3.0 (-)	3.5 (2.4-3.5)	3.7 (1.3)
FOS_Baseline-GPD_SWS-FSS	4.0 (-)	3.0 (-)	3.5 (2.3-3.5)	3.7 (1.3)
FOS_Weir860-GPD_FSC	4.0 (-)	3.0 (-)	3.5 (2.4-3.5)	3.7 (1.3)
FOS_ContWeir-GPD_FSC	4.0 (3.9-4.0)	3.0 (-)	3.5 (2.4-3.5)	3.7 (1.3)
FOS_Baseline wSPill-GPD_FSC	4.0 (3.9-4.0)	3.0 (-)	3.5 (2.4-3.5)	3.7 (1.3)
FOS_FriendTurb-GPD_FSC	4.0 (3.9-4.0)	3.0 (-)	3.5 (2.4-3.5)	3.7 (1.3)
FOS_Baseline-GPD_FSC	4.0 (3.9-4.0)	3.0 (-)	3.5 (2.4-3.5)	3.7 (1.3)
FOS_Baseline-GPD_Baseline HoR2	3.9 (3.8-3.9)	3.0 (-)	2.5 (2.4-3.5)	3.5 (1.7)
FOS_Weir860-GPD_FishHorn	3.7 (3.5-3.8)	3.0 (-)	3.2 (2.3-3.5)	3.5 (1.0)
FOS_Weir860-GPD_Baseline	3.6 (3.4-3.7)	3.0 (-)	2.5 (2.3-2.5)	3.3 (0.9)
FOS_FriendTurb-GPD_SWS	3.0 (2.9-3.3)	3.0 (-)	3.2 (2.3-3.5)	3.0 (0.7)
FOS_ContWeir-GPD_Baseline	3.1 (2.9-3.4)	3.0 (-)	2.5 (2.3-2.5)	3.0 (0.7)
FOS_Baseline wSpill-GPD_Baseline	3.1 (2.9-3.4)	3.0 (-)	2.5 (2.3-2.5)	3.0 (0.7)
FOS_Baseline-GPD_SWS	2.7 (2.5-2.9)	3.0 (-)	3.2 (2.3-3.5)	2.9 (0.6)
FOS_FriendTurb-GPD_Baseline	2.9 (2.7-3.0)	3.0 (-)	2.5 (2.3-2.5)	2.8 (0.7)
FOS_Baseline-GPD_FishHorn	2.6 (2.3-2.8)	3.0 (-)	2.5 (2.3-2.5)	2.7 (0.4)
Baseline	2.5 (2.2-2.8)	3.0 (-)	2.5 (2.3-2.5)	2.6 (0.4)
FOS_Baseline-GPD_Baseline HoR1	2.4 (2.0-2.6)	3.0 (-)	2.5 (2.3-2.5)	2.5 (0.2)

2.7. Analytical Considerations and Caveats

2.7.1. Environmental Effects

The modeled performance of each SLAM alternative was primarily influenced by the passage survival and dam passage efficiency inputs from the Fish Benefit Workbook (FBW); however, there were other model components that appeared to be significant. Specifically, the relative influence of environmental factors (temperature and total dissolved gas) was considerable. In many cases, although the average mortality imposed by the factors was relatively small, occasional high mortality events (mortality > 30%) produced dramatic declines in abundance. In many instances it is likely that the continued input of first generation hatchery progeny prevented populations from being extirpated in the simulations. Although the modeled TDG effects were significant, we were unable to document TDG mortality events.

Both temperature and TDG-influenced mortalities were estimated through models initially developed by third parties. TDG levels were modeled based on spill/flow patterns at the projects, and the relationship between TDG and alevin/juvenile mortalities was established using TDG-exposure studies in shallow troughs. No on-site information was available to validate the model results and there is a strong likelihood that fish migration behavior influences the severity of TDG-related mortality (Beeman and Maule, 2006) such that the model overestimates mortality rates. Specifically, fish actively migrating downstream are not likely to linger in any locale (and especially so after passing through a dam), and migrating juveniles spend much of their time at depths that would minimize TDG effects (via depth compensation). Furthermore, efforts to calibrate the models to recent data were complicated by data limitations (no TDG related mortality data exists), and violations to stationarity assumptions (changes in operations at the projects). Recent assessments by ODFW[3], suggest that the observed PSM levels (based on carcass recoveries) are overestimates of population level mortalities. Differences in river conditions prior to and after spawning, with prespawn mortalities being easier to observe and recover likely bias the empirical estimates. While it is possible that our SLAM model overestimates the influence of PSM and TDG, these factors are still clearly important in determining population performance and need to be monitored. Additionally, the modeled effects of PSM and TDG indirectly accounted for other episodic factors (scouring floods, etc) such that the overall effect mimicked empirical data. Steelhead models did not include PSM and other temperature related effects because the timing of winter-run steelhead adult return and subsequent egg incubation do not occur during periods of temperature extremes. For steelhead populations, juvenile abundance and productivity may instead be limited by over-wintering and over-summering mortalities. We have not attempted to model these capacities, which involve a complex interaction between annual temperature maximum and minimums and the availability of specific habitat types (off-channel or side channel features, pools, etc.). The absence of a major source of year–to-year variability from the SLAM model decreases trajectory variability and has strong effect on the population QET, reducing QET risk to very low levels, even at very low abundances. In an effort to simulate natural variability in the SLAM model, the reach capacities for each population were subjected to annual variability. This variability was modeled using annual smolt outmigration for the Clackamas River winter run steelhead. Winter-run smolt outmigration from 1959 to 2008 had a coefficient of variation of 47.8%. Therefore, reach capacities for North Santiam and South Santiam steelhead were set to vary annually ± 47.8% (based on a uniform distribution) in an effort to better capture natural stochastic effects. For comparison, the coefficient of variation for Chinook salmon juveniles in the Clackamas

[3] C. Sharpe. 2014. Upper Willamette River spring Chinook abundance, distribution and survival: McKenzie Addendum. Presentation.

River was 76.0% (this higher CV may be due to an undercounting of subyearlings at the North Fork Dam).

For both Chinook salmon and steelhead it was unclear if the models fully represented population demographic variability. Underestimation of variability will result in lower QET risk values and could indicate, incorrectly, that some populations are viable at relatively low abundances. Further studies on the factors influencing population variability, especially parameters that are environmentally correlated and appear to have a cyclical nature, would likely result in model outputs that more closely mimic observed patterns.

2.7.2. Reservoir Growth

A review of available information on juvenile salmonid growth and survival in Upper Willamette reservoirs did not support the use of a "universal" set of reservoir parameters. Ultimately, the work group of biologists assigned parameters to population models on a case-by-case basis. Although reservoirs may provide improved feeding and rearing conditions to juvenile salmonids, it is also clear that reservoirs provide a safe haven for potential salmonid predators. These predators may contribute to poor juvenile survival in the reservoirs. Relatively shallow warmer reservoirs appear to offer conditions for superior growth; however, these conditions are also conducive to supporting populations of introduced large-mouthed and small-mouthed bass as well as native northern pike minnow. Dam operations further complicate the analysis; for example, Fall Creek Reservoir, a relatively shallow reservoir, is drawn down annually in an effort to reduce predator abundance and stimulate juvenile salmonid emigration. Simulations were run assuming that this procedure was continued into the foreseeable future. Similar operations (drawdowns, etc.) were discussed in the context of model alternatives for each reservoir by the work group and underscore the need for customized models for each population.

Species-specific circumstances were also included in the modeling of reservoir survivals. The relatively low DPEs for steelhead increase the likelihood of extended reservoir rearing and the potential for predation loss. In some cases, downstream sampling outmigrating of juveniles suggests that reservoir-rearing results in larger fish with potentially higher survivals than river-reared fish – although sampling only records the survivors from reservoir rearing and may present a biased analysis of growth.

The presence of parasitic copepods (*Salmincola sp*.) in reservoirs and their effect on juvenile salmonid survival was also discussed. Reservoir survivals implicitly included parasite effects; however, mortalities may occur long after the fish have left the reservoirs and there is considerable uncertainty in the long-term effect of parasites (especially since the effects of other downstream environmental stressors are compounded). Research is proposed to investigate methods to control this infestation, and if successful may result in significantly improved overall survival.

Thermal stratification in reservoirs behind high head dams can affect the temperature profile of downstream reaches. Changes in downstream temperatures, especially those occurring during incubation, were considered by the biological work group when establishing egg to fry survivals. Both reservoir size and dam-specific water release options were evaluated. Primarily, the work group considered the detrimental effects of accelerating incubation.

Reservoirs may also influence the survival of returning adults. Deep reservoirs that thermally stratify can provide a thermal refuge for returning adults during the prespawning holding period when upstream river temperatures are at their highest. Recent radio tagging studies suggest that

some adult Chinook salmon do take advantage of the cooler deep water in reservoirs, although the survival benefit has not been quantified. Thermal stratification may also influence predation, by separating bass and pike minnow, which prefer upper warmer waters, from juvenile salmonids, which prefer deeper cooler waters

Some studies suggest that juveniles, having passed through the dam will move more quickly through the rest of the basin. How this affects downstream survivals or DPE values for subsequent passage structures encountered is unknown. Downstream habitat conditions play a major role in the survival of juveniles' post-dam passage. We did not address the potential for future degradation or improvement in habitat (maintaining stationarity assumptions), but changes in upstream or downstream habitat will certainly influence juvenile survival, and would likely influence life history trajectories differently.

Reservoirs are fixtures in Upper Willamette River tributaries and will likely continue to be so for the foreseeable future. They affect a variety of life-history stages either directly through upstream and downstream passage survival or indirectly by altering the ecological nature of the river from free-flowing to impoundment. The SLAM model includes a limited number of specific effects, while other, more complex, effects are incorporated into a single life-stage term.

2.7.3. Stationarity

In parameterizing the model for baseline conditions one of the major assumptions was that of stationarity; that conditions (other than those modified in the model alternatives) would not change over the course of the model run. For example, climate change assumptions are not included in the present version of the Chinook salmon and steelhead models.[4] Additionally, population trends are not included. Both Chinook salmon and steelhead are currently exhibiting declines in annual abundance at Willamette Falls (Figure 2.7), although some individual populations are experiencing upward trends. Model baselines are calibrated to recent 5-year average returns; however, if the factors responsible for the present day declines continue, the model will overestimate abundance (and overestimate the abundance and productivity VSP score) at the end of the 100-year run. Alternatively, if habitat, predation control, or ocean conditions improve, due to factors unrelated to fish passage, the model would underestimate abundance. Extending any short-term trend over the 100 year trajectory would likely lead to an extreme abundance outcome.

The application of stationarity also applies to individual populations. For example, estimates of NOR spring-run Chinook salmon returning to the North Santiam River show a positive trend from 2001 to 2014, while a similar population series for the McKenzie River would yield a stable or slightly negative trend (Figure 2.8). It is not evident whether these trends reflect cyclical changes in ocean or freshwater conditions, or permanent changes in productivity or survival. For this reason it is important to emphasize that the SLAM output and VSP scores do not reflect these trends and therefore the SLAM generated VSPs should be considered as relative measures of baseline and passage alternative conditions. In contrast, evaluations of the current status of the Chinook salmon and steelhead populations in the Upper Willamette River would consider these trends, in both a short term and long term context. Furthermore, as a precautionary approach, the focus would likely be on the lower bound of any VSP measure.

[4] We envision including climate change provisions into future models. This would include varying stream temperatures and modifications in seasonal and annual hydrologic cycles.

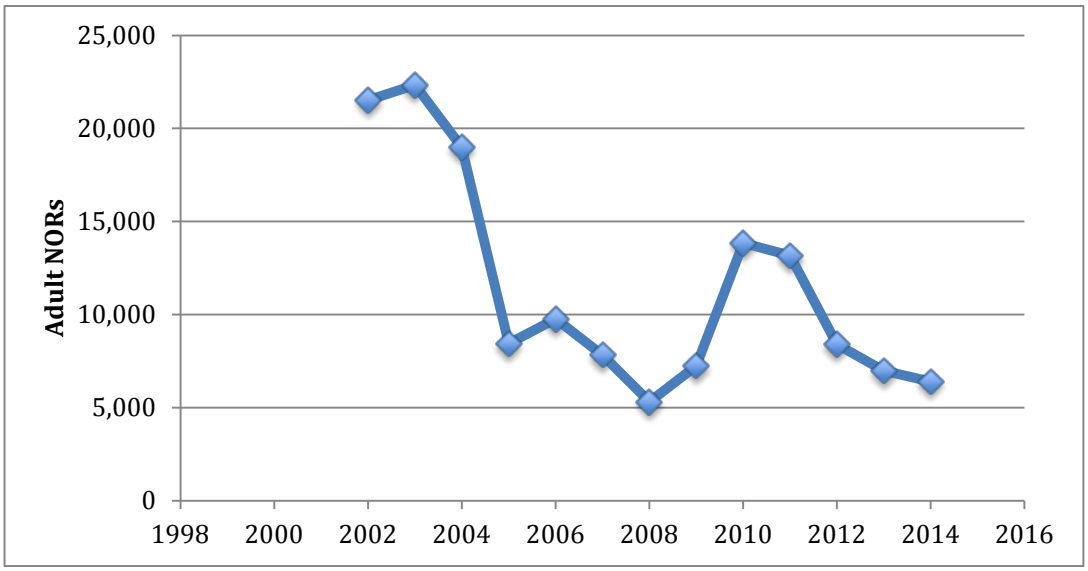


Figure 2.7: Estimated passage of spring-run Chinook salmon natural-origin recruits (NORs) at Willamette Falls from 2002 to 2014.

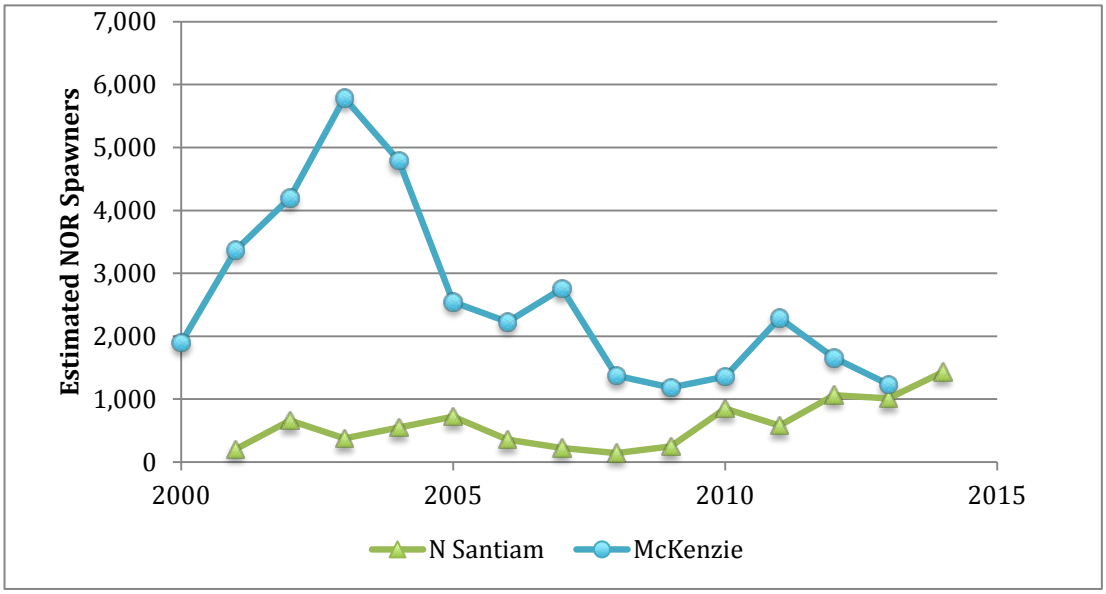


Figure 2.8: Estimated abundance of spring-run Chinook salmon natural-origin recruits (NORs) for the North Santiam River and McKenzie River from 2000 to 2014.

2.7.4. Climate Change

As stated in the previous section, climate change was not incorporated in any of the baseline or alternatives considered in this report. The primary reasons for this were the lack of sufficient data to formulate functional relationships relating climate effects to biological responses, and none of the dam passage alternatives from the fish benefit workbook considered climate change effects.

We ran prospective model simulations out to 100 years to calculate measures of population health and VSP scores, which is well within the temporal scope of studies of climate change effects where significant atmospheric and environmental changes are expected to occur globally and including the Pacific Northwest (IPCC 2014). Some of the salmonid-centric freshwater climate change effects anticipated by the end of the century in the Pacific Northwest include increased summer stream temperatures, lower summer flows from reduced mountain snowpack, precipitation falling more as rain than snow, an earlier peak in spring flows, and more frequent and intense winter precipitation events (Chang and Jones 2010; Mantua et al. 2010; Mote and Salathé 2010; Salathé et al. 2014; Tohver et al. 2014; Warner et al. 2015). Though there may be some spatial variability in how these changes are manifest depending on local conditions and context (e.g., Tague et al. 2008), these are the overall expected trends. Future ocean conditions for salmonids are less well understood (e.g., Overland and Wang 2007; King et al. 2011), and while some progress has been made in understanding some of the expected abiotic changes many challenges remain in forecasting the biological responses in the marine realm (e.g., Stock et al. 2011).

Given these anticipated effects, the future state of ecosystems on which salmonids depend will undoubtedly be different. Evidence suggests that salmonid responses are likely to be complex and perhaps population-specific (Crozier and Zabel 2006). There are several opportunities to introduce climate effects in the life cycle modeling in several life history stages and processes. However, there are little to no empirical data to describe the form of the response. And many questions arise when considering incorporating climate impacts. For example, rising stream temperatures can increase primary productivity and fish metabolism in places where low temperatures may limit fish growth and productivity, and yet in places where temperatures are high an increase can limit growth and productivity. Increasing temperatures during egg incubation can hasten development rates and introduce mismatches between emergence and optimal resource availability. Stream flow is another consideration. Depending on the magnitude of climate change, many of the Upper Willamette Basin tributaries will shift from a snowfall-driven hydrograph to a mixed rain/snow or rain-driven hydrograph. Higher flows during incubation could lead to more redd-scouring events. How will operations of the dams and reservoirs be altered as the composition of wet and dry years change and the demands of flood control, hydropower generation, recreation, and irrigation change with an altered landscape? And how will these alterations impact reservoir and passage survival? Under baseline alternatives without passage conditions in the lower reaches may become increasingly inhospitable, and in the absence of access to cooler water reaches the status of populations could decline considerably. How might these factors combine and interact to influence juvenile life history or adult return strategies? Thus, which parameters change? In which basin? Chinook salmon and steelhead can exhibit a wide range of life history trajectories, but if the rate and magnitude of environmental changes exceeds that capacity for diversity the persistence of most populations will likely come into question. More research is required to formulate the scope for change in a life cycle context.

2.8. Baseline Calibration Considerations

The development of a population-specific set of baseline SLAM parameters provides the context for evaluating alternatives, and offers the only opportunity to fit the model to empirical data. As discussed earlier, stationarity and variability are significant effects influencing the SLAM model outputs for both the baselines and alternatives. The assumptions made for these effects can strongly influence the simulation outcome. For example, the baseline model for North Santiam River spring-run Chinook salmon included the assumptions that recent improvements in NOR

spawner abundance were the result of improvements in adult passage conditions at Bennett Dam, operational temperature control at Detroit Dam, and the contribution of returning progeny from hatchery-origin adults transported above Detroit Dam. Furthermore, it was assumed that these improvements would persist into the foreseeable future. As a result, the baseline for North Santiam Chinook salmon predicted a higher VSP score than was originally estimated by the TRT.

A reassessment of the North Santiam baseline under different assumptions illustrates the importance of model conditions. Four alternative sets of baseline conditions were used in SLAM simulations (Figure 2.9) to assess the effects on abundance and QET[5]. Predictably, improvements in conditions or accessibility resulted in improvements in NOR spawner abundance, although the absolute increases were not great.

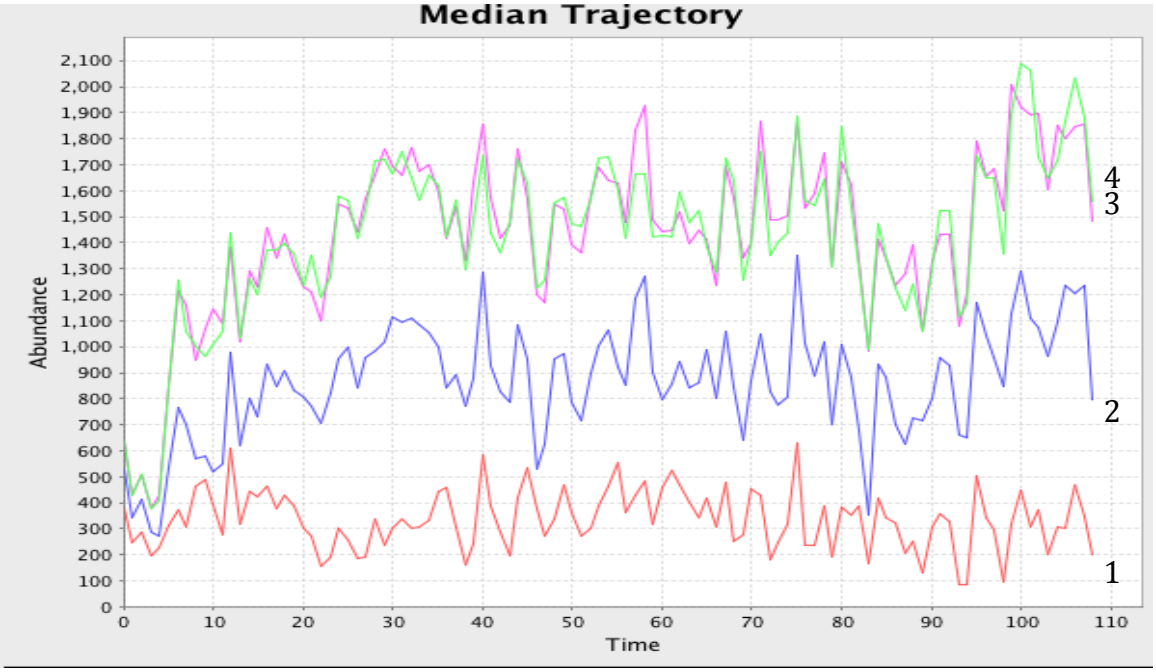


Figure 2.9: Median abundance output for SLAM baseline alternatives 1) assuming no adult passage improvements at Bennett Dam, no temperature control improvements in incubation below Detroit Dam, and no passage of adults above Detroit Dam (red), 2) as in #1, but hatchery-origin fish are transported above Detroit Dam (blue), 3) Bennett Dam improvements, operational temperature control, and passage of fish above Detroit (green), and 4) as in #3 but with an annual variability in spawner capacity CV of 78%[6] included (pink).

Alternatives 3 and 4 did not result in significantly different NOR spawner abundances because increasing variability about the capacity does not alter the median outcome if the variability is equally positive or negative. Increasing the variability, however, does increase the risk of falling below the QET level (Figure 2.10) by approximately 30%. Alternatives 1 and 2 both have dramatically higher QET risks, mostly related to the intermittently high levels of PSM and lower survival from egg to emergent fry in reaches below Detroit (Reaches B and G). Lowering egg to fry

[5] SLAM simulations were for 110 years, with 500 trajectories. These simulations were not part of the formal VSP scoring, and are presented for comparative purposes only.
[6] Capacity variability was set at 78% based on the CV for Clackamas River Chinook salmon juvenile production.

survival, especially in Reach B (which produces the majority of juveniles in the baseline scenarios) kept the population from rebuilding after a decline, increasing the risk of falling below QET in subsequent years. Thus the outcome of baseline simulations for a population depends on the time scale (short-term vs. long-term) selected to establish average spawner abundance, PSM, and pHOS, whether any operational or structural changes have occurred during that period, and if those changes will have a lasting effect into the future.

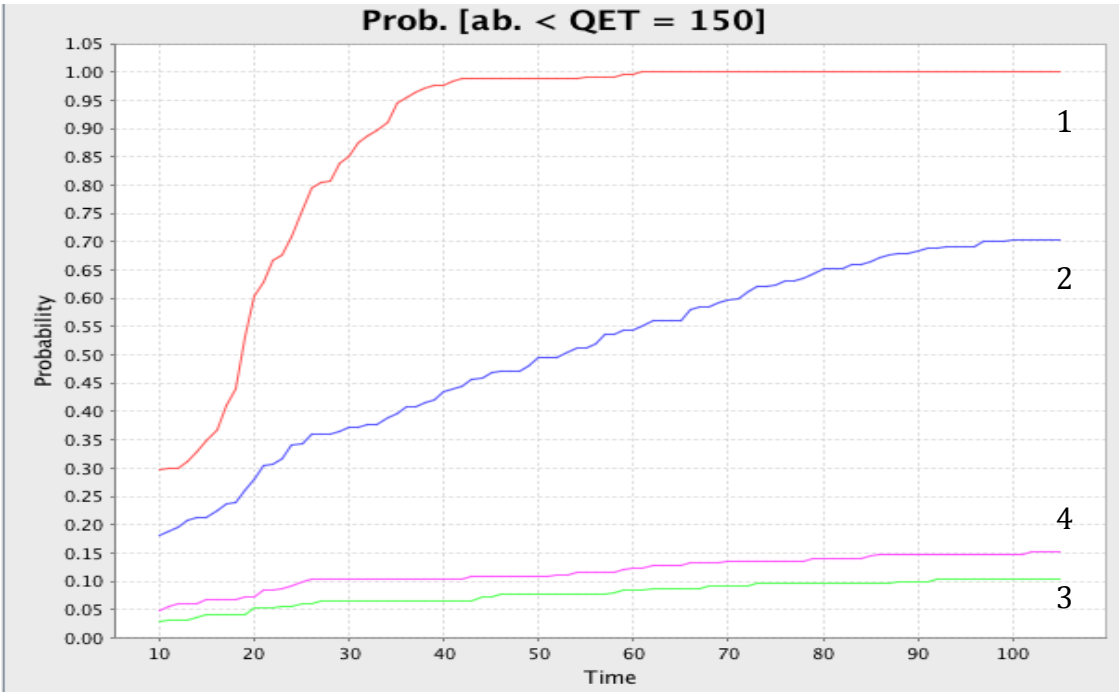


Figure 2.10: Risk of spawner abundance falling below a QET threshold of 150, based on output for SLAM baseline alternatives 1) assuming no improvements in adult passage at Bennett Dam, no temperature control improvements in incubation below Detroit Dam, and no passage of adults above Detroit Dam (red), 2) as in #1, but hatchery-origin fish are transported above Detroit Dam (blue), 3) Bennett Dam improvements, operational temperature control, and passage of fish above Detroit (green), and 4) as in #3 but with an annual variability in spawner capacity CV of 78% included (pink).

2.9. Alternative Considerations

Changes in passage survival and passage efficiency had significant and predictable effects on the performance of the populations modeled. In addition, there were downstream effects related incubation survival, changes in reservoir survival, and changes in the relative proportion of life history trajectories. In contrast to changes in NOR abundance, alternative QET risk levels were not always predictable. Changes in variability, which influences QET risk, do not always result in significant changes in median abundance.

Beyond the obvious changes in life cycle parameters one must consider other possible changes related to alterations in river/reservoir conditions or juvenile or adult fish management, but are not currently reflected in the SLAM model alternatives. In those cases where returning adults are transported above the projects, one must consider possible changes in the relationship between temperature and PSM. In the majority of cases, given the return timing of adult Chinook salmon to their natal basin, adults would be transported to colder headwater areas prior to the onset of deleterious temperatures. In these cases, modeled PSM levels would be too high and the PSM

model would need to be reconfigured with a reduction in overall mortality. Similarly, proposed changes in adult fish collection and transport are likely to result in improved survivals, although the magnitude of this improvement is unknown.

Changes in reservoir level due to operational modifications can affect reservoir and downstream temperatures, incubation temperatures, juvenile outmigration timing, and adult prespawning conditions. In most case the physical consequences of these actions are generally predictable, although there is some uncertainty in their ultimate effect on individual survival and population status. For example, changes in dam discharge timing and egress port will create long-term changes in the temperature profile of water releases. This, in turn, may result in changes in Chinook salmon incubation timing in the fall and to a lesser extent in steelhead in the spring; but the ultimate effect on survival is less clear and subject to a number of additional factors. Any environmental change will have some physiological effect, although this will almost always be mediated to some degree by behavioral responses. Juvenile and adult salmon and steelhead can migrate to different locations to optimize their environment. Efforts by the work group of biologists to quantify these survival and life history changes revealed a range of opinions regarding potential changes, underscoring the uncertainty. One consideration in parameterizing the alternatives, was the assumption of stationarity for other life stage parameters not specifically considered in an alternative. Certainly, climate change, habitat restoration or degradation, and changes in harvest or hatchery policy will likely impact population status.

2.10. Future Efforts

2.10.1. Influence of Hatchery-Origin Juveniles

Native late-winter steelhead in the Upper Willamette River are no longer supplemented with hatchery-origin fish, with the last production releases in the late 1990s. There are, however, feral non-native early-winter steelhead and naturally- and hatchery-produced non-native summer run present in the basin. There has not been an effort to separately model the effects on non-native steelhead on native steelhead production. Interactions between native late-winter run and non-native early winter run are thought to be minimal given that early-winter steelhead have apparently established themselves in tributaries draining the Coastal Crest to the west of the Willamette Valley; tributaries not historically utilized by late-winter steelhead. Thus the focus has been on interactions between native steelhead and non-native summer run steelhead in tributaries draining the Cascade Mountains. Hatchery-reared summer run steelhead are thought to emigrate soon after release and may have a limited effect on native steelhead, although residualized summer-run steelhead my prey on juvenile salmonids. The progeny of feral summer-run steelhead could compete for food and territory resources during their freshwater residency. These competition or inbreeding effects are implicitly captured in the parameters for reaches where we can calibrate to baseline conditions and are included as one of the continuing conditions for predicting future population growth. It may be necessary to model these effects under an alternative that reduces summer run abundance. Kostow et al. 2003, estimated that summer-run steelhead reduced native late-winter Clackamas River steelhead productivity through competition for spawning and rearing habitat, rather than interbreeding. Under this assumption, improvements to winter steelhead abundance should occur quickly if summer run steelhead production is reduced, although this improvement may only affect reaches below currently impassable dams. In those reaches where adult transport is, or will be undertaken, it is assumed that summer-run steelhead would not be moved upstream. Nevertheless, more effort is needed to understand to what degree feral summer-run steelhead may limit productivity under different alternatives.

2.10.2. Prespawning Mortality

Much of the past work with prespawning mortality in Chinook salmon has attempted to correlate tributary temperatures with observed mortalities. Recent work using radio-tagged Chinook salmon with internal temperature sensors suggests that, prior to entering their natal tributary, conditions in the mainstem Willamette River may be more influential in predicting prespawning mortality levels (Jepson et al. 2014). In addition to thermal effects, prespawn mortality levels could also be influenced by a number of additional factors and their interactions, including, but not limited to: agricultural, industrial, and domestic contaminants in the tributaries and mainstem. Alternatively, providing adult passage above the dams may reduce thermal stressors sufficiently to minimize prespawning mortality levels. Water quality conditions (flow, water chemistry, and temperature) in the mainstem Willamette River are a likely contributory factor to prespawning mortality and should be incorporated into future prespawning mortality models.

2.10.3. Egg Viability

As discussed above, water quality can have a direct effect on the survival of returning adults. Less apparent, but potentially equally important is effect of non-lethal temperature levels or levels of contaminants on the viability of gametes. Basic information on egg to emergent fry survival is unavailable for most reaches, and any future study would need to be able to parse out egg viability effects from incubation effects (e.g., gravel quality, sedimentation, and scour).

2.10.4. Capacity Estimates

The present SLAM model includes estimates of spawner capacities for tributary reaches. There were a number of assumptions that were made in establishing these capacities, especially for reaches that are currently inaccessible or accessible only through trap and haul programs. These assumptions need to be empirically validated, especially the relationships between available habitat and spawners, redds, and emergent fry. In addition to spawner capacity, rearing capacities may be limiting in some reaches, but were not available for inclusion in the SLAM model.

We selected spawner capacity because eggs and fry are static and subject to predictable conditions, while juvenile salmonids are dynamic and can respond (by moving) according to local conditions (habitat, inter- and intraspecific competition). Modeling the movement of fish through space and time is subject to considerable uncertainty. Similarly, the timing and duration of reservoir rearing for juveniles produced in headwater regions is subject to a number of variables. Alternations in dam operation or the construction of passage structures will likely influence predator density, parasite prevalence, outmigration timing, and reservoir productivity. Simply, as a reach approaches capacity fish do not die they simply move to alternative areas, which may or may not be as hospitable as the reach they just left.[7] Capacity models would have to account for differences in juvenile fish age and size, as well as size-dependent duration of rearing in each reach. Capacity limits may be different for different age classes, in part due to the degree to which either resource (food) limitations, social interactions, or refuge habitat (refuge from flow events and/or thermal extremes) control juvenile density. It is likely that populations with diverse juvenile age structures will have higher rearing capacities than those with simpler juvenile life history structure. Rearing duration may also be related to alternate passage specific flow and reservoir characteristics. Understanding habitat limitations will assist in the implementation of recovery plans.

[7] In contrast, as a reach nears its spawner capacity over the course of the season excess eggs and fry are killed through redd superimposition.

CHAPTER 3. PARAMETERIZATION OF WILLAMETTE LIFE CYCLE MODELS OF SPRING-RUN CHINOOK SALMON AND STEELHEAD

3.1. General Approach to Parameterization and Calibration

This chapter reviews information utilized to develop life-cycle models for Upper Willamette River Chinook salmon and steelhead. There were three general classes of parameters utilized in the SLAM model: survival/mortality, life history trajectory options, and productivity. These parameters, in turn, were applied as appropriate to three life cycle phases 1) the regional phase, where parameters were common to fish from all reaches from all basins (life stages in the ocean, estuary, and Columbia and Willamette mainstem); 2) basin phase, where parameters were shared by fish from all the reaches from a single basin (outmigrating juveniles, returning adults), and 3) reach phase, where parameters were specific to a reach with a basin (the life cycle span from returning adults through juvenile outmigration).

Regional parameters were generally sourced from databases on coded-wire-tagged hatchery fish or data from fish sampled at Willamette Falls. Basin-scale parameters were developed from information obtained at mainstem dams in the lower reaches of tributaries: North Santiam River (Bennett Dam), South Santiam River (Lebanon Dam), and McKenzie River (Leaburg Dam). Data from these dams provided multi-reach estimates of escapement and a foundation for setting basin parameters. Harvest data (Chinook salmon only) was available on a regional and basin-scale basis and included some life history information. Finally, dam counts and spawner surveys (carcass counts and life history data) provided reach specific information for adult escapement. Juvenile sampling below dams was useful in informing life history trajectories, but less useful in estimating survivals due to uncertainty in catch efficiency expansions. As a starting point for each specific reach, the default values for unknown parameters were based on those reported in the literature for pristine conditions. Parameters were then calibrated using recent adult escapement information from the last 5 years[8], with the focus being on adjustments to early juvenile survival (the set of parameters with arguably the greatest uncertainty).

Biological information specific to each basin was utilized, where available, to inform the SLAM parameters. Where reach specific data were lacking, more general data sources were utilized. In a number of cases, the parameterization process ultimately relied on expert opinion from biologists familiar with the Upper Willamette Basin.[9] Finally, this Chapter outlines how SLAM demographic output is converted into component VSP metrics for the evaluation of dam passage alternatives.

3.2. Chinook Salmon: Life History Strategies

3.2.1. Juvenile Life History

Chinook salmon exhibit a variety of juvenile life-history strategies. Two generalized types of freshwater life history were described by Gilbert (1912) based on scale patterns: stream-type Chinook salmon that reside in freshwater for a year or more, or ocean-type Chinook salmon that migrate within their first year. These definitions were more broadly used by Healey (1983 and 1991) to distinguish populations of Chinook salmon. Under Healey's definition, ocean-type populations are not limited to sub-yearling freshwater migrants, but are much more plastic in their

[8] There have been a number of operational changes in fish passage, temperature control, etc. in recent years, such that only recent returns reflect current conditions.
[9] See Appendix for a list of participants

age at emigration than stream-type Chinook salmon, which rarely emigrate at less than a year old. Ocean- and stream-type Chinook salmon populations also exhibit distinct oceanic migration patterns. Ocean-type Chinook salmon appear to be coastally oriented in their ocean migrations, whereas stream-type populations move quickly offshore to the North Central Pacific. Using Healey's definition, Upper Willamette River spring-run Chinook salmon would be classified as ocean type. Juvenile Chinook salmon are observed migrating past Willamette Falls as fry, larger subyearlings, yearlings, and two-year-old fish. Coded-wire tagged adults from the Upper Willamette Basin are caught in coastal fisheries from Oregon to Alaska (Myers et al 2006).

One of the earliest studies of juvenile Chinook salmon outmigrants was done on outmigrating fish at Willamette Falls from 1965 to 1967 (Massey 1967). Subyearling Chinook salmon (75 to 150mm in length) emigrating during the spring/summer solstice (May to July) accounted for 62.7% of the total outmigration (Figure 3.1). Fry Chinook salmon (< 75mm) accounted for 17.6% of the outmigrants during the first twelve-months, while larger yearlings (> 150mm) represented only 3.8% of the fish sampled during the year. These estimates are not adjusted for size-dependent sampling biases or the presence of hatchery fish, but do indicate that significant numbers of each size class are present.[10] Friesen et al. (2007) observed that juvenile Chinook salmon were present below Willamette Falls in the greatest numbers during the winter and spring months. It is important to note that little of the historical higher elevation rearing habitat is currently accessible to naturally spawning fish, and the age structure of outmigrating headwater-origin juveniles following the restoration of access may be different from that currently observed. Retrospective juvenile life history analysis of scales from returning adults generally identifies two or three outmigrant strategies: subyearling (sometimes separated into spring and fall outmigrants) and yearling.

There are numerous studies on the age and size of outmigrants below the dams. It is clear from these studies that the mode of downstream passage, water flow through the dam, reservoir height, and time of year, may all influence the magnitude and temporal distribution of juvenile passage; however, there was little information on the correlation between the life history stage at dam passage and the ultimate timing of saltwater entry. Recent studies of gill Na^+K^+ ATPase suggest that juveniles successfully passing the dams are undergoing smoltification and may be more likely to emigrate rather than rear in the lower reaches of the tributaries (Romer et al. 2013a). Estimates for the timing and passage success of age classes passing the dams were provided by the USACE as part of the Fish Benefit Workbook. Additionally, for juveniles moving through a reservoir, workgroups provided expert opinion estimates for reservoir survival and the relative proportion of each life history type that emigrates or resides in the reservoir at least until the next life history stage. In the absence of specific data the distribution of juvenile life histories emigrating from non-impounded areas was set, as a default, at equal proportions (33%) for each of the three outmigrant age classes.

[10]An earlier study by Dimick and Merryfield (1945) reported that few Chinook salmon migrate in the main river [Willamette River] during June, July, and August, but instead were migrating out of the tributaries earlier in the spring as fry and later in the Autumn with the rains. It should be noted that for much of the 20th Century conditions in the Lower Willamette River were effectively lethal to juvenile salmonids during the late spring and summer migration (i.e., June, July, and August).

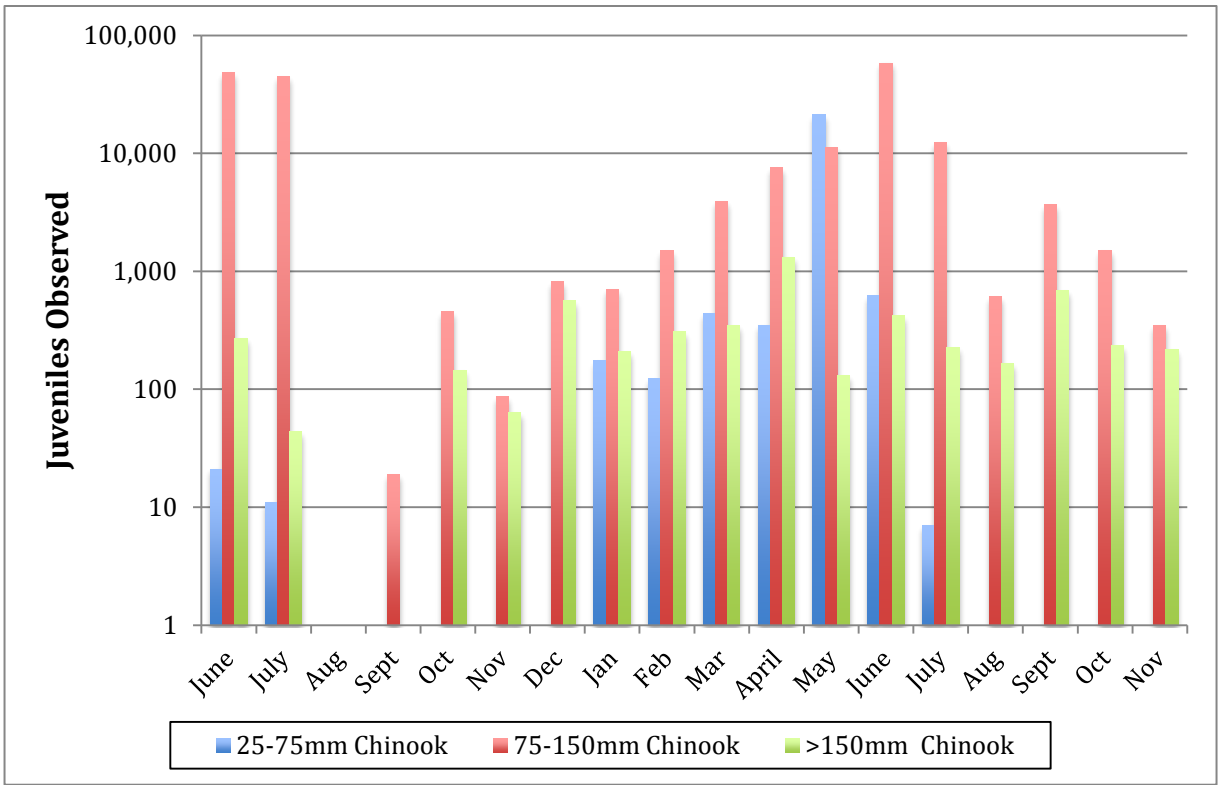


Figure 3.1: Size and time of passage for juvenile Chinook salmon at Willamette Falls 1965-1966 (Data from Massey 1967).

According to Mattson (1962) 18-55% of spring-run Chinook salmon in the McKenzie River migrated as first year spring sub-yearlings, 12-48% as fall sub-yearlings, and 20-32% as second spring yearling smolts. A similar spring-run Chinook salmon outmigration pattern was observed in the Cowlitz River prior to the construction of the three mainstem dams, Mayfield, Mossyrock, and Cowlitz Falls (Stockley 1961). There is a shift in the proportional representation of life history types when the distribution of outmigrating juvenile Chinook salmon is compared to the juvenile life histories represented in the scale patterns of returning adults. This is due, in part, to the differential survival of the juvenile outmigrant class in the estuary and ocean. Mattson (1963) reported that of the returning adult spring-run Chinook salmon caught in the sport fishery from 1946 to 1951 at Willamette Falls, approximately 14.8% of the fish (range 12.8-21.7%) had emigrated as subyearlings. The contribution of subyearlings was highest among 3 and 4-year-old adults. More recently, Schroeder et al. (2007) reported that of the returning adult Chinook salmon sampled (1998-2001) the proportion that had emigrated as subyearlings was 17% (range 2-28%) from the McKenzie, 35% (range 10-48%) from the North Santiam, and 59% (range 16-84%), from the South Santiam River. This adult data underscores the magnitude of year-to-year variability in juvenile life history strategies, which could represent either differences between years in growth and the initiation of smoltification or differences in the survival of juveniles after they leave their natal stream.

3.2.2. Age at Maturation

Generally, spring-run Chinook salmon return to the Upper Willamette River as four or five year-olds, with five-year olds historically being the predominant proportion of the run (Mattson 1963).

Tributary specific age distributions were not provided by Mattson; however, based on measurements of fork length, three-year-old males (jacks) were present among the Chinook salmon sampled in 1947 from both the North Santiam and McKenzie rivers, in addition to larger six year-old males (Figure 3.2). It is not clear what the contribution of hatchery-origin adults was to the fish sampled by Mattson, although given the status of hatchery programs in 1940s the returns would have been relatively low. Wallis (1961, 1963) in his review of the Upper Willamette River hatchery programs concluded that the hatchery programs provided little if any benefit to the salmon runs in either the McKenzie or North Santiam rivers.

Most of the available age structure data is from more recent studies, subsequent to the construction of tributary dams and the loss of much of the natural spawning habitat (Table 3.1). Concurrent with the loss of natural production has been an increase in the contribution by hatchery-origin fish to escapement. Until recently, ocean harvest rates were high enough to have had strong effect on age structure (PSC 2012); we assumed that present lower rates will continue into the future. Age structure in the existing SLAM model is determined via the relative survival of specific brood years in fresh water and the ocean in addition to the maturation rates for each ocean-age. Parameters were set in the initial SLAM model in the Upper Willamette River Recovery Plan (ODFW and NMFS 2011) and in the R2 Resource Consultants (R2 hereafter) version of the SLAM models (Hendrix and Shi 2012, Hendrix et al. 2012a, 2012b).

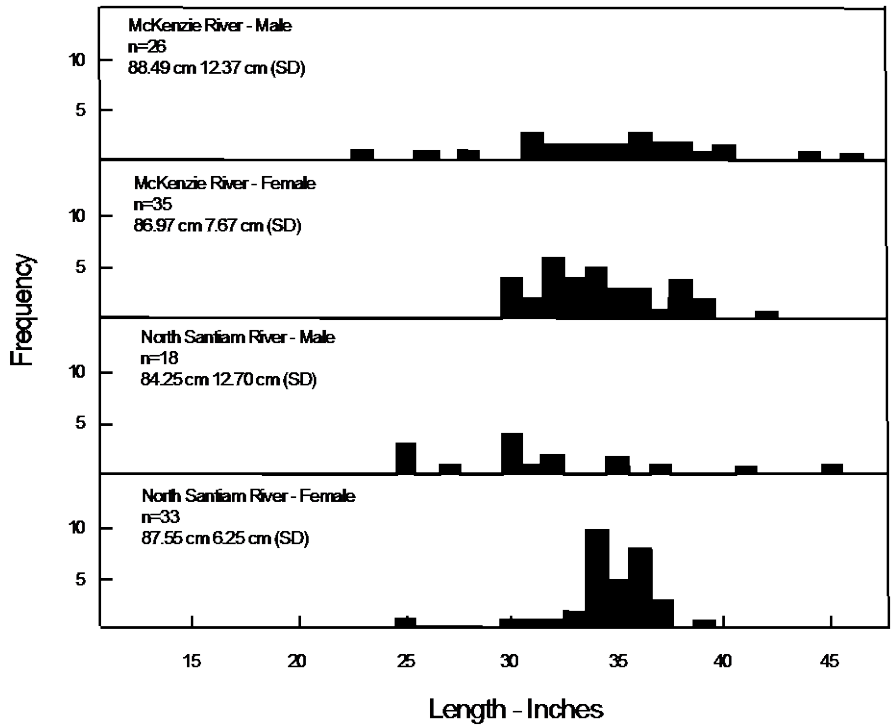


Figure 3.2: Size distribution for Chinook salmon recovered from the McKenzie and North Santiam rivers in 1947 from Mattson (1963).

Table 3.1: Upper Willamette River Basin adult spring-run Chinook salmon age structure. Fish samples are mixed origin unless indicated otherwise (Rich and Holmes 1929, Mattson 1962, Collins 1980, Bennett 1989, Schroeder et al. 2007, Johnson and Friesen 2013).

Sample Site (*source*)	Year	3-year Old	4-year Old	5-year Old	6-year Old
Lower Columbia River (*Study*[11])	1927	1.3%	5.3%	52.0%	41.3%
Willamette River (*Sport Fishery*)	1946-51	4.2%	24.2%	61.1%	10.5%
Willamette River (*Sport Fishery*)	1970-79	2.3%	47.4%	48.6%	1.7%
Willamette River (*Sport Fishery*)	1978-87	1.8%	55.9%	41.2%	1.1%
Willamette River (*Sport Fishery*)	1989-2005	1.5%	54.2%	43.5%	0.7%
McKenzie River (*Wild*)	2001-06	0.5%	26.7%	70.8%	2.0%
South Santiam River (*Wild*)	2002-06	1.3%	59.2%	38.1%	1.4%
North Santiam River (*Wild*)	2001-06	4.8%	48.6%	44.6%	2.4%
Naturally-spawning (Hatchery)	1989-2005	1.9%	42.6%	55.1%	1.1%

3.2.3. Pre-Spawning Mortality

Recent studies have documented high levels of prespawning mortality (PSM) among returning spring-run Chinook salmon adults in a number of Upper Willamette River subbasins. Schreck et al. (2013) discuss a number of potential causal (primarily pathogenic) factors that may be responsible for prespawning mortality. Roumasset (2012) analyzed prespawning mortality in Willamette and Sandy River basins (11 index reaches) and evaluated the influence of a number of possible contributing factors. Three factors were found to substantially contribute to observed variability in PSM across years and between reaches: stream temperature, fish density, and the relative presence of hatchery-origin and natural-origin spawning adults (Roumasset 2012). The temperature variable was defined as the average maximum daily stream temperature for the hottest seven consecutive days from each year (7-DAM T), which generally occurs between July and September when Chinook salmon adults are holding in the river before spawning. Density and the proportion of naturally-produced spawning naturally (%wild) were both significant, but highly correlated. This was thought to be due to the large numbers of hatchery-origin fish aggregating near structures (hatchery collection sites), where PSM was especially high. A simplified logistic model, including only the temperature and % wild factor, was initially assessed.

We related PSM to both temperature, as described above, and % wild in each reach. In contrast to Roumasset (2012), we included population (basin) as a separate effect in order to identify any population-specific PSM relationships. In addition to the sample sites assessed by Roumasset, we included above dam reaches in the North Santiam, South Santiam, and McKenzie rivers and Hill Creek in our model development. For our initial analysis, we used a logit transform on PSM (Table 3.2). This is desirable because it can produce threshold type behavior, and the back-transformed estimates are bounded on the range 0 to 1. The model that was identified as providing the best fit was the one where temperature was entered additively along with an interaction between % wild and Population (Table 3.2).

Attempts to calibrate the SLAM model using a general (all-basins) version of the prespawning mortality model resulted in a number of reaches experiencing near 100% mortality in most years.

[11] The homing study by Rich and Holmes (1929) involved releasing fish from Upper Willamette River hatcheries reared at the Bonneville Hatchery at 11 months. Fish were fin clipped and adult recoveries reported from throughout the Lower Columbia River. Although the age structure reported would be biased by hatchery rearing, it does constitute the earliest report of Upper Willamette River spring Chinook age structure.

Further analysis indicated that this was due, in part, to the location of the temperature gauges (some were placed in the lower most section of a reach) and ultimately to the PSM equation itself. The threshold nature of logit transformed PSM model was overly sensitive to small changes in temperature (±1°C) near the inflection point of the model and predicted near 100% mortality for conditions that empirically only resulted in moderate mortality. Another issue in developing a predictive PSM model was that many of the time series for PSM included operational changes in water releases from the dams and changes in fish handling procedures below the dam. A number of factors clearly violated stationarity assumptions. Because of these issues with the logit-transform model, we examined models with untransformed PSM (Table 3.3). For these simple linear models, the most supported model contained temperature and % wild, but no population effects.

PSM = -9.5789 + (%Wild * -2.39) + (Temp * 0.5492)

Note that prespawning mortality estimates only considered the loss of returning adults once they had migrated to their natal reach. Mortalities incurred by adults in fresh water prior to their natal reach were included in the transition from "returning adults" to "in-river harvest."

Table 3.2: Results of the multiple linear regression with PSM Logit Transformed. AICc is AIC corrected for sample size. Δ AICc is AIC corrected for sample size. Weight is the AIC weight, and it provides an indication of the relative support for an individual model. The "*" means that the variables were treated as interactions, with the main effects also included in the model.

Model	AICc	Δ AICc	Weight	R^2
%Wild	250.8	35.4	0	0.008
maxT	237.7	22.3	0	0.311
%Wild + maxT	235.4	19.9	0	0.347
%Wild * maxT	236.5	21.1	0	0.350
maxT + Popn	226.9	11.5	0.003	0.504
maxT * River	225.6	10.2	0.006	0.586
maxT + %Wild + Popn	225.9	10.5	0.005	0.516
maxT + %Wild ***** Popn	**215.4**	**0.0**	**0.985**	**0.630**

Table 3.3: Results of the multiple linear regression with PSM untransformed. AICc is AIC corrected for sample size. Δ AICc is AIC corrected for sample size. Weight is the AIC weight, and it provides an indication of the relative support for an individual model. The "*" means that the variables were treated as interactions, with the main effects also included in the model.

Model	AICc	Δ AICc	Weight	R^2
%Wild	36.4	10.1	0.005	0.100
maxT	33.0	6.7	0.03	0.236
%Wild **+ maxT**	**26.3**	**0**	**0.85**	**0.400**
%Wild * maxT	32.6	6.4	0.035	0.404
maxT + Popn	34.3	8	0.015	0.443
maxT * River	53.7	27.4	0	0.465
maxT + %Wild + Popn	31.6	5.4	0.058	0.530
maxT + %Wild ***** Popn	36.3	10	0.006	0.583

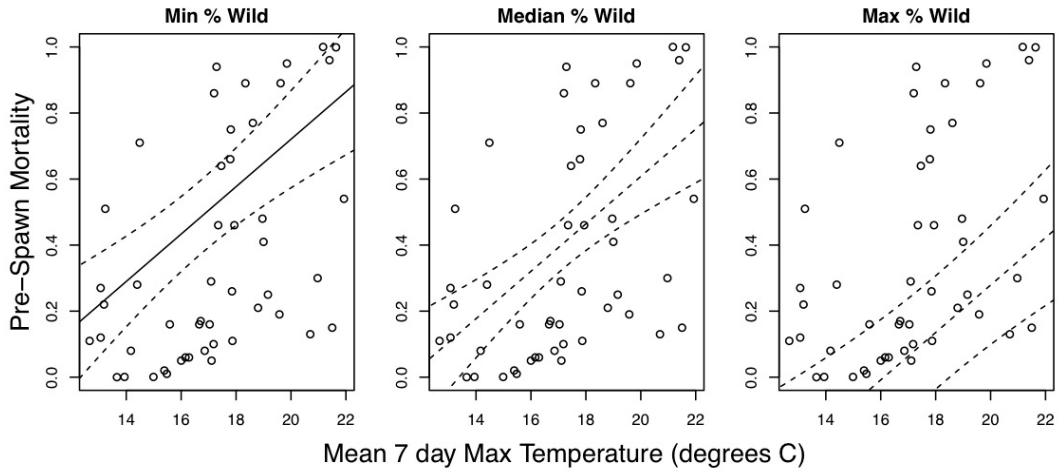


Figure 3.3: Plots of the most supported linear model for PSM vs temperature and % Wild, with 95% confidence intervals about the relationships. In the left plot, % Wild was set to the minimum value (0%). In the middle plot, % Wild was set to the median value (25%). In the right plot, % wild was set to its maximum value (98%).

Recent work by Jepson et al. (2014) using internal thermal monitors suggests that the highest temperatures experienced by returning adults are in the mainstem Willamette River prior to entering the tributaries. Furthermore, it may be that PSM is related to the total number of temperature units experienced by the fish throughout their freshwater migration. Additionally, it did not appear that migrating salmon utilized coldwater refugees (other than holding in the Clackamas River). Thermal exposure likely varies on a fish by fish basis depending on migration timing and behavior. At present, the Jepson et al. (2014) represents the first year of a preliminary study and no working model is available for incorporation. Additionally, SLAM is very limited in its ability to account for individual fish differences thermal exposure. Although recent studies suggest new approaches to understanding PSM, the Roumasset (2012) model represents the most recent peer-reviewed modeling approach and until other models are fully developed it will continue to be the basis for predicting PSM.

3.2.4. Spawner Capacity

Ultimately, the potential abundance of any population is limited by the capacity of the spawning and rearing habitat available. The life cycle model used spawner habitat (egg) capacity as the primary density dependent factor in a Beverton-Holt model. There are a number of ways to estimate the capacity of river or its component reaches. In the R2's SLAM model parameterization, spawning capacity (redds or juveniles) was estimated through contemporary surveys of available spawning habitat and estimated redd area (based on several different studies). In general, it is assumed that each redd represents at least 2.5[12] or more spawning adults and that males and females were equally represented. For our estimates of capacity, we relied on information from habitat surveys and run-size estimates conducted during the 1930s and 40s, prior to the construction of Upper Willamette River tributary dams (Craig and Townsend 1945, Mattson 1948,

[12] The ratio of adults per redd varies considerably, in part because adult estimates can be calculated from run size, escapement, or actual spawners. Oregon Department of Fish and Wildlife currently estimates 2.5 adults per redd. SLAM does not utilize redd counts as an estimate of abundance, instead baseline conditions are calibrated using counts of NORs. R2 productivity was based on redds and is provided for comparative purposes.

Parkhurst et al. 1950). In many instances the capacities differed by an order of magnitude (Table 3.2). Similarly, we did not utilize the mitigation escapement goals established for each dam at the time of its construction. As with contemporary escapement estimates, Chinook salmon (and steelhead) populations were likely much reduced during the 1960s, when most of the dams were constructed and mitigation goals established. This is especially true if we consider the probable contribution of natural origin spawners (NORs) to overall escapement. We utilized historical estimates of egg capacities to reflect the fact that the amount of spawning gravel has not decreased proportionally with the decrease observed in run size. In other words, the decline in Chinook salmon run sizes in the Upper Willamette Basin is not generally thought to be due to a loss of spawning gravel. Therefore, in order to calibrate the SLAM baseline scenarios to contemporary run sizes, it was necessary to identify those downstream life stages where survivals have been dramatically reduced relative to historical conditions. These life stages will, in turn, become the focus of potential efforts for recovery/restoration.

We used the Parkhurst et al. (1950) estimates of salmon spawner capacity[13] as a maximum, with most egg capacity estimates equivalent to 33-50% of the Parkhurst estimates (Appendix 3.4a). These capacities were also compared to other estimates of historical capacity (see Appendix 3.5). Adjustments to capacities reflected spawner habitat lost to reservoir area and degradation of habitat quality.

During the development of the life cycle model there was considerable discussion regarding the establishment of reach capacities. In order to test the sensitivity of the life-cycle model results we reanalyzed baseline and alternatives for the McKenzie River spring-run Chinook salmon population using our capacity estimate for Reach C, and capacities set at 50% and 25% of the current capacity estimate (Figure 3.4a and 3.4b).

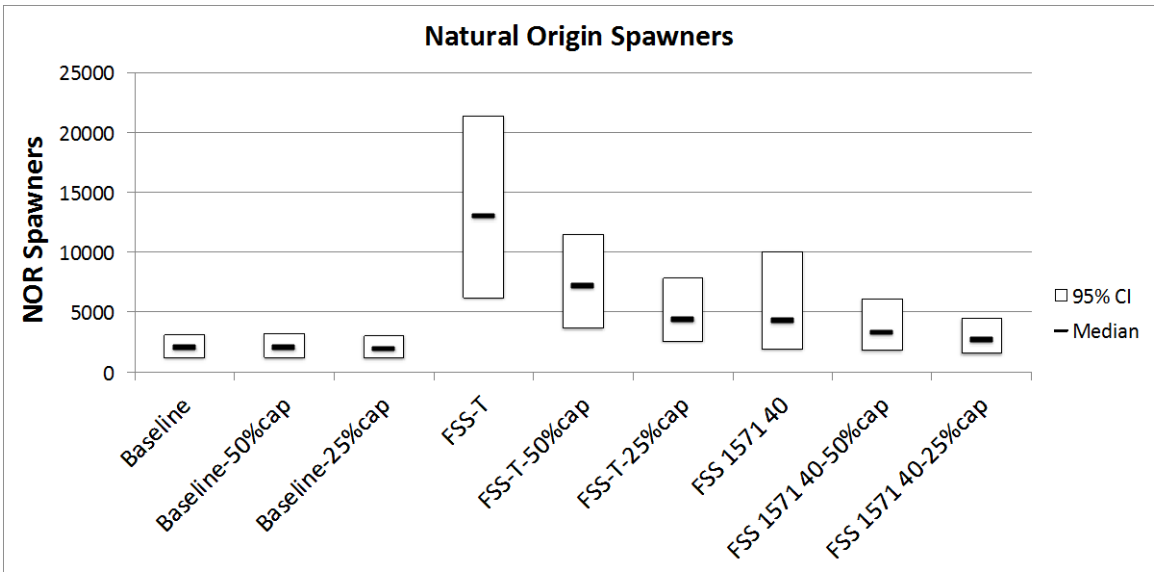


Figure 3.4a. Median abundances for McKenzie River spring-run Chinook salmon baseline and passage alternatives utilizing different capacities for Reach C.

[13] Parkhurst et al. (1950) capacities were based on the survey team's estimate of gravel available for spawning salmon. Surveys were conducted from 1938 to 1945 prior to dam construction.

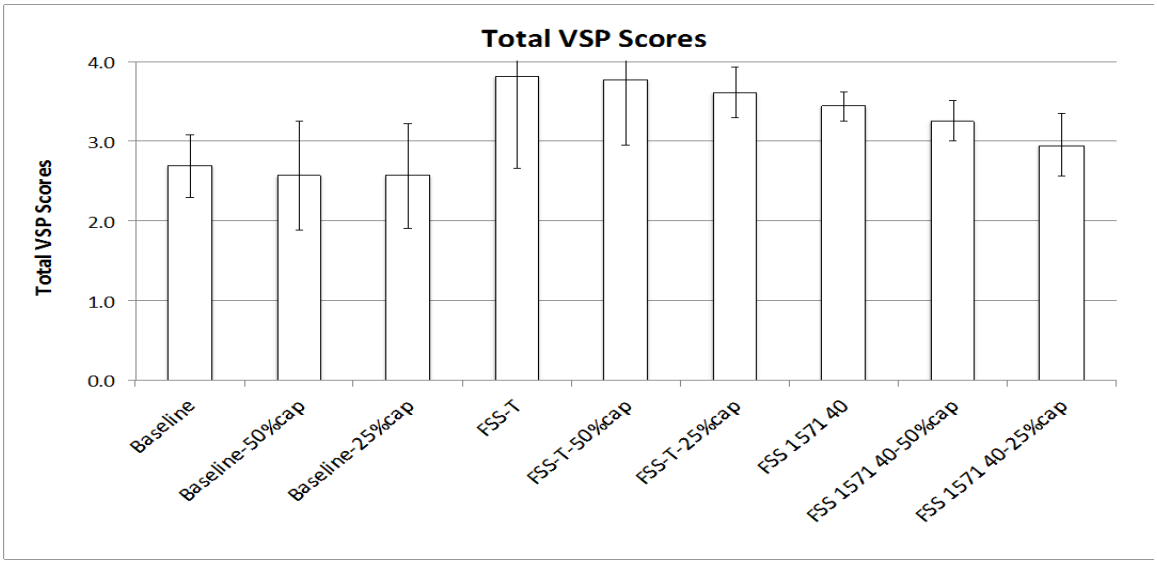


Figure 3.4b. Median VSP scores for McKenzie River spring-run Chinook salmon baseline and passage alternatives utilizing different capacities for Reach C.

Under baseline conditions, where fish in Reach C are not self-sustaining, varying the capacity of Reach C has little effect. The FSS-T and FSS 1571 (4) alternatives were sensitive to changes in capacity when comparing total NOR abundance, but much less so when comparing VSP. As discussed earlier, VSP scores are more closely tied to persistence than simply abundance, and regardless of Reach C capacity the overall probably of persistence was relatively similar for each alternative. Additionally, differences in abundance scores could be used to confer relative certainty of persistence. Perhaps more importantly, changes in capacity did not affect the relative ranking of alternatives (the most suitable role for VSP scores under the current modeling regime).

3.2.5. Capacity Estimates

In modeling population demographics for the Upper Willamette River populations with SLAM, we focused on spawning habitat as the limiting factor. This followed the template initially developed by R2, and (in part) reflects the absence of any rearing habitat capacity estimates. Spawner capacity, or the amount of habitat suitable for egg deposition, was incorporated using a Beverton-Holt (density-dependent) model, to reflect superimposition of redds and spawning in less desirable substrate as spawner density increased. Reach specific capacity thresholds were established based on historical habitat surveys (Table 3.4) conducted primarily during the 1930s, 40s, and 50s. In many cases it is clear that the current ability of those accessible reaches to support previous levels of abundance has been dramatically reduced. This reduction, however, is more directly related to the quality of the available habitat, not the quantity. For that reason the decline in productivity for downstream reaches relative to historical is reflected in the early incubation and rearing survival of naturally produced juvenile salmonids. This would suggest that improvements in habitat could result in improved juvenile survival and increases in overall abundance. Alternatively, reducing spawner capacity as an approach to reflect historical declines in productivity suggests that the habitat cannot provide space for more adults and that populations may be at overescapement. For example, for the McKenzie River R2 suggested a capacity of 1,697 redds, assuming 4500 eggs per redd, a 5.0% survival from egg to smolt, and a 2.0% survival from smolt to adult the maximum adult return would only be 7,637 fish, or if one uses the 2.5 spawners per redd expansion (ODFW), the capacity would be 4,243 adults, both an order or magnitude less than estimated 80,000 spawners

that Parkhurst et al (1950) estimated the entire basin could support and may have supported historically. Measures of juvenile Na^+K^+ATPase in juveniles emigrating past the dams suggest that they are physiologically smolting and likely to continue their down stream journey rather than reside in the tributary (Romer et al. 2013a). Establishing near-historical spawner capacity levels better reflects the biology of the situation and places an emphasis on areas for possible improvement.

Table 3.4: Comparisons of reach capacities based on historical habitat surveys (Parkhurst et al. 1950) and contemporary surveys and estimates (R2 manuals).

Tributary	Reach	SLAM Reach	Parkhurst Capacity (Adults)	R2/Recovery Plan Estimate[14] (Redds)
North Santiam River				
	Blw Bennett Dam	A	-	44
	Btwn Bennett and MCF	B	-	563
	Blw Detroit	A,B,F	20,000	-
	North Santiam River	C	2,500	58
	Breitenbush River	D	3,000	446
	Upper North Santiam	E	10,000	525
	MCF to Detroit Dam	F	-	62
South Santiam River				
	Blw Lebanon Dam	A	-	37
	Thomas/Crabtree Creek	B	8,000	203
	Lebanon to Foster Dam	C	-	848
	Wiley Creek	D	-	23
	South Santiam above Foster Dam	E		1,436
	South Santiam	A,C,E	20,000	-
	Quartzville Creek	F	3,000	147
	Middle Santiam River	G	15,000	381
McKenzie River				
	Blw Leaburg Dam	A	-	148
	Above Leaburg Dam	B	-	833
	Above Hendrick's Bridge	A,B	50,000	-
	Above Cougar Dam	C	13,000	716
Middle Fork Willamette River				
	Lower Fall Creek	A		88
	Upper Fall Creek	B		209
	Fall Creek		2,000	
	Above Dexter/Lookout Pt Dams	C		410
	Above Hills Creek	D		291
	North Fork Willamette		20,000	
	Upper Middle Fork		10,000	

[14] Estimates of capacity were provided by R2 for Chinook salmon in the North Santiam, South Santiam, and McKenzie rivers (Hendrix and Shi 2012, Hendrix et al. 2012a, 2012b). Middle Fork Willamette capacities were calculated from SLAM juvenile production estimates in the Upper Willamette Recovery Plan, Appendix D (ODFW and NMFS 2011).

3.2.5.1. North Santiam River Reaches

The North Santiam River is divided into six reaches: Reach A, from the confluence with the South Santiam to Bennett Dam; Reach B, from Bennett Dam to the Minto Fish Collection Facility; Reach C, the Little North Santiam River; Reach D, the Breitenbush River (above Detroit Dam); Reach E, the North Santiam River (above Detroit Dam); and Reach F, from the Minto Fish Collection Facility to Big Cliff Dam (Figure 3.5). Reach-specific spawning capacities developed by R2 (Hendrix et al. 2012a) suggest that there is habitat available for 588 redds below Detroit Dam, and room for an additional 796 redds above Detroit Dam (medium estimate in range). This below Detroit Dam capacity estimate is close to the 557 redds[15] observed in 2012 (Sharpe 2013a) and is considerably lower than the historical estimates of above and below Detroit Dam capacities, even considering the loss of spawning habitat by the creation of the reservoirs.

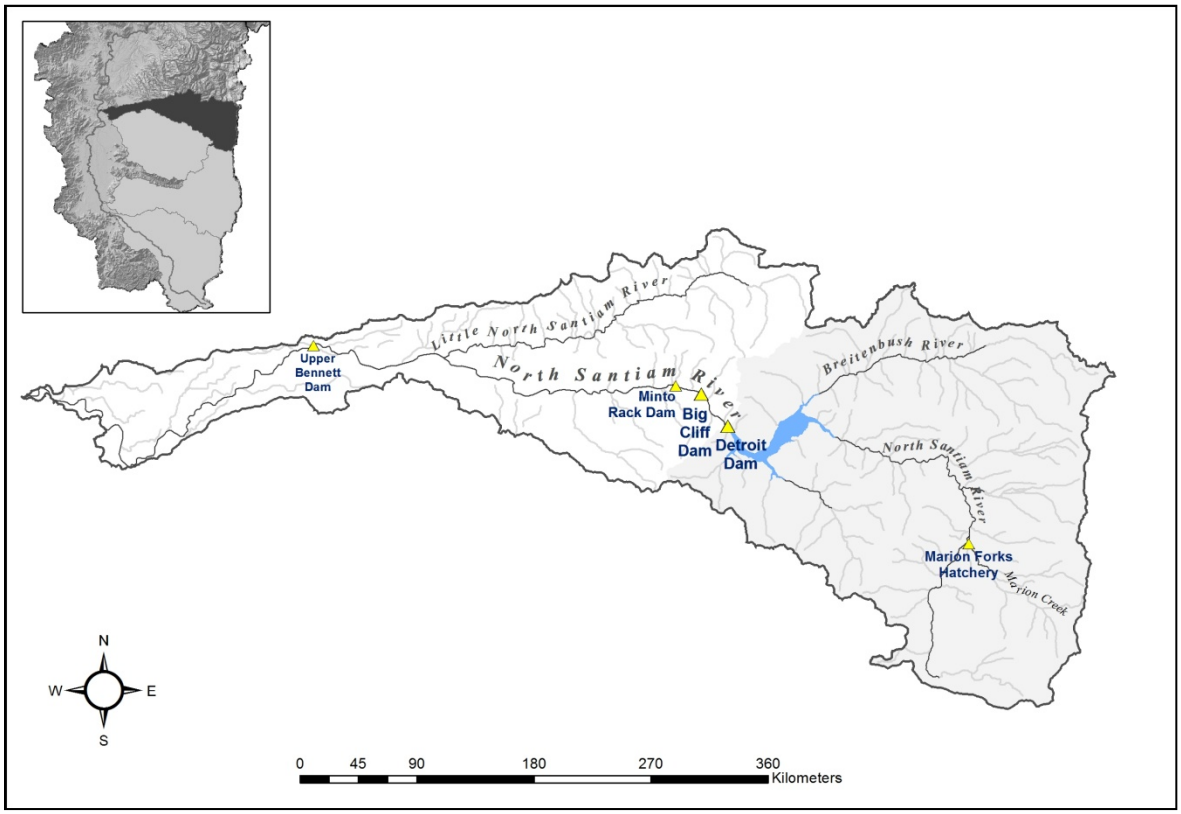


Figure 3.5: North Santiam River Basin, shaded portion denotes anthropogenically inaccessible habitat, man-made barrier (M. Sheer, unpublished).

Available historical information suggests that much of the historical spawning habitat was above the current location of Detroit Dam. The Oregon Fish Commission (OFC) hatchery rack was located near Jefferson, below the confluence of the North Santiam and Breitenbush Rivers and below most of the natural-spawning areas, except for the Little North Santiam River (Wallis 1963a), so much of the natural spawning abundance above the weir was likely greatly diminished by hatchery operations. In 1911, 1.5 million eggs were collected. The largest egg collection was 13.2 million in 1934. This would correspond to 4,125 females @ 3,200 eggs/female (Wallis 1963a). The estimated run size for the entire North Santiam River basin was 2,830 in 1947 (Mattson 1948). Within the

[15] Of the spawners below Detroit Dam, approximately 75% were identified as hatchery-origin fish.

North Santiam River, the principal spawning areas were located from 2 km above the town of Stayton up through the Breitenbush River (Mattson 1948). Mattson further estimated that 71% of the North Santiam Chinook salmon spawned above the Detroit Dam site. Similarly, Craig and Townsend (1946) reported that two-thirds of the salmon would spawn above the dam site, and only one-tenth of those spawning above the dam site utilized the area that would be inundated by the reservoir (between the mouth of the Breitenbush River and the dam site). Finally, Parkhurst et al. (1950) estimated that there was sufficient habitat in the North Santiam to accommodate at least 30,000 salmon adults, with much of this habitat below the dam site (although the preferred spawning areas were all above the dam site). Based on habitat loss with the construction of the Big Cliff and Detroit dams (including the reservoir pools) and habitat loss and degradation below the dams, spawner (egg) capacities were reduced from those described in pre-dam studies (Table 3.5).

Table 3.5: Egg capacities and their adult equivalents for North Santiam River reaches utilized in the Chinook salmon SLAM model.

Tributary	Reach	SLAM Reach	Mean Capacity (eggs)	Adult Spawners (@ 2250 eggs)
North Santiam River				
	Blw Bennett Dam	A	300,000	133
	Btwn Bennett and MCF	B	5,000,000	2,222
	Blw Detroit	A,B,F	5,800,000	2,578
	Little North Santiam River	C	1,500,000	667
	Breitenbush River	D	6,000,000	2,667
	Upper North Santiam	E	12,500,000	5,556
	MCF to Detroit Dam	F	500,000	222
	Total Spawners	A - F		11,468

3.2.5.2. South Santiam River Reaches

The South Santiam River is divided into seven reaches: Reach A, from the confluence with the North Santiam to Lebanon Dam; Reach B, Thomas and Crabtree Creeks; Reach C, from Lebanon Dam to Foster Dam; Reach D, Wiley Creek; Reach E, the South Santiam River (above Foster Dam); Reach F, the Quartzville Creek (above Green Peter Dam); and Reach G, Middle Santiam River (above Green Peter Dam) (Figure 3.6).

In the Technical Memorandum from R2, those reaches that are currently accessible (not including those above Green Peter Dam) could support 1,651 redds (medium estimate) or approximately 4,128 spawners, at 2.5 spawners per redd (Hendrix et al. 2012b). The areas above Green Peter Dam were estimated to potentially support an additional 415 redds, or 2,066 redds for the entire basin. This estimate is considerably lower than historical estimates, even considering the loss of spawning habitat by the creation of the reservoirs. OFDW redd surveys in 2012 identified 443 redds between Lebanon and Foster Dams, and 222 redds above Foster Dam (Sharpe 2013b). The majority of the spawners below Foster Dam were first generation hatchery fish, while the majority of the spawners above Foster Dam were natural origin spawners (only unmarked fish are currently passed above the dam, although some unmarked hatchery-origin fish are included[16]).

[16] Analysis of otoliths from caracasses recovered above Foster Dam is used to estimate pHOS.

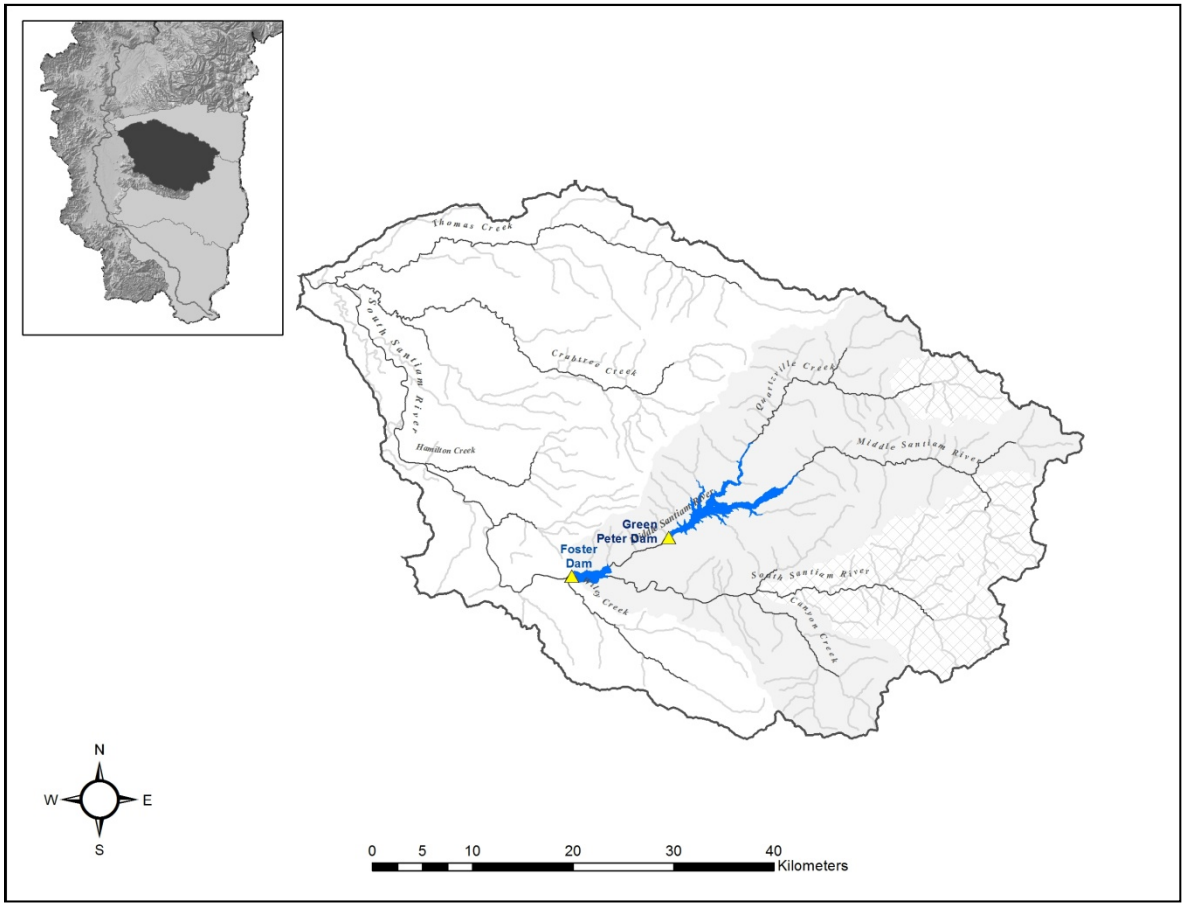


Figure 3.6: South Santiam River Basin, shaded portion denotes anthropogenically inaccessible habitat (man-made barrier), and cross-hatched areas are historically inaccessible habitat (natural barrier).

Much of the historical information on the South Santiam spring-run Chinook salmon comes from hatchery records. Broodstock collection activities began in 1923 with a weir placed across the river near the town of Foster (Wallis 1961), well below the natural holding and spawning areas (Mattson 1948). Escapement to the South Santiam River was estimated to be 1,300 in 1947 (Mattson 1948). Spawning Chinook salmon were also reported by Mattson (1948) in Thomas Creek (above the Jordan Dam), and Crabtree Creek (above the State Game hatchery). Chinook salmon were observed as far upstream as Tamolitsh Falls (Craig and Townsend 1946, Mattson 1948). Wallis (1961) estimated that because of poor husbandry practices, releases from the South Santiam Hatchery did not significantly contribute to escapements; therefore returning adult estimates may mostly reflect natural productivity. Parkhurst et al. (1950) estimated that there was spawning habitat available for 20,000 spawners in the South Fork Santiam River above Lebanon. Overall, at the time of the Mattson (1948) survey, the South Santiam Basin accounted for 12% of the spawning abundance of Chinook salmon in the Upper Willamette Basin, which would suggest a historical salmon run of nearly 40,000 fish (Appendix 5). Based on habitat loss with the construction of the Foster and Green Peter dams (including the reservoir pools) and habitat loss and degradation below the dams, spawner (egg) capacities we reduced from those described in pre-dam studies (Table 3.6).

Table 3.6: Egg and spawner capacities for South Santiam River reaches.

Tributary	Reach	SLAM Reach	Mean Capacity (eggs)	Adult Spawners (@ 2250 eggs)
South Santiam River				
	Blw Lebanon Dam	A	150,000	67
	Thomas/Crabtree Creek	B	1,500,000	667
	Lebanon to Foster Dam	C	4,000,000	1,778
	Wiley Creek	D	500,000	222
	South Santiam above Foster Dam	E	7,000,000	3,111
	South Santiam	A,B,C,D,E	12,150,000	5,400
	Quartzville Creek	F	2,000,000	889
	Middle Santiam River	G	4,500,000	2,000
Total				8,289

3.2.5.3. McKenzie River Reaches[17]

The McKenzie River is divided into three reaches: Reach A, from the confluence with the Willamette River to Leaburg Dam; Reach B, the McKenzie River upstream of Leaburg Dam; Reach C, the South Fork McKenzie River (above Cougar Dam) (Figure 3.7). One of the major factors influencing the overall population performance was the capacity set for each of the three reaches. Given that the focus of the modeling exercise is the contribution of spawning Chinook salmon in the South Fork McKenzie above Cougar Dam to the entire population, the spawner capacity estimate used for the South Fork was especially important.

In the version of the SLAM model developed by R2, the mode of the triangular distribution used to calculate yearly capacity estimate for Reach C (South Fork McKenzie above Cougar Dam) was 2,544,750 eggs, based on 585 redds with 4350 eggs/redd (Hendrix and Bing, 2012). In converting adult spawner numbers to redds and then egg capacity R2 assumed a 1:1 male to female ratio and two adults per redd. ODFW currently assumes a 2.5 adult spawners for each redd[18] This capacity was estimated using an averaged surface area for each redd (in units of ft^2) as reported in the literature combined with an estimate by R2 of available spawning habitat (R2 2009). For those reaches where habitat surveys were not available R2 used a number of different methodologies to estimate capacity, including: recent redd counts, river flow, and redd densities from similar reaches.

In reviewing the capacity estimates provided by R2, it was apparent that these model-based capacities were substantially lower than empirical observations prior to and during the construction of Cougar Dam. We initially relied on habitat surveys conducted during the 1930s and 40s, prior to the construction of Upper Willamette River tributary dams (Parkhurst et al. 1950). In the specific case of the South Fork McKenzie (Reach C, above Cougar Dam), the Parkhurst et al. (1950) estimate for the South Fork was 13,000 spawners, we in turn, used a mean capacity of 17,000,000 eggs which equates to 7,555 spawners (at 2,250 eggs/spawner). This is a 60% reduction from the Parkhurst et al. (1950) estimate, reflecting both a conservative approach to the initial estimate and adjusting for the loss of spawning area due to the reservoir and spawning area below Cougar Dam.

[17] For the purposes of SLAM modeling, spawner capacity was set as the number of eggs that could be deposited in suitable spawning habitat. Run/spawner estimates were considered to inform this capacity.
[18] B. Hudson, ODFW. 23 December 2013. Letter to J. Casey, US Army Corp of Engineers.

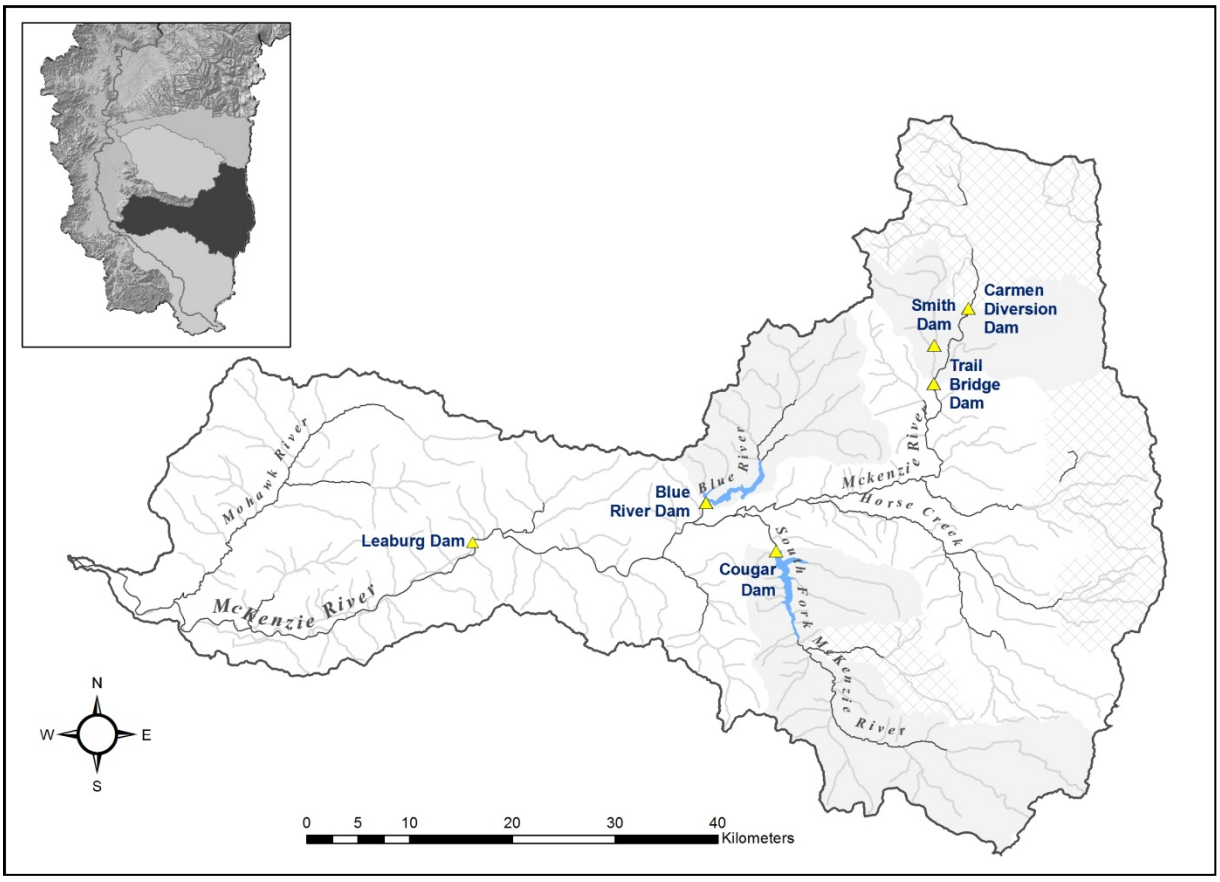


Figure 3.7: McKenzie River Basin, shaded portion denotes anthropogenically inaccessible habitat, man-made barrier, and cross-hatched areas are historically inaccessible habitat, natural barrier (M. Sheer, unpublished).

In addition to the Parkhurst et al. (1950) study there are a number of other surveys that would support our higher estimate for reach capacities over those proposed by R2. According to Mattson (1963) the run size of spring-run Chinook salmon returning to the Upper Willamette River from 1946 to 1953 varied from a low of 23,600 to a high of 92,600 (Willamette Falls count plus lower Willamette River sport catch), and approximately 40% of the run was destined for the McKenzie River (9,440 to 37,040 adults, respectively). Given the degradation of much of the Lower Willamette River, and lower gradient areas of the Upper Willamette River, these run size estimates are potentially a third or less of historical run sizes (McElhany et al. 2008, Appendix 3.5). Willis et al. (1960) estimated that 47% of the fish passing Willamette Falls returned to the McKenzie River in 1958. Furthermore, of the 2,089 redds counted in the McKenzie River above Leaburg Dam in 1958 (9,000 fish were counted at the dam), 686 redds (32.8%) were counted in the South Fork McKenzie. On a basin-wide basis, 3,198 redds were estimated (above and below Leaburg Dam), of which 21.4% were found in the South Fork. Even under the high harvest levels and depressed migratory conditions in the 1950s, there were more redds observed in the South Fork than were set by R2 as the capacity (585 redds). Based on the adult to redd count ratios observed, Willis et al. (1960) set the South Fork spawning population at 4,390 fish. This number is 11.2% of the 39,000 spring-run Chinook salmon escapement calculated at the falls (a relatively low run). With regard to the impact of Cougar Dam on the capacity of the South Fork McKenzie River, Mattson (1955) as cited by Willis et al. (1960) suggests that the South Fork McKenzie River alone could easily accommodate 7,000 – 8,000 spawning Chinook after Cougar Dam was built. In 1956, when 58,600 Chinook salmon were

counted at Willamette Falls, surveys of the South Fork McKenzie River reported 805 redds (Mattson 1957). The greatest concentration of redds was observed upstream of the estimated extent of the reservoir (14% below project, 13% in future pool, and 73% above pool). In 1959, 861 redds were observed in the South Fork McKenzie (the Willamette Falls count was 31,900 that year), with 678 redds located above the site of the reservoir (Ingram and Korn 1969). Mattson further suggested that placement of the McKenzie Hatchery racks could have intercepted a portion of the run destined for the South Fork McKenzie River. At the time that these escapement estimates were made, Wallis (1961) was reviewing the performance of the McKenzie River Hatchery. He concluded that the hatchery was making only a small contribution to the total run. Thus, the fish observed in the South Fork McKenzie likely were natural origin fish and reflect the productivity of the tributary at that time and the relatively high ocean and freshwater harvest rates. From 1960 to 1967, Ingram and Korn (1969) monitored adult salmon passed over the Cougar Dam site. This time frame includes from the beginning of construction in 1960, to the filling of the pool in 1964, to the cessation of adult passage to the upper South Fork. Peak adult return to the below-dam trap was 2,121 adults. Furthermore, the authors suggest that a number of adults were diverted prior to reaching the trap. These studies taken together suggest that the capacity of the South Fork McKenzie, above the Cougar Project, was, and is, greater than suggested by the R2 estimates. Furthermore, observations of spawning Chinook salmon at the time do not indicate that the basin was near capacity. The 7,000 to 8,000 Chinook salmon estimate by Mattson (1955) corresponds to the capacity used in the current SLAM model. Although information for the other tributaries is not as detailed as for the McKenzie River, available information suggests that the R2-derived values for spawner (redd) capacities are also underestimates for the other populations.

Overall, we consider estimates by Mattson (1948) to be the most appropriate. Mattson (1948) characterized the McKenzie River as the most productive watershed for Chinook salmon in the Upper Willamette Basin, accounting for 40% of the spawning abundance above Willamette Falls. Although the population was already depressed in 1947, Mattson estimated that the McKenzie River run was 4,780 fish. Parkhurst et al. (1950) estimated that there was habitat available for 63,000 spawning adults. Historical peak run size estimates for the McKenzie are in excess of 100,000 fish (Appendix 3.5). Based on habitat loss with the construction of the Cougar, Trail Bridge, and Blue River dams (including reservoir pools) and habitat loss and degradation below the dams, spawner (egg) capacities we reduced from those described in pre-dam studies (Table 3.7).

Table 3.7: Spring-run Chinook salmon egg and spawner capacities for McKenzie River reaches used in life cycle models.

Tributary	Reach	SLAM Reach	Mean Capacity (eggs)	Adult Spawners (@ 2,250 eggs)
McKenzie River				
	Blw Leaburg Dam	A	1,250,000	556
	Above Leaburg Dam	B	8,000,000	3,556
	Above Hendrick's Bridge	A,B	9,250,000	4,111
	Above Cougar Dam	C	17,000,000	7556
	Total	A – C		11,667

3.2.5.4. Middle Fork Willamette River Reaches

The Middle Fork River is divided into five reaches: Reach A, Middle Fork Willamette River below Dexter Dam; Reach B, Little Fall Creek and Fall Creek below Fall Creek Dam; Reach C, Fall Creek (above Fall Creek Dam); Reach D, the Middle Fork and North Fork Willamette River (between Lookout Point and Hill Creek dams); and Reach E, Hills Creek (above Hills Creek Dam) (Figure 3.8).

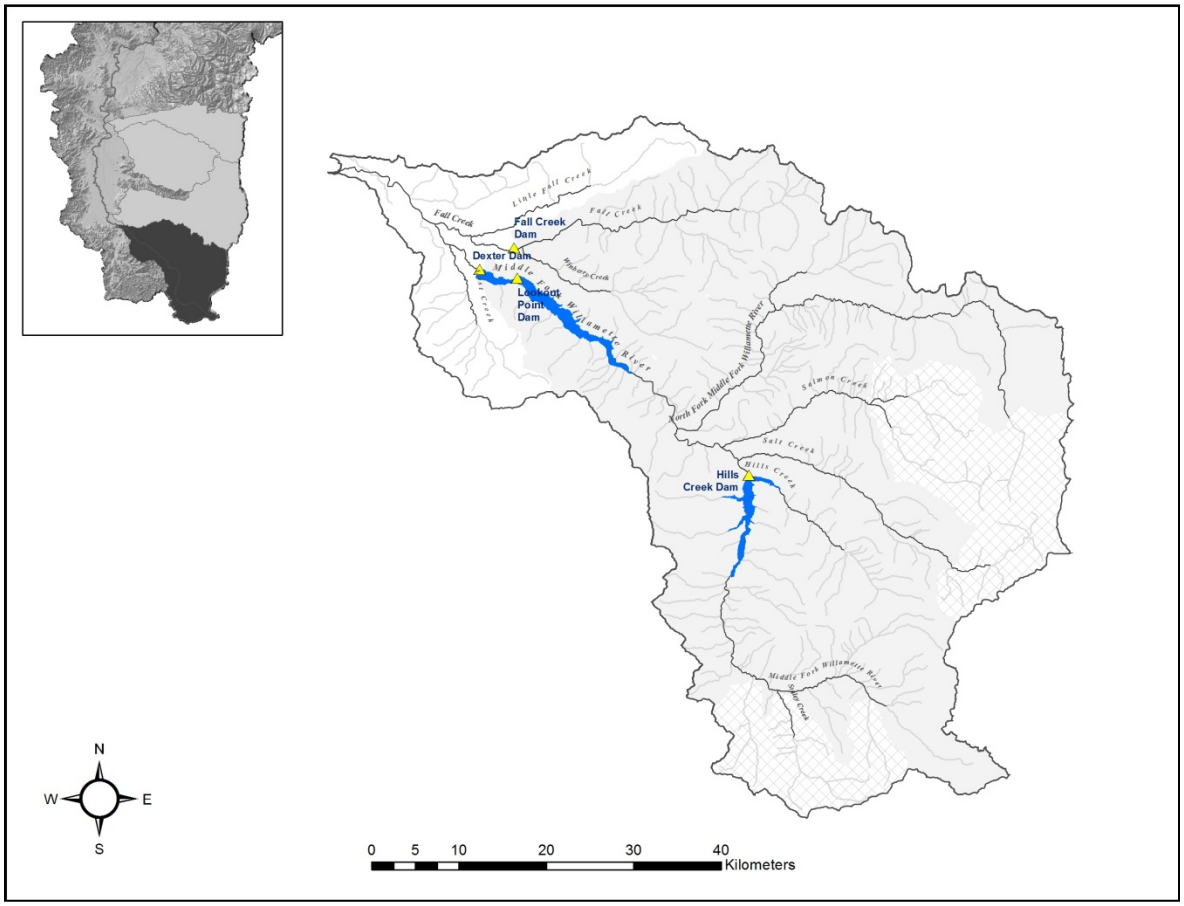


Figure 3.8: Middle Fork Willamette River Basin, shaded portion denotes anthropogenically inaccessible habitat (man-made barrier), and cross-hatched areas are historically inaccessible habitat (natural barrier).

The Middle Fork Willamette River spawning aggregations were historically observed in Fall Creek, Salmon Creek, North Fork Middle Willamette River, mainstem Middle Fork Willamette River, and Salt Creek (Mattson 1948, Parkhurst et al. 1950). Based on records (1909–present) from the Willamette River Hatchery (Dexter Ponds), the largest egg collection, 11,389,000 in 1918 (Wallis 1962), would correspond to 3,559 females (@ 3,200 eggs/female). Mattson (1948) estimated the run size to the Middle Fork Willamette River to be 2,550 in 1947, and that the Middle Fork accounted for 21% of the spawning Chinook salmon above Willamette Falls. At this time a large proportion of natural spawners were intercepted at the hatchery weirs and a number of small dams with poor fish passage facilities likely limited accessibility to spawning grounds. Parkhurst et al. (1950) reported that survey crews observed about 1,000 natural spawners in addition to the fish held at the hatchery ponds.

Parkhurst et al. (1950) estimated the Fall Creek basin could support several thousand salmon, but by 1938 the run had already been severely depleted. In 1947, the run had dwindled to an estimated 60 fish (Mattson 1948). Willis et al. (1960) reports that in surveys conducted prior to the construction of Lookout Point Dam few redds were constructed downstream of the Lookout Point Dam site. Parkhurst et al. (1950) estimated that, in total, there was spawning habitat available for about 30,000 spawners in the Middle Fork Willamette River (Appendix 3.5). Given the relatively low position of the Dexter and Lookout Dams in the basin, it is likely that much of the historical spawning habitat (aside from the area above Hills Creek Dam) would be accessible to transported adults.

In estimating the capacity of the Middle Fork Willamette River, we considered historical escapement estimates, impaired habitat, and the spawning habitat currently inundated by reservoir pools (Table 3.8).

Table 3.8: Spring-run Chinook salmon egg and spawner capacities for Middle Fork Willamette River reaches used in life cycle models.

Tributary	Reach	SLAM Reach	Mean Capacity (eggs)	Adult Spawners (@ 2250 eggs)
Middle Fork Willamette River				
	Below Dexter Dam	A	150,000	67
	Lower Fall Creek	B	500,000	222
	Upper Fall Creek	C	2,000,000	889
	Fall Creek	B,C	2,500,000	1,111
	Above Dexter/Lookout Pt Dams	D	20,000,000	8,889
	Above Hills Creek	E	10,000,000	4,444
	Total			14,511

3.2.6. Fecundity

In the R2 McKenzie River Chinook salmon SLAM, Hendrix et al. (2012) utilized fecundities from 4000 to 4500 eggs per female (2,000 to 2,250 per spawner assuming a 1:1 sex ratio). Rich (1940) reported average fecundities for female Chinook salmon returning: Middle Fork Willamette River, 5,084; McKenzie River, 4,928; North Santiam River, 5,200; and South Santiam River, 4,000 eggs per female. Later, Howell et al. (1985) reported the overall average for Willamette River hatcheries of 4,258 eggs per female; with Marion Forks Hatchery having an average of 5,374 eggs per female in 1983. Recent hatchery Chinook salmon egg takes for the McKenzie Hatchery (BY 1997-2001) and South Santiam Hatchery (1998-2002) were 4380±72 eggs/female and 4280±139 eggs/female, respectively (ODFW 2003, 2004). Changes in fecundity over time could be due to differences in average female size, age, or relative fecundity (eggs per unit body weight). Cannon et al. (2010) reported that presently there is no difference in length between similarly aged unmarked and marked Chinook salmon. Therefore, we assumed that there was no difference in fecundity between similar age HOR and NOR spawning adults. Based on the results of Johnson and Friesen (2013) we assumed a 1:1 sex ratio; therefore the life-cycle models used one-half the female fecundity for adult fecundity. Differences in the average age of NORs and HORs suggest that the average fecundity set for HORs be set at 2000 eggs per spawner, less than the 2250 eggs per spawner set for NORs. In an effort to simplify the SLAM model, returning adults were pooled prior to estimating egg production. Year to year variability in spawner age, size, and sex ratio were not accounted for in the SLAM model, instead a single basin-wide weighted average using age-specific fecundities was utilized; our

understanding of how these population characteristics are correlated with ocean and freshwater environmental conditions is not sufficient to adequately model these effects.

3.2.7. Survival

In developing life-cycle models for Chinook salmon in the Upper Willamette Basin life-history stage specific and reach specific parameters needed to be estimated for each tributary. In some cases, life-history and reach-specific data were available. In most cases, survivals were estimated using data from the literature. Where survival studies were conducted in pristine or near-pristine conditions, adjustments were made to better reflect habitat conditions in the reaches. Additionally, available data often described survival across multiple life-cycle model life-history stages. In these cases, survivals were apportioned based on presumed fish size (earlier life-history stages with younger smaller fish are more likely to be subject to higher mortalities). Overall survival estimates were validated during the baseline calibration process.

Incubation success, the survival from egg to emergent fry, depends on a number of environmental factors, including: gravel conditions (fines), temperature, and flow. In addition, the size and age of spawning adults can affect egg quality and redd characteristics. Accordingly, egg to fry survival varies considerably between studies. Coble (1961) observed survivals of 16-62% in the Alsea River (an Oregon coastal stream). A review by Sheppard (1972) indicated that under good conditions survival ranged from 65-85%. Bjornn (1978) reported survivals of 40-94% from eyed egg to fry in gravel incubation channels. Chinook salmon naturalized in New Zealand rivers exhibited an egg to fry survival of 49.6% (Unwin 1997). Quinn (2005) reported that range-wide Chinook salmon egg to fry survival averaged 38.0%, with overall estimates from egg to smolt of 10.1%. In study on the Yakima River (Fast et al. 1991), six spring-run Chinook salmon redds were capped in 1985, and the estimated mean survival rate was 62.4% ranging from 29.3% up to 84.8%. In 1986, eight redds were successfully capped, and the mean egg-to-fry survival rate was estimated at 56.7%. Within individual redds, survival ranged from 21.9% to 90%. The overall estimated mean egg-to-fry survival rate for both years combined was 59.6%. Based on these estimates we selected egg to fry survivals of 50-60% for river reaches with little or no habitat degradation. Reaches containing degraded habitat have correspondingly lower survival rates.

Survival estimates for the period from emergent fry to smolt has been less well documented (Table 3.9). Most studies have focused on survival during downstream migration prior to smoltification, in part because tagging methodology was limited to larger juveniles. The more recent advent of smaller passive integrated transponder (PIT) tags and genetic analyses may provide a more detailed understanding of survival from egg to smolt in each of the life history trajectories.

Table 3.9: Survival estimates for juvenile Chinook salmon during selected life history segments.

Chinook Salmon						
Egg to Fry	Fry to JOM Reservoir	JOM to Parr	Parr to River Migrants	Cumulative Egg to River Migrant	Source	Note
	13.30%		86.00%	11.4%	ODFW/NMFS 2011	McKenzie Reach C (mode)
	1 to 17 %			1-17%	Seiler et al. 2002	Skagit
	1 to 20 %			1-20%	Scofield & Griffith 2012	Snohomish
	3.0%			3.0%	Volkhardt et al. 2006	Bear Creek
	10.2%			10.2%	Volkhardt et al. 2007	Cedar River 1998-2004
	10.7%			10.7%	Major and Mighell 1969	Yakima 1957-1961
			18.2%		Yanke et al. 2009	Average (Summer to Spring)
	4.2-6.5%			4.2-6.5%	Fast 1988	Yakima
	4.8%			4.8%	Mullan 1988	Wenatchee Spring Run
	5.5%			5.5%	Lindsey et al. 1985	John Day River Spring Run
59.6%					Fast 1991	Yakima Spring Run
65.3%	10.1%			6.6%	McIssac 1990	Lewis River Late Fall Run
38.0%	10.1%			3.8%	Quinn 2005	
49.6%					Unwin 1997	New Zealand Natural
	14.8%		35.6%	5.3%	Kiefer and Lockhard 1993	Crooked River, Id

3.2.8. Temperature Effects and Survival

The effect of temperature on the survival of developing Chinook salmon eggs and embryos may significantly influence the overall productivity of Chinook salmon populations in the Willamette Basin. With the construction of the Willamette River dams and the creation of reservoirs the temperature profiles of the releases from the dams was altered considerably. Craig and Townsend (1946) studied the potential for temperature changes and concluded that temperature increases, especially in the late summer and autumn would have a serious effect on Chinook salmon below most of the Upper Willamette Dams. Kostow (1995) and Cramer et al. (1996) reported that changes in the thermal regime below the USACE dams could have modified emergence timing enough to affect early survival. Indirect or latent temperature effects would be in addition to mortality directly related to incubation and pre-emergence temperatures (Figures 3.10 and 3.11). Jensen et al. (2006) found that the survival of Chinook salmon eggs during incubation and emergence was related to the temperatures that the parents had been subjected to. Similar temperature related effects were reported by Fulton (1963) and Berman (1990). Lahnsteiner and Leitner (2013) found that elevated temperatures prior to spawning resulted in a degradation in both egg and sperm quality. Thus, sub-lethal temperature exposure of adults degraded the quality of their gametes and subsequent survival of their progeny. Pankhurst and King (2010) identified a number of temperature related changes in steroid production during gametogenesis in female Atlantic salmon (*Salmo* salar) that resulted in changes in egg size and quality. In attempting to model temperature effects on egg to emergent fry survival, consideration needs to be made of the complete suite of effects, including both the prespawning temperatures and post-spawning incubation temperatures (Figure 3.12).

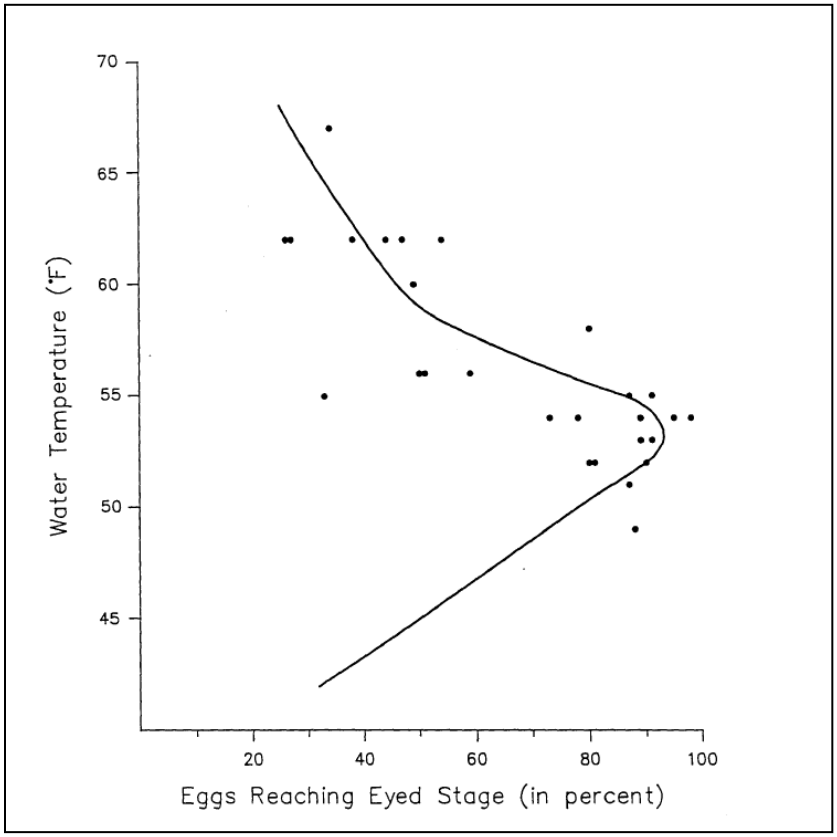


Figure 3.10: Relationship between survival to eyed-stage in Chinook salmon and incubation temperature. From CDWR 1988.

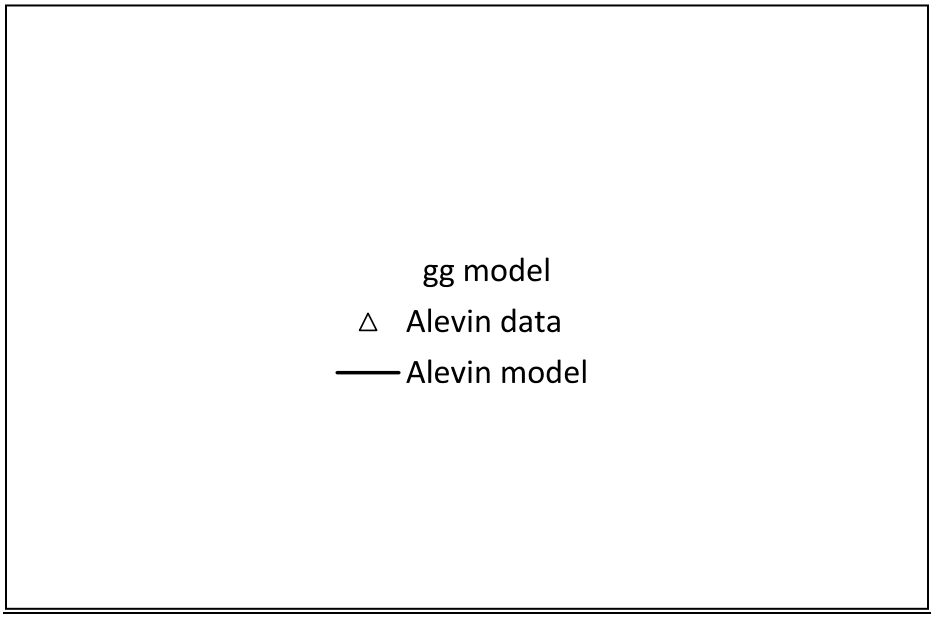


Figure 3.11: Temperature effects on Chinook salmon incubation and early rearing survival (from Jager 2011).

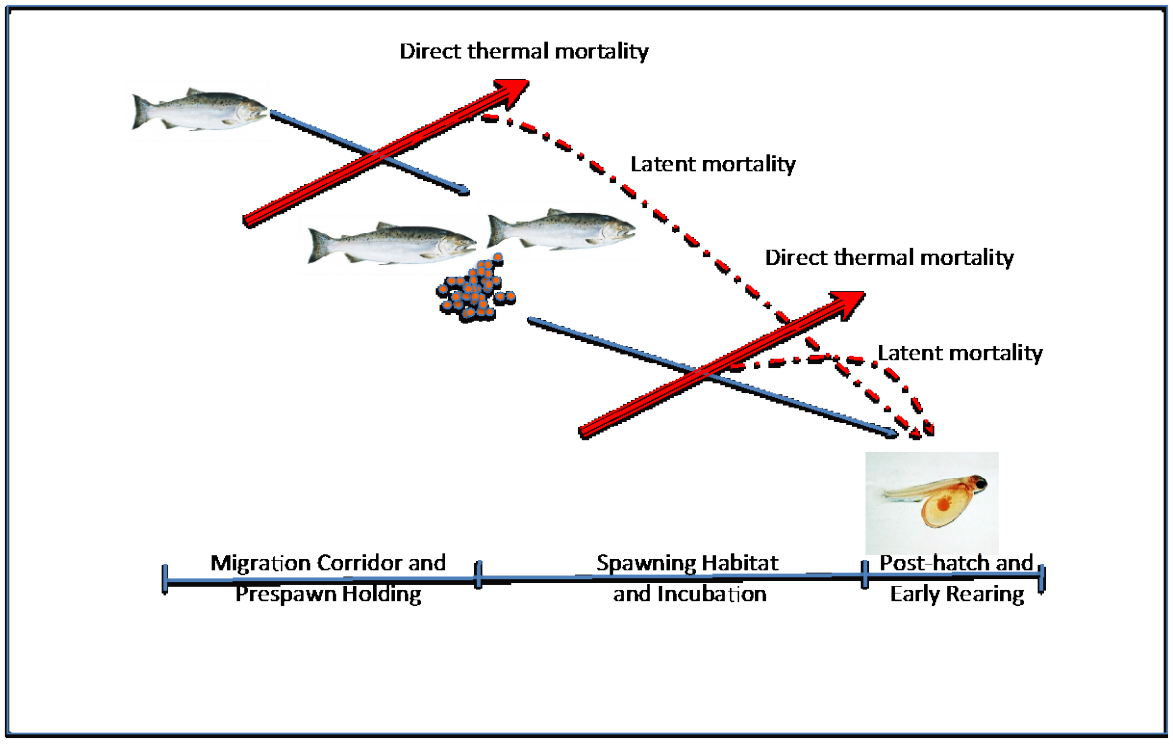


Figure 3.12: Types and timing of temperature-related mortalities during Chinook salmon adult migration and juvenile incubation and rearing.

Temperature effects also appear to be dependent on the life stage of exposure. After emergence from their redds, juvenile Chinook salmon appear to be more tolerant of a wider temperature range than eggs or alevins (Jager 2011). Furthermore, in contrast to eggs or emergent fry, juvenile salmonids can actively emigrate from adverse thermal conditions. A review by the California Department of Water Resources (CDWR 1988) identified an incubation temperature of 50–55°F (10-12.8°C) as being optimal for survival and growth. During incubation, temperatures over 60°F (15.6°C) resulted in generally low survival to the eyed stage (Figure 3.10), whereas later in development, temperatures of 55–57.5°F (12.8-14.2°C) resulted in a 50% mortality during yolk-sac absorption.

Based on the work of Jager (2001) (Figure 3.11) an equation was developed on the relationship between temperature and egg/alevins survival (Figure 3.13). The focus of this relationship was the change in survival due to high temperatures, 12° to 18°C. It should be noted that the relationship was established using fall-run Chinook salmon from tributaries to the San Joaquin River, and those populations may be more adapted to a warmer temperature regime. For the most part we did not find temperatures in the tributaries that would suggest direct mortality would be a factor.

Of the three types of temperature-related mortalities, (adult pre-spawning mortality, mortalities due to impaired gamete development, and incubation mortalities) quantitative relationships have been developed for all but impaired egg development. Temperature effects on gamete development may not be expressed until later in post-fertilization development, and are likely confounded with direct temperature effects on developing embryos. It is challenging to predict these temperature effects on returning adult fish since they can actively respond to temperature exposure (in contrast to eggs and fry in redds).

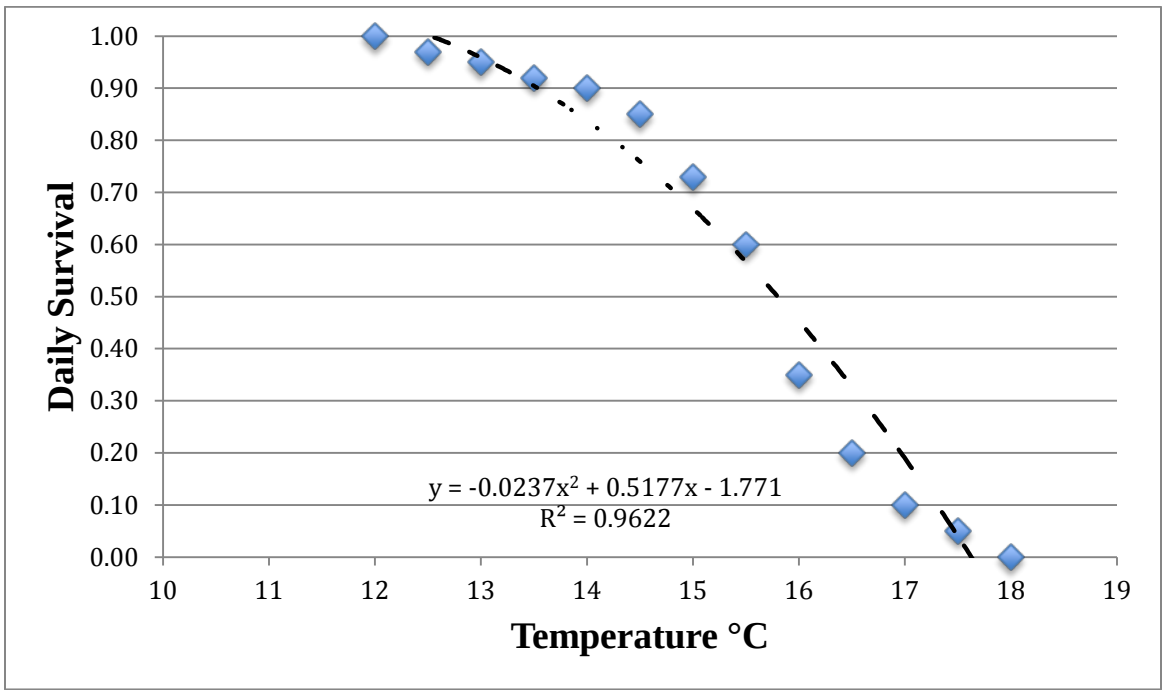


Figure 3.13: Daily survival of Chinook salmon embryos reared under different temperature regimes. This relationship was developed from the survival curve developed by Jager 2011 (Figure 3.10).

Temperature Effects in the North Santiam

The thermal regime in the North Santiam River has been identified as a potential factor limiting Chinook salmon viability by a number of sources; therefore, initial modeling efforts focused on this tributary in order to quantify the effects of high temperature on survival during incubation, and the possible benefits of installing a temperature control structure[19].

The temperature-survival relationship from Figure 3.13 was used to assess conditions in the North Santiam River below Detroit Dam. During normal incubation (September 15 and later) temperatures are only briefly at or near temperatures that might directly effect incubation survival (> 12°C). Additionally, the temporal spawning distribution for North Santiam River Chinook salmon presented by Sharpe (2013a) indicates that a very small proportion of the adults spawn prior to September 15th. Finally, temperatures experienced by incubating eggs are likely to be less than ambient river temperatures, due to cooler subgravel conditions, in general, and the potential for redd site construction in areas with cooler and more thermally stable groundwater seeps.

Modification of incubation temperatures may also cause a deviation from the normal development rate of eggs and alevins. Specifically, the release of warmer impounded water during the incubation period (September to January) from behind the dams accelerates development such that emergence is too early and "out-of-sync" with the environmental conditions that would normally support fry survival and growth. Historical temperature data for the North Santiam suggests that in extreme (warm) years the emergence date can be accelerated by over a month for the earliest spawners and by nearly two months for fish spawning at peak of the spawning period (Tables 3.10 and 3.11). Efforts to control the temperature of water released from Detroit Dam began in 2007,

[19] Based on the analysis of the North Santiam River thermal effects, similar model modifications were employed for the other populations.

and in the limited time since then temperatures (development rates) have been less variable from year to year. The timing of developmental events since 2007 under the operational temperature control is similar to the projected development of Chinook salmon eggs under a temperature regime with a temperature control structure in place.

Under temperature control structure alternatives (Figure 3.14), both direct temperature-related mortalities and those mortalities related to developmental asynchrony with the environment were adjusted from baseline conditions; however, in the absence of a quantitative model to predict these effects a panel of scientists was assembled to estimate the relative change in survival due to temperature changes resulting from operational or structural changes.

Table 3.10: Estimated average date (mm.dd) of 50% hatch and 50% emergence for temperature regimes in the North Santiam River under historical conditions or projected temperatures during Cool, Normal, and Wet water years with temperature structure in place. Hatch date and emergence date were based on a Sept 15th spawning date and 500 temperature units (TUs) to hatch and 500 TUs to emergence.

Temperature Regime	Hatch Date (earliest/latest)	Emergence Date (earliest/latest)
Historical (2007-2013)	11.03 (11.02/11.05)	01.10 (01.08/01.14)
Historical High (2001)	10.20	12.03
Cool Wet	10.29	01.13
Normal	10.29	01.10
Hot Dry	10.29	12.26

Table 3.11: Estimated average date (mm.dd) of 50% hatch and 50% emergence for temperature regimes in the North Santiam River under historical conditions or projected temperatures during Cool, Normal, and Wet water years with temperature structure in place.. Hatch date and emergence date were based on a Sept 25th spawning date (peak spawning date) and 500 temperature units (TUs) to hatch and 500 TUs to emergence.

Temperature Regime	Hatch Date (earliest/latest)	Emergence Date (earliest/latest)
Historical (2007-2013)	11.13 (11.13/11.13)	02.03 (02.03/02.06)
Historical High (2001)	10.29	12.30
Cool Wet	11.13	02.14
Normal	11.13	02.05
Hot Dry	11.13	01.22

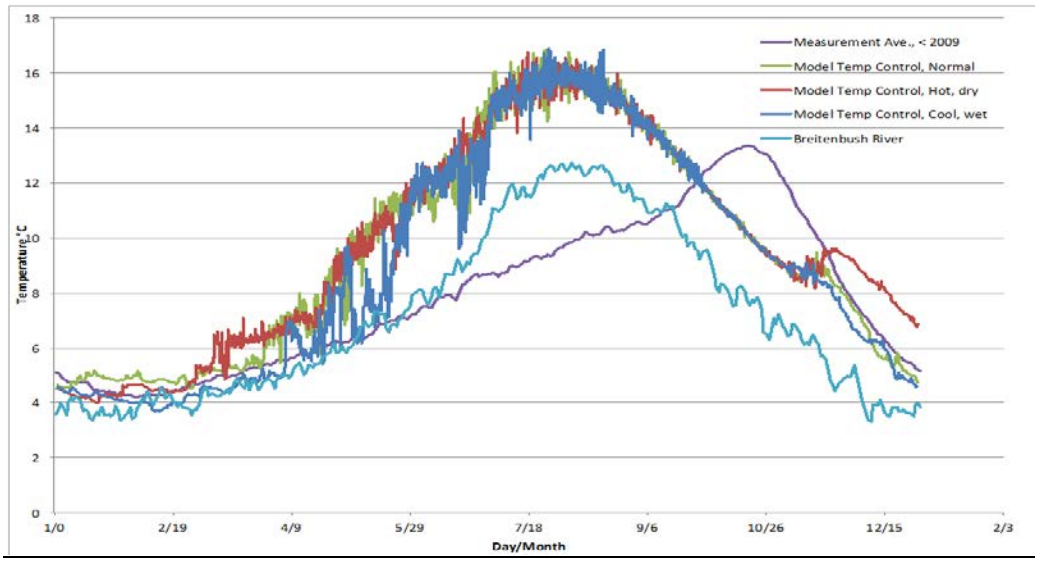


Figure 3.14: Below Detroit Dam thermal regime in the North Santiam River under historical post-dam construction (prior to 2009) and under temperature control scenarios. Temperature control structure scenarios represent normal, hot and dry, and cool and wet water years. The light blue line (Breitenbush River) represents average daily temperatures upstream of the reservoir (2006-2011). Graph modified from D. Turner, USACE.

In calibrating the SLAM model we utilized recent adult returns, but given that temperature control efforts began in 2009, any survival benefits would not be detected until 2012, at the earliest[20]. Chinook salmon counts at Bennett Dam in 2012 and 2013 have exhibited a two-fold increase over previous years; the degree that this is related to temperature regime improvements remains to be established, but suggests that the benefits could be substantial.

One of the consequences of a temperature control structure (aka selective withdrawal structure, SWS) is an increase in summer temperatures over those resulting from operational temperature controls in June, July, and August. Without access to coldwater refugia or headwater reaches, extended exposure to elevated temperatures could result in elevated prespawning mortalities or degraded gamete quality.

Paradoxically, temperatures below Big Cliff and Detroit Dam have increased subsequent to the initiation of operational temperature controls (structural temperature control would further increase summer temperatures slightly), but the level of prespawning mortality has dropped by nearly 50% (Table 3.12). With only a few years of empirical data it is difficult to assign causal factors; however, it was suggested that a reduction in adult fish passage and handling injuries at Bennett Dam was a contributing factor. Additionally, improvements in the incubation temperature regime (closer to historical "normal") below Detroit/Big Cliff Dam may have improved egg to juvenile survival, although anecdotal information suggests emergence is still somewhat advanced. Overall, increases in NOR counts at Bennett Dam in combination with decreased PSM have increased the abundance of NOR spawners in the reach below Big Cliff/Detroit Dam by four-fold.

[20] Temperature control began unofficially in 2007 with a powerhouse fire at Detroit Dam, and was operationally formalized in subsequent years. In that case returns from 2010 onward may be indicative of survival improvements.

Table 3.12: Prespawning mortality rate (PSM), proportion hatchery origin spawner (pHOS) and proportion wild (1-pHOS), seven-day average maximum temperature 7-DAM (°C), for Reach B North Santiam River (between Bennett Dam and Minto Fish Facility) and natural origin recruit count at Bennett Dam corresponding to their smolt year (Yr). Red-shaded years indicate operational temperatures controls were in place at Detroit Dam. The last three NOR counts also correspond to improved fish passage and handling at Bennett Dam. (Data from Roumasset 2012, Sharpe 2013a).

Population	Location	Reach	Smolt Year	PSM	pHOS	pWild	Temp 7 DM	NORs Produced
NSantiam	Above Bennett	B	2000				16.84	462
NSantiam	Above Bennett	B	2001	0.75			19.99	635
NSantiam	Above Bennett	B	2002	0.50			16.91	539
NSantiam	Above Bennett	B	2003	0.64	0.97	0.03	17.46	290
NSantiam	Above Bennett	B	2004	0.75	0.86	0.14	17.81	182
NSantiam	Above Bennett	B	2005	0.46	0.70	0.30	17.35	195
NSantiam	Above Bennett	B	2006	0.16	0.68	0.32	17.04	548
NSantiam	Above Bennett	B	2007	0.41	0.75	0.25	19.00	712
NSantiam	Above Bennett	B	2008	0.30			19.26	821
NSantiam	Above Bennett	B	2009	0.30	0.49	0.51	20.97	1038
NSantiam	Above Bennett	B	2010	0.48	0.72	0.28	18.96	
NSantiam	Above Bennett	B	2011		0.65	0.35	18.88	
NSantiam	Above Bennett	B	2012	0.19	0.76	0.24	19.58	
NSantiam	Above Bennett	B	2013	0.21	0.63	0.37	18.80	

Increased summer temperatures during the late summer may also affect those salmon migrating through reaches impacted by temperature control operations or structures; however, when temperature control actions are undertaken in tandem with adult trap and haul activities early returning fish could be passed above the dams prior to the onset of potentially deleterious temperatures. Later-returning adults might be subjected to higher temperatures, but only briefly. In any of the temperature control structure water year scenarios, temperatures do not appear to be high enough to inhibit upstream migration, 19-23°C (Carter 2005), but may be high enough to induce more rapid upstream migration. Temperatures above Detroit Reservoir would appear to provide optimal temperatures year round (Figure 3.10). Under current conditions, early returning adults are at a selective disadvantage relative to later returning adults due to their protracted exposure to higher temperatures while constrained to areas below Detroit Dam. If water temperatures are selecting against early-returning adults, this may in part explain observed delays in return/spawn timing (HSRG 2009), and an increased likelihood that spring-run and fall-run Chinook salmon might interbreed. Restoring a more natural thermal profile to the river could restore historical timing of migration and spawning by selecting against late summer returning fish, in addition to other life history changes.

3.2.9. Total Dissolved Gas

Gas supersaturation, a consequence of spill during dam operation, can potentially have a profound effect on the survival of both juvenile and adult salmon. In the R2 version of the SLAM model (Hendrix et al. 2012), the relationship between total dissolved gas (TDG) and mortality was given as:

Monthly TDG mortality = 1/(1+EXP(-B))

For alevins: B = -26.04159 + 0.05780*Days + 0.18702*TDG

For juveniles: B = -38.88004 + 0.08763*Days + 0.30916*TDG

R2 used TDG >=105% for alevin TDG threshold (level at which mortality effects begin) and >=115% for juvenile TDG threshold. Days were defined as the number of days per month when TDG values exceeded the life stage specific threshold. We also determined the monthly average of daily TDG ('TDG" in above equation) when daily TDG is >=105% (alevins) or >=115%(juveniles). Monthly TDG mortalities were calculated and then adjusted by a month-specific weighting, whereby this month-specific weighting accounts for the presence of alevin and juveniles in a given month. Specifically, Monthly TDG Mortalities were multiplied by weights of w=0.25 for December, w=0.5 for January, w=0.25 for February, and w=0 for the rest of the year. Annual TDG mortality was then calculate by summing the monthly TDG mortalities.

The Hendrix et al (2012) equation above was based upon mortality studies by Rucker and Kangas (1974). Preliminary calibration runs of SLAM using TDG data for Foster Dam (74 year period) resulted in high mortalities among juvenile Chinook salmon in the reach downstream of Foster Dam, much higher than empirical estimates. The discrepancy between predicted and actual mortality may be due to the data used in the R2 model to develop the mortality model. The study by Rucker and Kangas (1974) exposed juvenile salmon to supersaturated gas conditions in very shallow troughs; whereas the effects of supersaturation are strongly affected by depth; fish at even one or two meters depth are exposed to greatly reduced TDG levels (Dawley et al. 1975). In addition, if TDG levels are measured at the spillway they do not reflect the levels experienced by the fish. In-river studies with tagged salmon indicate that, on average, fish experienced an 18.6% reduction in TDG relative to TDG river measurements; for example a surface TDG level of 125.6% supersaturation is corresponds to a TDG level of 102.1% supersaturation experienced by the fish based on average depth (Beeman et al. 1997). In most cases the estimated levels of TDG exposure to the fish were below the threshold for mortality due to short-term exposure (Table 3.13). Similarly, salmon redds downstream of Bonneville Dam were “protected” from TDG effects by water depth, except during period of low water (Arntzen et al. 2009). Exposure to supersaturation effects in both juveniles and adults also depends on migrational delays at specific passage structures and the availability of deeper water refuges.

The majority of gas bubble disease studies in the literature for Pacific salmon were carried out in the Snake and Mid-Columbia rivers where fish have to migrate through a series of dams, such that elevated levels of total dissolved gas cannot be dispersed in the inter-dam reaches. Therefore, where emigrating juveniles that do not rapidly move through multiple reservoirs or dam passage structures they are likely to be exposed to sustained high levels of TDG.

Table 3.13: Tracking data from juvenile Chinook salmon released in the Columbia River. Reproduced from Beeman et al. 1997.

Table 2. Radio frequency in MHz, length (mm), weight (g), release date and time, total number of contacts (X-Y), number of fish depths recorded, minimum, maximum, and median fish depth (m), median TDG and median uncompensated TDG (percent) of hatchery steelhead released at Ice Harbor Dam during spring, 1996. nd indicates no data available.

Radio Tag Frequency	Date/Time of Release	Fork Length	Weight	X-Y Contacts	Depth Contacts	--- Fish Depth --- Minimum	Maximum	Median	TDG	Uncompensated TDG
149.873	5/22/96 - 0825	244	120.6	0	0	nd	nd	nd	nd	nd
149.953	6/01/96 - 1120	236	99.5	29	17	0.66	3.38	1.51	118.0	102.6
149.581	6/05/96 - 1032	203	71.5	26	26	-0.07[a]	6.19	2.30	125.8	106.5
149.774	6/05/96 - 1032	197	61.2	12	12	1.04	4.36	1.84	120.3	102.7
149.446	6/12/96 - 0915	228	92.7	3	3	1.13	1.84	1.13	127.3	112.1
149.912	6/12/96 - 0915	213	83.3	3	3	0.78	1.79	1.39	130.9	113.7
149.522	6/19/96 - 1223	241	118.4	6	4	3.50	6.80	4.05	133.9	94.7
149.816	6/19/96 - 1223	273	233.9	29	29	0.08	9.25	4.27	123.0	82.4
149.46 1	6/26/96 - 1110	23 1	95.6	0	0	nd	nd	nd	nd	nd
149.483	6/26/96 - 1 110	234	101.0	39	39	-0.23[a]	9.54	1.08	119.9	107.4
149.935	6/26/96 - 1 110	236	112.9	4	0	nd	nd	nd	nd	nd

[a] Negative numbers are possible near a depth of 0 m due to the accuracy and precision of the tag.

Without specific information on fish movements it is not possible to develop specific models for each population and reach; however, in order to bring the TDG mortality equation more in line with presumed mortalities (especially juvenile salmonids) it was assumed that the fish were migrating at a depth of 1 to 2m, which would result in a 15% reduction in TDG level. This is an interim solution until such time as on site mortality or gas bubble disease validation can be obtained.

3.2.10. Ocean Survival

Estimates of estuary and ocean survival for Chinook salmon in the SLAM model were included in the R2 version. These 73 year time series were developed by ODFW earlier in the model's development. Tributary-specific estimates of ocean survival are not available for naturally-produced fish, although coded-wire-tag recoveries do provide estimates of smolt to adult survival rates for hatchery-origin releases of fish (Appendix 3.1). In general, Chinook salmon survival was roughly correlated with ocean productivity indices; both the El Niño Index and the Pacific Decadal Oscillation Index (Figure 3.15). Because the impact of ocean conditions uniformly affects the different scenarios in SLAM, development of alternatives to the R2 SLAM ocean data sets have been a lower priority and not completed to date. R2 and ODFW provided two sets of age-specific ocean survivals; one for the progeny of naturally-produced parents and one for the progeny of hatchery-produced parents. In general, hatchery survivals were 50-75% of their naturally-produced counterparts. Given these survival rates, the survival of the progeny of hatchery-origin parents was extremely low (so much so that many populations were projected to be extirpated within a few years). Genetically-based pedigree analysis of the naturally-produced progeny of hatchery-origin fish and coded-wire-tag marked hatchery releases would suggest a substantially higher survival estimate. Hatchery domestication effects were consolidated in the survival from eggs to emergent fry using the pNI (proportionate natural influence) estimate (see the later section on Fitness Effects). The hatchery ocean survival data files were ultimately utilized to capture the survival of hatchery-produced progeny in the estuary and during the first ocean years. The use of the R2 data

files for ocean survival should be seen as an interim step to the development of estuary and ocean survivals based on ocean parameters. Ultimately, because marine conditions and terrestrial weather patterns are correlated, both marine and freshwater survivals and possibly juvenile life history strategies would be correlated to ocean conditions. As we developed the capacity to test life cycle model parameter sensitivity in the R version of the life-cycle models, we developed an estuary/early ocean conditions component (see next section).

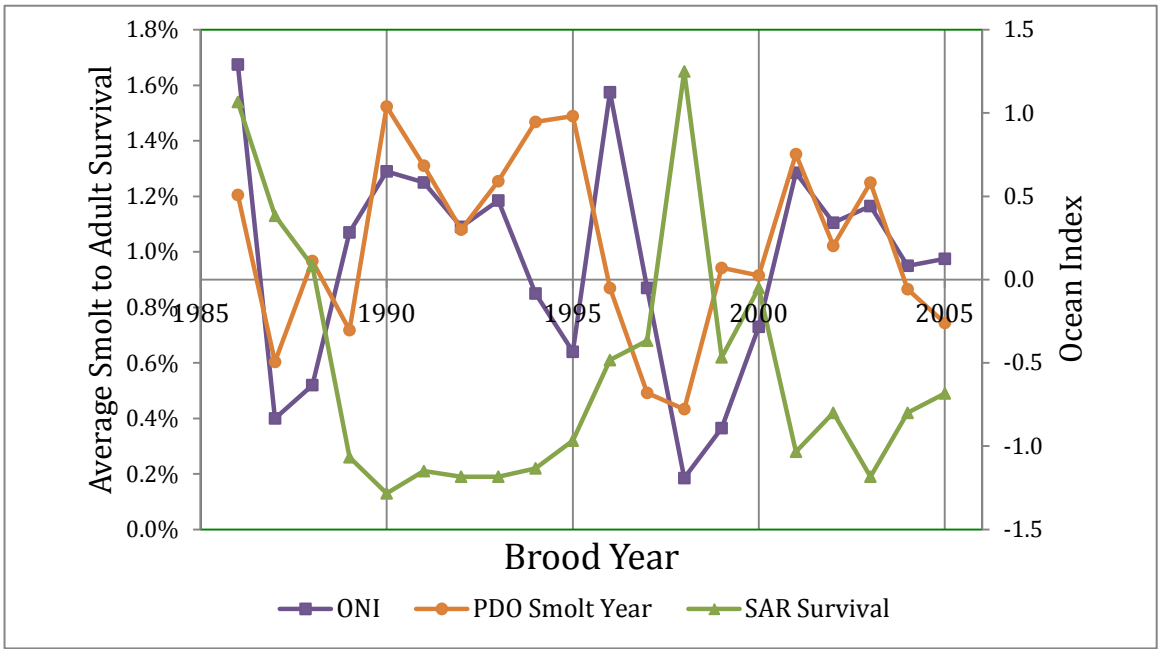


Figure 3.15: Average smolt to adult survival for hatchery reared Chinook salmon juveniles from 101 release groups from the McKenzie Hatchery (Brood Years 1986-2005). ONI – Oceanic Niño Index, PDO – Pacific Decadal Oscillation.

3.2.11. R-coded Version of Ocean Survival

In an effort to tie the estuary and early ocean survival aspect of the salmonid life cycle to a dynamic marine influence, the R version of the life-cycle models' modules of estuary and ocean survival drew upon the framework of Zabel et al. (2006), ICTRT and Zabel (2007), and Zabel et al. (2013), which relates estuary and early ocean survival to large-scale Pacific Ocean basin level drivers and regional oceanic conditions, and it incorporates stochasticity into this survival period.

First, for each basin and population we estimated estuary/early ocean survival, *s*3, for brood years from smolt-to-adult (SAR) estimates from coded-wire tagged hatchery fish (Regional Mark Processing Center, rmpc.org) by taking into account river survival through the mainstem (upstream and downstream), age-class composition of returning adults, and harvest (Zabel et al. 2006). We lacked SAR estimates for the steelhead populations, and as a proxy we applied a relationship we developed from SAR estimates for Clackamas winter steelhead (Portland Gas and Electric (PGE), unpublished data). A revised estimate of PGE's Clackamas steelhead smolt counts (K. Malone, BioAnalysts, Inc., Boise, ID) applied to the steelhead SAR estimates slightly improved the estuary/ocean model fit. We assumed that subsequent yearly survival in the ocean after the first year was constant (*SO*, set at 0.8; Ricker 1976) due to the lack of sufficient data on marine survival of Willamette River anadromous salmonids. The equation for the estimated *s*3 was as follows:

$$s3 = \frac{SAR}{(p_3 + p_4 \cdot SO + p_5 \cdot SO \cdot SO + p_6 \cdot SO \cdot SO \cdot SO)}$$

where p_t is the proportion of t-year olds. We used these estimates of estuary/early ocean survival, *s*3, to relate them to a suite of candidate indicators, including monthly spring through fall Pacific Decadal Oscillation index (PDO; April, May, June, July, August, September; http://jisao.washington.edu/pdo/PDO.latest), the monthly Pacific coastal upwelling index (at 45° N 125° W) in the spring and summer/fall (April, May, Sept; http://www.pfeg.noaa.gov/products/PFEL/modeled/indices/upwelling/NA/data_download.html) , and historical monthly and seasonal river flows in both the Willamette (at Salem, http://waterdata.usgs.gov/nwis/nwisman/?site_no=14191000&agency_cd= USGS; J. Ammann, USACE Portland District) and Columbia river mainstems (at The Dalles, http://nwis.waterdata.usgs.gov/wa/nwis/annual/?site_no=14105700&agency_cd= USGS), which influence migration timing and are representative of freshwater conditions. The choice of indicators was based on previous studies (e.g., Zabel et al. 2006, Scheuerell and Williams 2010; Zabel et al. 2013), but was constrained to those that have a long period of record to be able to encompass the ocean cycles observed over the last several decades. We used logit-transformed *s*3 as the response variable to ensure that survival estimates would be constrained to the (0, 1) range. The candidate model set comprised all possible combinations of predictor variables with a maximum of up to 3 predictors (ICTRT and Zabel 2007; Zabel et al. 2013). We used AICc as a measure of data support among the candidate models (Burnham and Anderson 2002). For McKenzie River Chinook salmon hatchery fish, the data most supported a model that included coastal upwelling in the spring and fall, and spring PDO (Fig. 3.15). For North Santiam Chinook salmon hatchery fish, the model with the most data support included upwelling and PDO in the spring (Fig. 3.17). For South Santiam and Middle Fork Chinook salmon hatchery fish, the data supported a model that included upwelling in the fall and PDO in spring (Figs. 3.18 & 3.19). The data most supported a model fitted to Clackamas steelhead that included fall upwelling, spring PDO, and mean summer mainstem Willamette River flow (Fig. 3.20).

We used these relationships to make predictions over the entire scope of the predictors to get a range of *s*3 over observed ocean cycles (Figs 3.15 – 3.19, solid lines, bottom plots). Using these estimated historical *s*3 time series, we integrated them into the life cycle models stochastically in two ways. First, for reach run of 100 years of the model, we chose random start locations in the historical time series and as needed we extended the time series starting with the beginning of the time series and moving forward. Second, we sampled yearly from the 95% prediction intervals about the *s*3 relationship (e.g. within the bounds of the dashed lines in the lower panels in Figs 3.16 – 3.20).

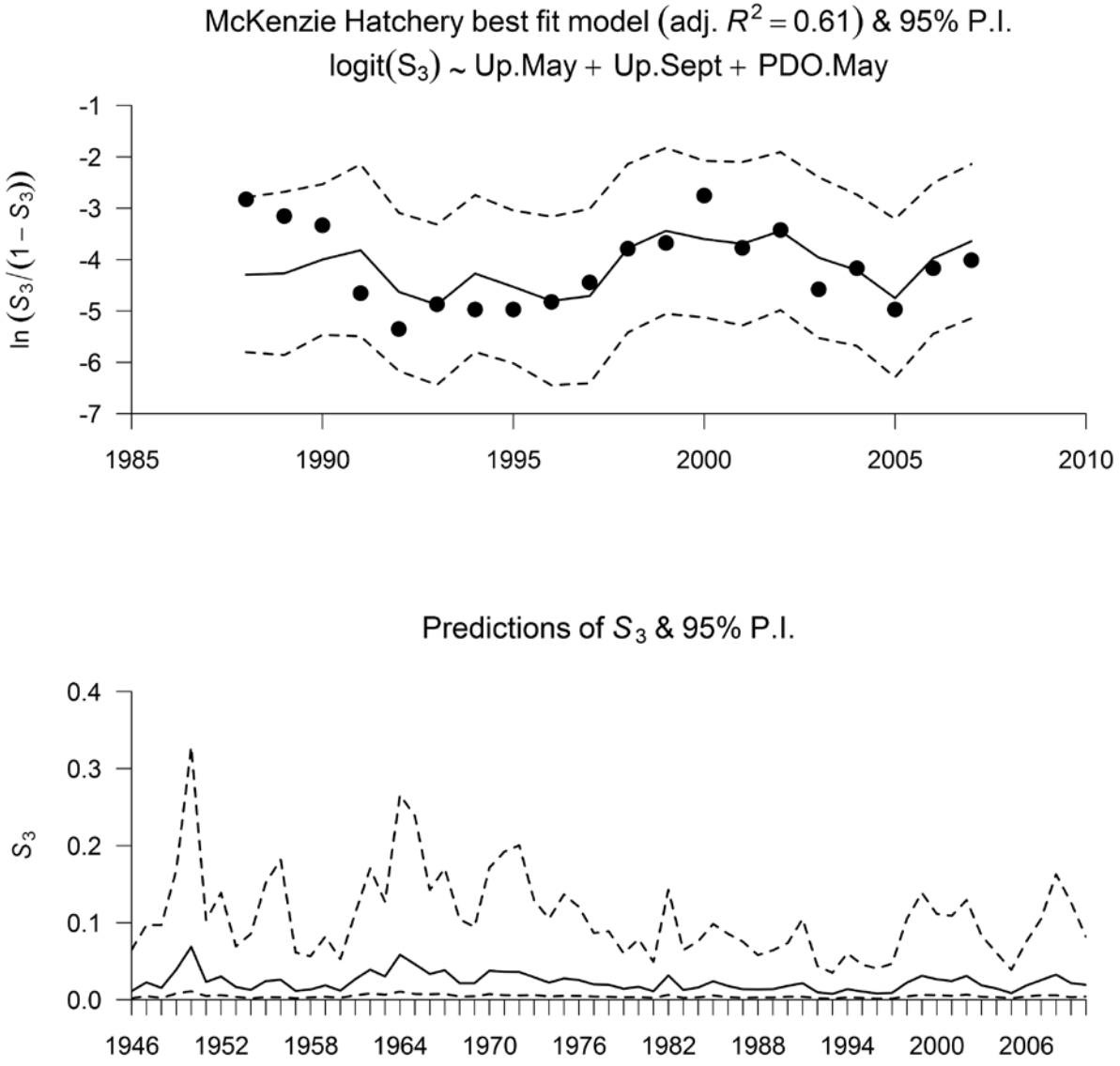


Figure 3.16: Marine predictors (top) that were in the best fitted model to estimated estuary/early ocean survival of McKenzie hatchery Chinook salmon, and hind cast predictions (bottom) of estuary and early ocean (s3) survival across the full historical range of the predictors. Points are the data, solid lines are the fitted relationships, and the dashed lines are 95% prediction intervals.

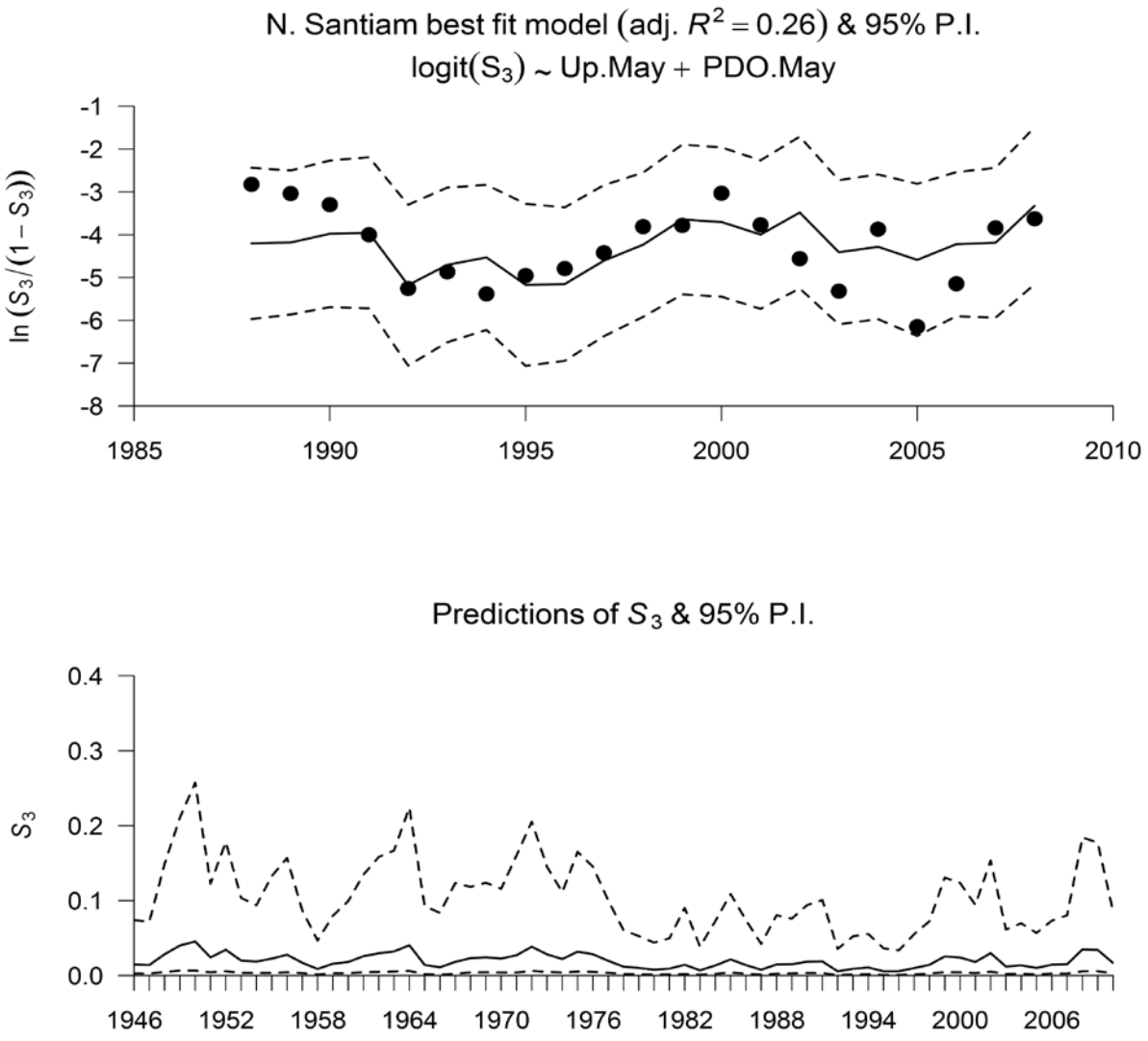


Figure 3.17: Marine predictors (top) that were in the best fitted model to estimated estuary/early ocean survival of North Santiam hatchery Chinook salmon, and hind cast predictions (bottom) of estuary and early ocean (s3) survival across the full historical range of the predictors. Points are the data, solid lines are the fitted relationships, and the dashed lines are 95% prediction intervals.

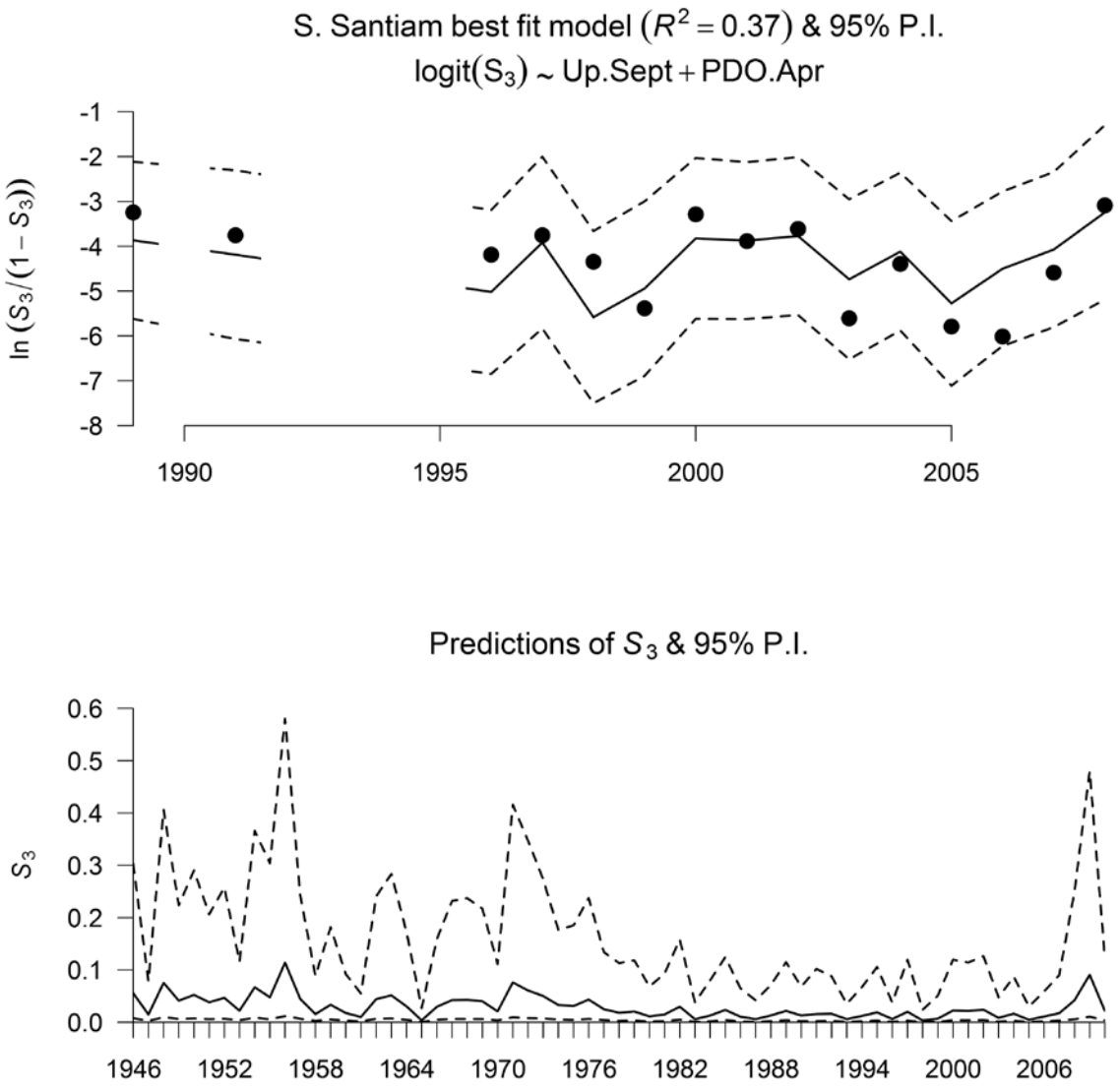


Figure 3.18: Marine predictors (top) that were in the best fitted model to estimated estuary/early ocean survival of South Santiam hatchery Chinook salmon, and hind cast predictions (bottom) of estuary and early ocean (s3) survival across the full historical range of the predictors. Points are the data, solid lines are the fitted relationships, and the dashed lines are 95% prediction intervals.

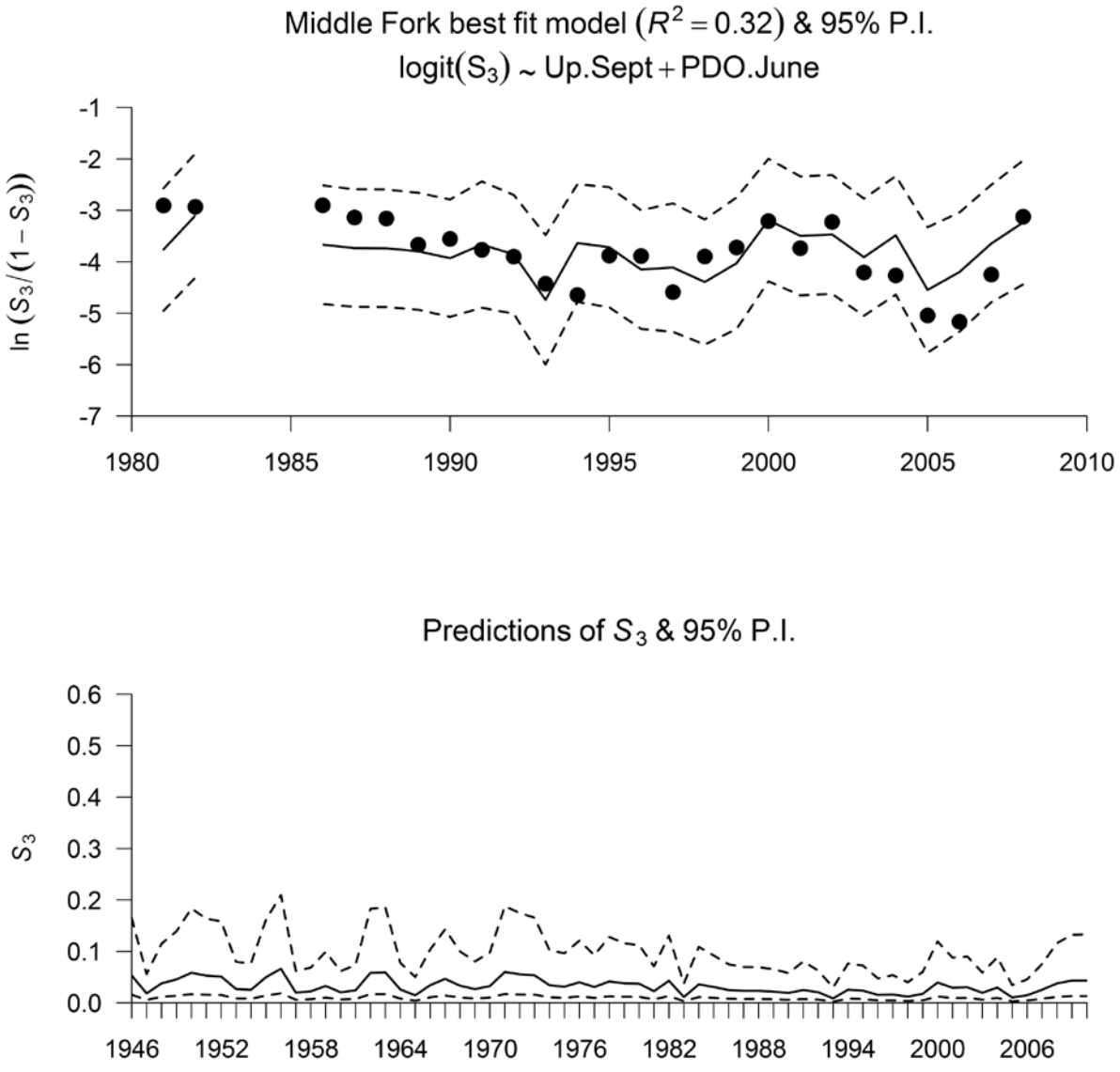


Figure 3.19: Marine predictors (top) that were in the best fitted model to estimated estuary/early ocean survival of Middle Fork Willamette River hatchery Chinook salmon, and hind cast predictions (bottom) of estuary and early ocean (s3) survival across the full historical range of the predictors. Points are the data, solid lines are the fitted relationships, and the dashed lines are 95% prediction intervals.

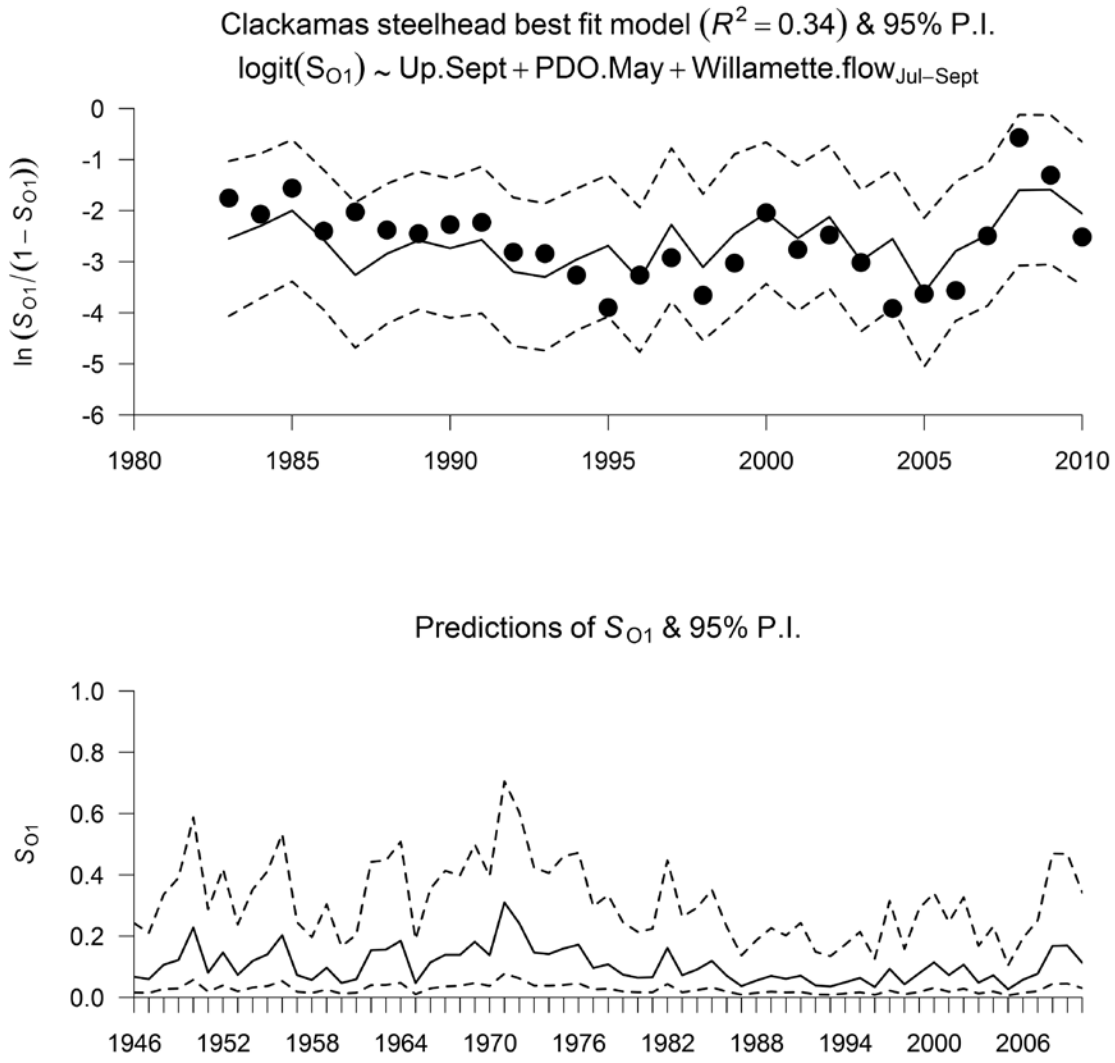


Figure 3.20: Marine predictors (top) that were in the best fitted model to estimated estuary/early ocean survival of Clackamas River winter steelhead, and hind cast predictions (bottom) of estuary and early ocean (*s*01, refers to estuary and ocean entry year, similar to *s*3 for Upper Willamette River Chinook salmon) survival across the full historical range of the predictors.

We made an adjustment to *s*3 to account for the data source we used for developing these relationships. In the Chinook salmon life cycle models we multiplied the yearly estimated *s*3 by a factor of 2 because the SAR data was from coded-wire tagged hatchery fish, and there is some evidence from other basins, such as in the Upper Columbia River, that suggests hatchery SARs are about half those of wild fish (Zabel et al. 2013). In the North and South winter steelhead life cycle models, we multiplied *s*3 by 1.5 to account for the potential for a hatchery influence on the Clackamas steelhead population and to match baseline conditions to recent spawner counts.

3.2.12. Harvest

Chinook salmon are subject to ocean, estuary, and freshwater harvest. Changes in non-terminal ocean fisheries can influence age structure, and certain fisheries (i.e. gill nets) can also result in size/age selective harvest. Age-specific ocean-harvest rates were initially included in the SLAM model based on values reported in the R2 version of SLAM. Later SLAM versions utilized overall ocean harvests from 2006 to 2010 (PSC 2012) and can be found in Appendix 3.3. Estuary, mainstem Columbia River, lower Willamette River, and tributary commercial and recreational fishery impacts were included into a single "In-river harvest" life stage survival adjustment. Due to their ESA listed status, natural origin Willamette River spring Chinook salmon are not directly harvested in the freshwater commercial or recreational fisheries but are subject to a net entanglement or hook mortality. The recreational catch and release fishery for unmarked fish results in an incidental mortality of 10.0% for the mainstem fishery and 12.2% for the Willamette River fishery (ODFW 2013) with encounter rates based on hatchery-origin fish harvest rate. In addition, the incidental mortality rate for unmarked spring-run Chinook salmon caught and released in the Columbia River tangle net fishery is 14.7% and 40.0% for the large-mesh gill net fishery (ODFW 2013).

Although there is no longer a directed fishery for natural-origin spring-run Chinook salmon, selective marking has allowed for a relatively higher harvest rate on hatchery-origin fish and therefore a higher encounter rate for natural-origin fish. Tributary specific rates exist for some of the Upper Willamette River populations, and where these were unavailable, estimates from geographically proximate populations were used. Recent estimates for harvest include:

Ocean Harvest (2006-2010): 9.0% PSC (2012)
Freshwater Harvest (2007-2011) ODFW (2013)
- Columbia River Harvest: 5.18%
- Lower Willamette Recreational Fishery (2007-2011) 20.8% HOR, 5.18% NOR
- North Santiam River
  - Recreational Harvest: 10.6% HOR, 1.25% NOR
  - Total freshwater impact for NORs: 9.0%
- McKenzie River
  - Recreational Harvest: 12.6% HOR, 1.54% NOR
  - Total freshwater impact for NORs: 9.8%

In addition to known harvest effects, the "In-river harvest" life stage also included mortalities from unknown causes between Willamette Falls and the tributaries. This mortality accounts for the shortfall in adults when comparing counts at Willamette Falls with carcass counts (including known pre-spawning mortalities), dam counts, hatchery returns, and tributary harvest. In some years the drop-out rate is considerable and may be related to mortalities prior to reach census points in the tributaries[21].

3.2.13. Natural Origin Spawners (NORs)

The SLAM model for each population was calibrated using baseline conditions and recent (last five years) run reconstructions for natural returns (Table 3.14). Life stage survivals were adjusted such that the median outcome of 500 model iterations approximated recent returns. Some of these estimates are based on dam counts and do not take into account prespawning mortality, so the

[21] This life stage has since been partitioned into two life history stages: estimated in-river harvest and mainstem idiopathic mortalities, to distinguish to these sources of mortality.

actual number of spawners would be considerably less in some years. Other counts are adjusted for both the observed proportions of marked and unmarked adults and the proportion of unmarked adults that are of hatchery-origin (based on a subsample of otoliths). Other estimates represent expansions from redd counts. Baseline conditions for each tributary's life cycle model included estimates of current dam passage survivals and a number of other effects. In parameterizing survivals for life history stages in baseline accessible reaches, effects such as habitat conditions and ecological interactions with hatchery fish were included in the overall survival estimate. Unless SLAM alternatives specifically address hatchery operations or habitat changes from dam operations, these effects are considered to remain unchanged.

Table 3.14: Spawning escapement of natural-origin recruits (NORs) returning to Upper Willamette River tributaries.[22]

Return Year	Bennett Natural	N. Santiam Natural[1]	Foster Natural[2]	Leaburg Natural
2008	139	142	834	1,365
2009	186	250	326	1,185
2010	744	844	568	1,357
2011	515	577	956	2,288
2012	1,014	1,065	705	1,654
Mean	520	576	678	1,570

[1] Includes natural origin spawners below the dams (expanded from redd counts).
[2] C. Sharpe, Oregon Department of Fish and Wildlife, unpublished data.

3.2.14. Habitat (Spatial Structure)

The existing SLAM project is designed to model Chinook salmon and steelhead populations in the Upper Willamette Basin that are currently influenced by both passable and impassable dams. One of the obvious effects of these dams is to prevent returning adults from reaching habitat that was historically used for spawning and incubation and rearing. In describing this lost habitat we are endeavoring to describe not only the quantitative changes in available habitat, but also the qualitative changes. Spatial structure provides geographic distribution, both to promote ecological diversity as a foundation for life history variation and as a hedge against catastrophic events. Ecologically, differences throughout the basin occupied by a demographically independent population (DIP) provide varying levels of suitability for spawning and rearing. In comparing present-day with historical range, one can also evaluate a productivity-weighted measure of habitat in addition to simple basin measurements of watershed area and stream length or wetted area.

Chinook are currently excluded from significant portions of the North and South Santiam rivers, McKenzie River, and Middle Fork Willamette River. In the case of the McKenzie River, downstream passage through Cougar Dam has been partially restored, although not to a level where the above Cougar Dam spawning aggregation can be considered self-supporting. Similarly, Fall Creek Dam and Foster Dam currently provide varying levels of downstream juvenile passage. In all three cases adults are trapped below the dam and transported to the reservoir or headwater reaches.

Historically available habitat is generally estimated using natural long-standing barriers or species-specific maximum stream gradients as upper limits to migration. In some cases, stream surveys conducted prior to dam construction are available to confirm salmonid accessibility (Parkhurst et al. 1950, Willis et al. 1960). Estimates of accessible, inaccessible, and historical habitat for both

[22] Personal Communication: Cameron Sharpe, ODFW, 20 May 2013.

Chinook salmon and steelhead are available from a number of sources (Mattson 1948, Maher et al. 2005, Sheer and Steel 2006). VSP scoring for spatial structure is discussed in the second part of this document.

3.3. Steelhead

Evaluation of dam project alternatives included understanding population-level impacts for steelhead. We include background information on parameter and model development of the steelhead models.

3.3.1. Life History Strategies

O. mykiss can exhibit an anadromous life history (steelhead) or can remain in freshwater (rainbow trout) throughout their life in either fluvial or adfluvial habitats. Although the specific mechanisms for determining whether a resident or anadromous life history will be exhibited are not completely understood, it is clear that anadromous parents can produce non-anadromous progeny, and non-anadromous parents can give rise to anadromous progeny. The situation may be further complicated in areas where the progeny of steelhead (residualized steelhead) were isolated in headwater areas following the construction of dams without fish passage facilities, such as in the upper Willamette River. In the absence of information on the status of resident rainbow trout or residualized steelhead above and below dams in the North and South Santiam rivers; the life history discussion will deal primarily with the anadromous life history strategy.

3.3.2. Capacity Estimates

In modeling population demographics for the Upper Willamette River, SLAM utilized spawning habitat as a capacity-limiting factor (as was the case with Chinook salmon). Spawner capacity, or the amount of habitat suitable for egg deposition, was incorporated using a Beverton-Holt (density-dependent) model. Reach specific capacity thresholds were estimated using habitat surveys conducted primarily during the 1930s, 40s, and 50s, and general descriptions of steelhead preference for distinct reaches. In many cases it is clear that the current ability of those reaches to support previous levels of abundance has been dramatically reduced. With the exception of spawning habitat lost due to creation of reservoir pools, this reduction in abundance is more directly related to the quality of the available habitat. In contrast to Chinook salmon, steelhead rear in freshwater habitats for an extended period (at least one, but more commonly two years). For that reason the decline in productivity for reaches is reflected in the early incubation and rearing survival of naturally produced juvenile salmonids. This would suggest that improvements in habitat could result in improved juvenile survival and increases in overall abundance. Alternatively, reducing spawner capacity as an approach to reflecting historical declines in productivity suggests that the habitat cannot provide space for more adults and that populations may be at overescapement. Establishing near-historical spawner capacity levels better reflects the biology of the situation and more readily focus on areas for possible improvement.

3.3.3. Santiam River Basin

Information on historical and current escapement and production capacities is less extensive for steelhead than Chinook salmon. River conditions during the winter and early spring are not conducive to redd surveys. Additionally, steelhead have not been a priority species (relative to Chinook salmon) in the allocation of management and monitoring resources. Limited historical hatchery and harvest data provides some perspective on abundance and distribution. Craig and Townsend (1946) summarized the current state of knowledge,

> *Little is know of the size of the total run of steelheads in the North and South Santiam rivers. All evidence points to these fish spawning far up in each stream. Water conditions during the period of their spawning migration are such as to make it uncertain as to the parts of the runs that have been stopped by the present racks (p. 28).*

Kostow (1995) estimated that the Santiam River produced about 60% of the steelhead in the Upper Willamette Basin. More recently, the termination of hatchery programs for winter-run steelhead in the Upper Willamette River in the late 1990s allows relatively accurate estimates of natural production for the entire Basin based on adult counts at Willamette Falls. For the last ten years (2003-2012) the Willamette Falls counts for adult late-winter steelhead averaged 4,493 and 6,892 early and late winter-run steelhead, respectively. Of the winter-run steelhead counted at Willamette Falls the majority likely return to the Santiam Basin.

3.3.4. North Santiam River Reaches

Native winter-run[23] historically spawned throughout the North Santiam Basin. Surveys done in 1940 estimated that the run of steelhead was at least 2,000 fish (Parkhurst et al. 1950). Parkhurst et al. (1950) also reported that large spawning aggregations existed in the Breitenbush, Little North Santiam, and Marion Fork rivers. The Oregon Fish Commission (OFC) hatchery rack was located near Jefferson, below the confluence of the North Santiam and Breitenbush Rivers and below most of the natural-spawning areas, except for the Little North Santiam River (Wallis 1963a). In 1930, 2.8 million eggs were collected, corresponding to 686 females @ 4,170 eggs/female (Wallis 1963a). On average 1,000 steelhead adults were collected at Minto Dam from 1952 to 1959 (Wevers et al. 1992). Additionally, from 1959 to 1964 counts of steelhead at Elkhorn Falls, Little North Fork Santiam averaged 120 adults. Recent estimates of escapement to the North Santiam River developed by proportional distribution of Willamette Falls counts based on index redd counts fluctuate between 2000 and 4000 winter-run steelhead adults.

3.3.4.1. South Santiam River Reaches

Parkhurst et al. (1950) estimated that there was spawning habitat available for 20,000 spawners in the South Fork Santiam River above Lebanon. Stream surveys in the 1940s noted that water conditions (due in part of pulp mill effluent[24]) and diversions likely limited the number of fish that were able to access upstream portions of the basin. Steelhead runs were reported in Thomas and Crabtree Creeks, the Middle Santiam River and Quartzville Creek (Parkhurst et al. (1950). Wade et al. (1987) reported that in 1971 the wild winter steelhead count at Foster Dam was 4,254 fish (approximately one-quarter of the Willamette Falls count for that year).

Fulton (1970) identified the South Santiam River as an important steelhead producer with good to excellent spawning and rearing areas.

Wade et al (1987) suggest that prior to the construction of Foster Dam, two-thirds of the steelhead passing the Foster Dam site were destined for the Middle Fork Santiam River to areas now above Green Peter Dam. On average, 2,600 steelhead passed the Foster Dam site prior to 1966. With the cessation of fish

[23] The winter steelhead run in the Upper Willamette River are considered by some management agencies as consisting of two temporal runs: an early-winter run that arrives at Willamette Falls prior to February 15th and spawns in tributaries draining the west side of the Basin, and a late-winter (native) run spawning in the larger tributaries draining the east side of the basin.

[24] Parkhurst et al (1950) noted that where the pulp mill effluent reentered the South Santiam River they were unable to detect any dissolved oxygen.

passage over Green Peter Dam in 1988, spawning is currently limited to the mainstem South Santiam, and Thomas, Crabtree, and Wiley Creeks.

3.3.5. Juvenile Life History

In general, steelhead do not display the same range of outmigration timing from the Willamette Basin displayed by spring-run Chinook salmon. Specifically, steelhead freshwater rearing in the headwaters can extend for months or years, yet the populations exhibit a relatively uniform age at ocean entry. The peak of downstream movement for subyearling *O. mykiss* (2012 brood year, BY) above Foster Dam was in mid August. August *O. mykiss* catch accounted for 47% of the total 2012 BY catch for the year, and fish averaged 55mm FL with a range of 29–77 mm. In 2012, a total of 1,044 subyearling *O. mykiss* (2012 BY) were captured in addition to 147 yearlings (2011 BY), and six larger fish that were not partitioned into a brood year category (Romer et al. 2013b). Juveniles sampled recently entering Foster Reservoir represented several brood years, a mix of subyearling, yearling, and two-year old fish, with subyearlings being in the majority [25]. Additionally, in light of differences in headwater habitat between the North and South Santiam Rivers, the proportion of older juveniles entering the reservoirs is thought to be higher in the North Santiam. Catches of juvenile *O. mykiss* below Foster Dam peaked in November and December, with subyearling fish constituting the majority of the catch (Romer et al. 2013b).

Emigrating *O. mykiss* were collected at Willamette Falls predominately during the spring and early summer, March to July (Figure 3.21), in 1965 and 1966 (Massey 1967). These steelhead ranged in size from 7.62 to 35.6 cm, with 69% of the juveniles in the 15.2 to 20.3 cm length range (based on body size, the majority of these fish would be two-years old). Howell et al. (1985) reviewed age data from the scales of returning adult steelhead (N=105) and found that 91.5% of the Upper Willamette river steelhead had entered salt water as two-year olds, with the remainder (8.5%) emigrating as three-year olds. Steelhead adults captured below Foster Dam from 1979 to 1982 represented 4 different freshwater age classes (Table 3.15); however the majority were 2 year-old juveniles (Howell et al. 1985). Entering the ocean as a second-year smolt is the most common juvenile life history strategy in the Lower Columbia and Upper Willamette basins (Myers et al. 2006). Recent examination of emigrating juveniles at Willamette Falls indicates only 2-year-old smolts passing the Falls.[9]

Table 3.15: Freshwater age of adult winter steelhead trapped at Foster Dam 1979-1982 (R. Youker, ODFW, unpublished – from Howell et al. 1985).

Freshwater age (yr)	1979		1980		1981		1982	
	%	n	%	n	%	n	%	n
1	0	0	2	9	2	5	0	0
2	60	57	89	430	87	246	89	180
3	40	38	9	43	11	32	9	19
4	0	0	0	0	0	0	2	4a

a - May have been 3 yr juvenile

[25] Personal Communication: Fred Monzyk, ODFW, November 1, 2013.

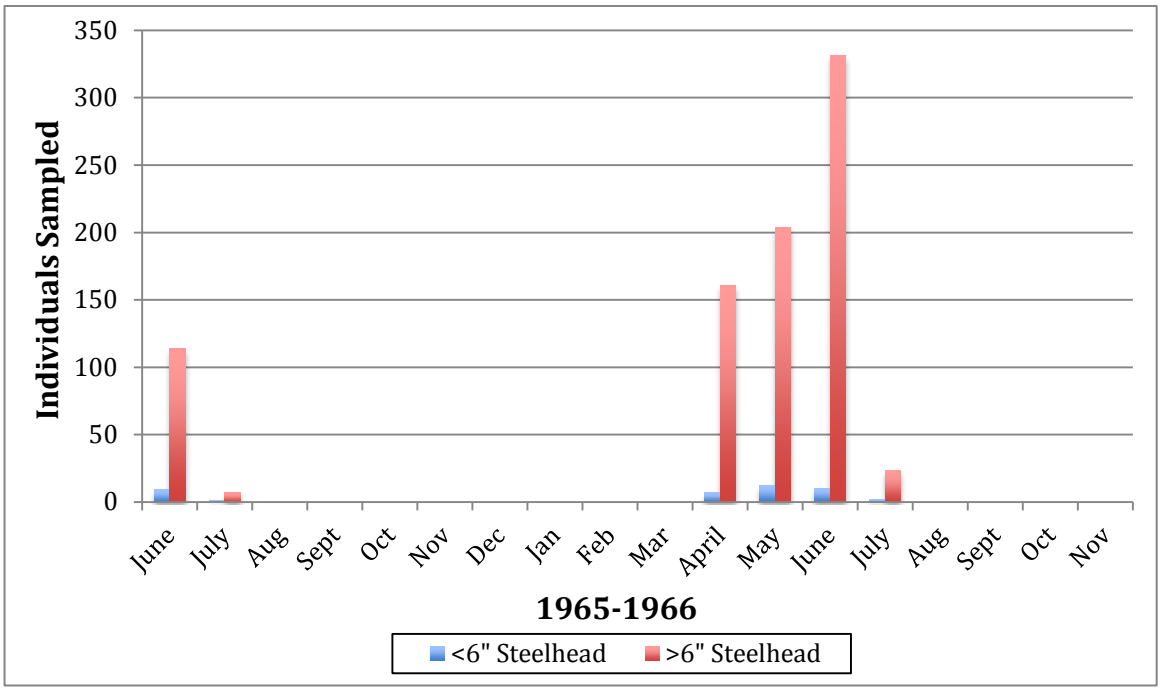


Figure 3.21: Size and timing of steelhead outmigration, based on sampling at Willamette Falls (Data from Massey 1966).

3.3.6. Survival

There are few studies that provide life history stage-specific survival estimates for steelhead during natural incubation and juvenile rearing (Table 3.16). Additionally, because steelhead spawn in a variety of stream types in coastal and inland basins and exhibit a number of life history trajectories, it is not clear how applicable the estimates are to Upper Willamette Basins.

Johnson and Cooper (1992) reported that survival from egg to emergent fry survival was 52.5% (31.6 -72.4%) for winter run steelhead. Ward and Slaney (1993) reported that the average egg-to-fry survival for winter run steelhead in a coastal stream (Keogh River) was 6.5%. Annual averages range from 1.8 to 11.5%. Similarly, fry-to-smolt survival (12.9% average) range widely from 3.3 to 21.9%. The authors suggested that density-dependent mortality was a major influence in survivals, with the fry-to-parr stage being critically limiting. Johnson and Cooper (1992) reported similar fry (fall fry) to smolt survivals, with an average of 9.8% and range of 4.6 to 14.3% for Snow Creek, a small independent coastal tributary in the Strait of Juan de Fuca. In studies with sea trout (*Salmo trutta*) Elliott (1989) concluded that there was a critical period with high density-dependent mortality early after emergence with later life stages exhibiting proportional survival. We employed a Beverton-Holt capacity model in the SLAM model at the spawner-to-egg stage, in part because juvenile capacity estimates were lacking for the populations.

Table 3.16: Life history stage specific survivals for steelhead.

Steelhead						
Egg to Fry	Fry to JOM	Reservoir	JOM to Parr	Parr to River Migrants	Egg to River Migrant	Source	Note
6.33%						ODFW/NMFS 2011	North Santiam Reach C (mode)
29.30%	13.50%					Quinn 2005	
52.50%	9.80%				1.79%	Johnson and Cooper 1992	Snow Creek
6.50%						Ward and Slaney 1992	Keogh River
2.60%						Rich et al. 1993	Idaho
				48.20%		Kiefer and Lockhard 1993	Crooked River, Id

3.3.7. Ocean Survival

Difficulties in sampling outmigrating winter steelhead smolts in Upper Willamette tributaries or at Willamette Falls, result in considerable uncertainty in ocean survival estimates. In the geographically proximate Clackamas River, monitoring efforts at North Fork Dam provide data on juvenile outmigrants and returning adults. For brood years 1981 to 2007, the smolt to adult survival averaged 6.8% (range 1.6 to 22.8%). For winter-run steelhead smolt outmigrating from Snow Creek (1978-1986), 0.40% returned as 1-salt adults, 5.44% as 2-salt adults, and 0.49% as 3-salt adults (Johnson and Cooper 1991). Studies on the Keogh River, British Columbia, indicated that winter steelhead smolt-to-adult survival from 1978 to 1983, a period of good ocean conditions, ranged from 8 to 25% (Ward and Wightman, 1989). More recently, marine survival of Keogh River winter run smolts averaged 3.1% from smolt to adult for 1991-1996 (McCubbing 2002).

Ocean survival estimates for the Clackamas River were strongly negatively correlated with ocean conditions (Pacific decadal oscillation, PDO) during the first months of ocean entry for smolts (Figure 3.22). As mentioned for Chinook salmon, replacing the R2 ocean survival data files was set as a secondary task due to the parallel effect it has on the SLAM scenarios.

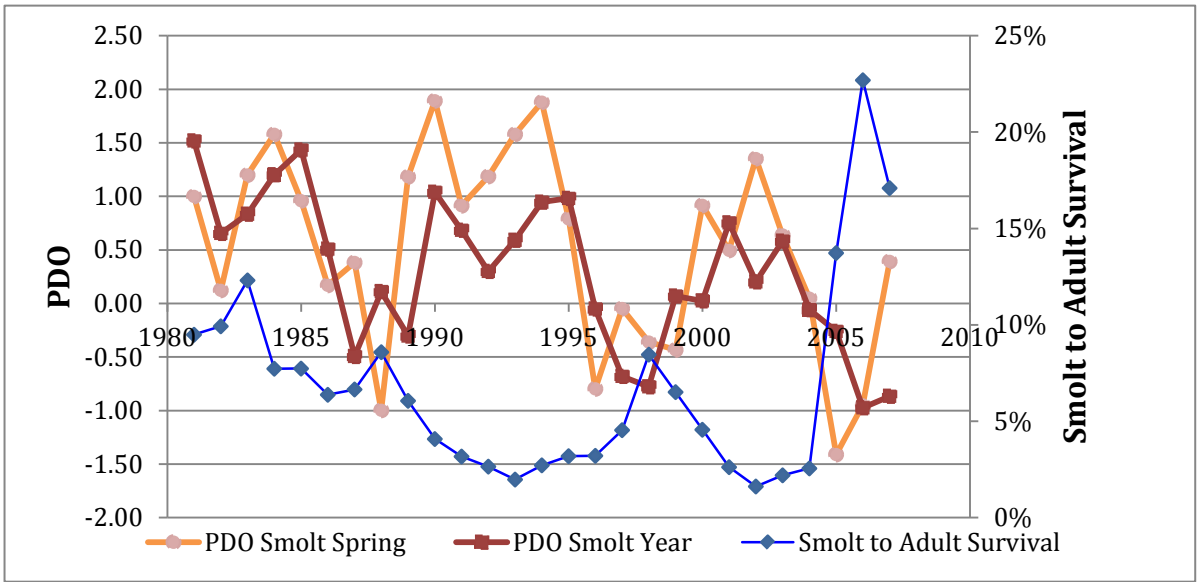


Figure 3.22: Smolt to Adult survival for Clackamas River winter steelhead and Pacific Decadal Oscillation (PDO) metrics for smolt outmigrant spring months or years.

3.3.8. Age Structure

Scale samples from unmarked winter steelhead taken from the North Santiam River in the 1980s (Table 3.17) indicated that 4 and 5 year-old fish constituted the majority of the run (generally thought to represent 2 and 3-salt ocean life histories).

Table 3.17: Age structure for Willamette River winter-run steelhead.

North Santiam Winter Steelhead[26]					
Age (Total years)	3	4	5	6	7
Proportion	0.000	0.481	0.412	0.101	0.006

This age structure is similar to that reported by Johnson and Cooper (1992) for steelhead returning to larger Puget Sound and Washington coastal rivers from 1986-1990.

The frequency of repeat spawners in Upper Willamette Basin tributaries is thought to be very low. Howell et al. (1985) reported that the repeat spawner rate in the South Santiam (sampled at Foster Dam) was 2% in 1979 and 1980 and 4% in 1981.

Age structure was used to influence the maturity rates for age classes in the SLAM model. Additionally, the fecundity of first time spawners was approximated by using a weighted average of fecundities for 4,5, and 6 year old steelhead (see steelhead fecundity).

3.3.9. Fecundity

Fecundity estimates are generally based on female size or age, in addition different relationships between age/size and fecundity exist for first time and repeat spawners. For Puget Sound and Washington Coast winter steelhead, Johnson and Cooper (1992) reported the average fecundity for 2-salt females as 3500 eggs, for 3-salt females as 5030 eggs (Table 3.18). Howell et al. (1985) reported the average fecundity for Upper Willamette winter-run hatchery steelhead ranged from 3,640 to 4,700 eggs/female. Wallis (1963) estimated that the average fecundity for hatchery winter run steelhead returning to the Minto Ponds during the 1950s was 3,400 eggs; noting at the time that the majority of the returning fish were 4 years olds (2-ocean fish). Average fecundity (based on total egg take and number of females spawned) for North Santiam winter steelhead returning to the North Santiam Hatchery (1956-1960) averaged 3924±169(SE) eggs (Wallis 1963) and to the Minto Hatchery (1960-1998) averaged 3,825 ± 118 (SE) eggs[27], although this is likely an underestimate given the likelihood of partially spawned females being sampled.

Utilizing the above age distribution for Upper Willamette winter-run steelhead and the age-based fecundities (Johnson and Cooper 1992), a weighted average fecundity for first-time spawners would be 4,494 eggs. Given the range of fecundities it was decided to set virgin female fecundity at 4,000 eggs (2,000 egg per adult based on a 50:50 sex ratio).

[26] Data from M. Chilcote (ODFW)
[27] Personal Communication: Cameron Sharpe, ODFW, 19 March 2013.

Table 3.18: Female size, age, and fecundity for winter steelhead from Puget Sound and Washington Coastal rivers.

Fecundity Study Data	River System							
	Green		Skagit		Quileute		Combined	
	a	b	a	b	a	b	a	b
2-Salt								
Mean FL (mm)	650	689	650	674	650	704	650	673
Mean Fecundity	3831	4202	3779	4317	3094	4045	3500	3887
Sample size	--	5	--	13	--	22	--	40
3-Salt								
Mean FL (mm)	750	800	750	795	750	835	750	786
Mean Fecundity	5221	6251	5625	6814	4559	6662	5030	5982
Sample size	--	15	--	26	--	25	--	66
4-Salt								
Mean FL (mm)	900	945	900	---	900	945	900	945
Mean Fecundity	7745	7304	9339	---	7469	7304	7987	7304
Sample size	--	--	--	--	--	1	--	1
Repeat Spawners								
Mean FL (mm)	800	808	800	808	800	800	800	803
Mean Fecundity	6003	7013	6731	7013	5429	4502	5925	5648
Sample size	--	--	--	4	--	11	--	15

a - Fecundity based on length/fecundity relationship for each specific river and mean length for each saltwater group.
b - Fecundity based on length/fecundity relationship from fish from tribal net fishery in each specific river.

Egg size may be an important effect influencing the survival and growth of subsequent progeny. Quinn et al. (2011) found that egg size increased with female age at spawning. Additionally, egg size and fecundity appears to increase in multiple spawners between their first and second maturation (data was only available for second-time repeat spawners). Egg size has been positively correlated with early growth and survival (Einum and Fleming 1999). Seamons and Quinn (2010) reported that repeat spawners contributed more adult offspring than their one-time spawning counterparts. Additionally, females produced more adult offspring in their second spawn relative than in their first spawn. This data suggests that the contribution of multiple spawners to population productivity increases with each repeat spawning, and that repeat spawners should be treated separately from first-time spawners.

3.3.10. Calibration

The calibration of the steelhead life cycle models presented a number of challenges. Firstly, population-specific estimates of winter run steelhead spawning escapement in the Upper Willamette River are based on expansions of redd counts with winter-run counts at Willamette Falls (Table 3.19).

With the cessation of hatchery releases of winter-run steelhead in the 1990s, all of the winter-run steelhead counted at Willamette Falls are assumed to be naturally-produced; however, managing agencies consider those returning adult steelhead passing the Falls prior to February 15th to be the feral progeny of non-native early-winter-run steelhead released into the Willamette River Basin (Howell et al. 1985). Genetic sapling at Willamette Falls is currently underway to assess the genetic distinctiveness of early-winter steelhead compared to late-winter steelhead.

Table 3.19: Estimates of winter-run steelhead escapement to tributaries of the Upper Willamette River DPS based on redd counts in index reaches.[28]

LATE-RUN WINTER STEELHEAD RUN SIZE ESTIMATES

				Redds per Mile				Miles of Habitat*				Run Size Estimate			
Year	Will. Falls Count	Minto Count	Foster Count	Molalla	N.Santiam	S.Santiam	Calapooia	Molalla	N.Santiam	S.Santiam	Calapooia	Molalla	N.Santiam	S.Santiam	Calapooia
2006	3251	225	419	9.4	13.1	6.6	6.3	95	100	78	26	808	1410	885	148
2007	3388	77	210	11.1	10.0	14.4	5.2	95	100	78	26	985	1014	1263	127
2008	2589	0	253	10.1	2.3	9.9	5.7	95	100	78	26	1062	255	1109	163
2009	2110	0	192	9.5	15.3	9.4	1.1	95	100	78	26	544	917	632	17
2010	4856	143	426	12.8	5.7	1.5	4.8	95	100	78	26	2573	1347	673	264
2011	4670			12.6	19.4	5.6	3.8	95	100	78	26	1523	2465	556	126

In addition to the redd expansion information, data was also available for adult counts at Bennett and Foster Dams for a number of years. Winter steelhead adult counts at Foster have averaged 309 fish over the last five years (2009-2013). In addition, index redd counts from Thomas, Crabtree, and Wiley creeks indicate significant spawning aggregations cumulatively accounting for up to a few hundred steelhead[29]. Bennett Dam monitoring has been inconsistent, in part due to recent modifications in the structure and changes in counting protocol; in 2013 and 2014, 688 and 875 winter steelhead were counted using a video system, respectively.[30] These quantitative estimates help in estimating the distribution of returning steelhead among the four Upper Willamette River tributaries.

3.4. Parameterization of VSP Criteria

3.4.1. Fitness Effects from Domestication of Naturally Spawning Hatchery-Origin Salmonids

There have been a number of empirical and theoretical studies on the effects of hatchery propagation and rearing on the long-term fitness of salmonids. Domestication concerns the genetic and behavioral consequences of hatchery propagation, but not the subsequent interactions between hatchery-origin and natural-origin fish: competition, predation, disease transmission, etc. The effect on fitness from genetic changes due to domestication or outbreeding (introduction and introgression of fish from non-local populations) may persist long after hatchery programs are eliminated or modified. Most studies have attempted to understand the loss of local adaptation; however, little is known regarding the rate or potential for reestablishment of local adaptation in a population. Busack and Currens (1995) reviewed many of the potential consequences of hatchery operations on a naturally spawning population. More recently, the advent of molecular parentage techniques has enabled researchers to assess the relative reproductive fitness of hatchery-origin and naturally-produced salmon and steelhead spawning *in situ*.

Studies with anadromous *O. mykiss* have demonstrated both the short and long term effects of artificial propagation and rearing on fitness (Araki et al. 2007, 2009). Similarly, the relative reproductive success of hatchery-origin coho salmon (*O. kisutch*) was generally lower for both 3-year-old males (62% of wild) and 3-year-old females (84% of wild), but higher for 2-year-old (jack) males (175% of wild) (Thériault et al. 2011). Alternatively, Ford et al. (2012) did not observe a dramatic reduction in the fitness of hatchery-reared Chinook salmon. Furthermore, Ford et al. (2012) concluded that the decrease appeared to be related to the earlier maturation of hatchery-reared males. Kostow et al. (2003) postulated that non-native summer-run steelhead in the

[28] Personal Communication: C. Sharpe, ODFW, 14 February 2012.
[29] Data from C. Sharpe, ODFW, 12 September 2013.
[30] Data from http://www.dfw.state.or.us/fish/fish_counts/north_santiam/bennett_dams.asp, 20 August 2014.

Clackamas River exhibited a lower relative reproductive success compared to native winter-run steelhead; in addition, the presence of summer-run steelhead juveniles depressed the native steelhead populations through competition rather than genetic introgression. In contrast to these findings, Hess et al. (2012) reported no significant difference in the reproductive success of naturally-spawning natural-origin and hatchery-origin summer-run Chinook salmon. It should be noted that the hatchery-reared fish in the Hess et al. (2012) study were the progeny of wild Chinook salmon from a stream system that has never had hatchery releases, in contrast to the Upper Willamette River Basin, where the majority of returning adults were hatchery reared for at least 50 years and some hatchery programs have been operating for over 100 years. Additionally, in the Hess study the difference between hatchery and natural-origin fish become non-significant only after excluding those fish that did not produce any returning adult progeny.

In initially developing the VSP scoring criteria, the UWLCR TRT adopted much of its quantification of hatchery influences from the All-H Hatchery Analyzer (AHA) model (HRTDG 2005). The AHA model estimates the degree to which hatchery and domestication influences erode local adaptation, delay the rate of adaptation, or create a genetic load of recessive deleterious alleles, etc. It should be remembered that hatchery and domestication influences are one part of a multi-function process, where the effects (domestication, inbreeding, natural and artificial selection) are multiplicative rather than additive over time. Because the effects of domestication are retained in a fish's genome, it is not possible to eliminate them simply by removing the fish from the hatchery environment. Instead, natural selective forces must reestablish the frequency of locally adapted genes (a process that can easily be protracted over many generations, depending on conditions).

The AHA model tries to simulate many of the effects of hatchery operations, and in doing so provides a useful indirect measure of the impact on diversity. Beyond domestication, the introduction of non-local genotypes (not addressed in the AHA model) is likely to have an erosive effect on locally-adapted life history traits and overall population fitness. In general, the AHA model concept focuses on the Proportionate Natural Influence (pNI), the relationship between the percent of hatchery origin natural spawners (pHOS) and the percent natural origin adults in the hatchery broodstock (pNOB), to determine the rate of domestication. The greater the proportion of natural-origin fish utilized as broodstock in the hatchery the slower the rate of hatchery domestication for the broodstock overall. Similarly, lowering the proportion of hatchery-origin fish that spawn in the wild decreases the frequency of "domesticated" genes entering the NOR segment of the population. pNI is calculated as pNOB/(pHOS + pNOB), with values near 1 indicating low levels of domestication and low values (near 0) indicating a strong domestication effect (Figure 3.23). pHOS is primarily a response variable dependent on the magnitude of hatchery production, differential survival of hatchery and natural-origin fish, and homing fidelity by hatchery fish to the hatchery, whereas pNOB is dependent on hatchery specific broodstock mating programs. Both pHOS and pNOB can be readily generated (in the form of a running average) from the SLAM model.

The relative influence of pNI on diversity (expressed as a change in fitness) increases substantially as hatchery operations progress for several generations. On a single generation basis, the longer fish stay in a hatchery environment rather than in a natural environment, the greater the potential for domestication selection or the relaxation of natural selection. In general, hatchery-rearing protocols in the Upper Willamette are relatively standardized. Juveniles are released following 9 to 14 months of rearing in the autumn or second spring. Additionally, the release of fish "off station" has been minimized in basins with natural populations. Incorporating natural origin fish into hatchery broodstocks, while minimizing hatchery strays onto the natural spawning grounds provides the highest pNI. While using natural-origin fish as broodstock is desirable, it should be noted that "mining" natural populations can result in other diversity concerns: direct selection of

temporal portions of the run, or severe reductions in the effective size of the natural spawning population.

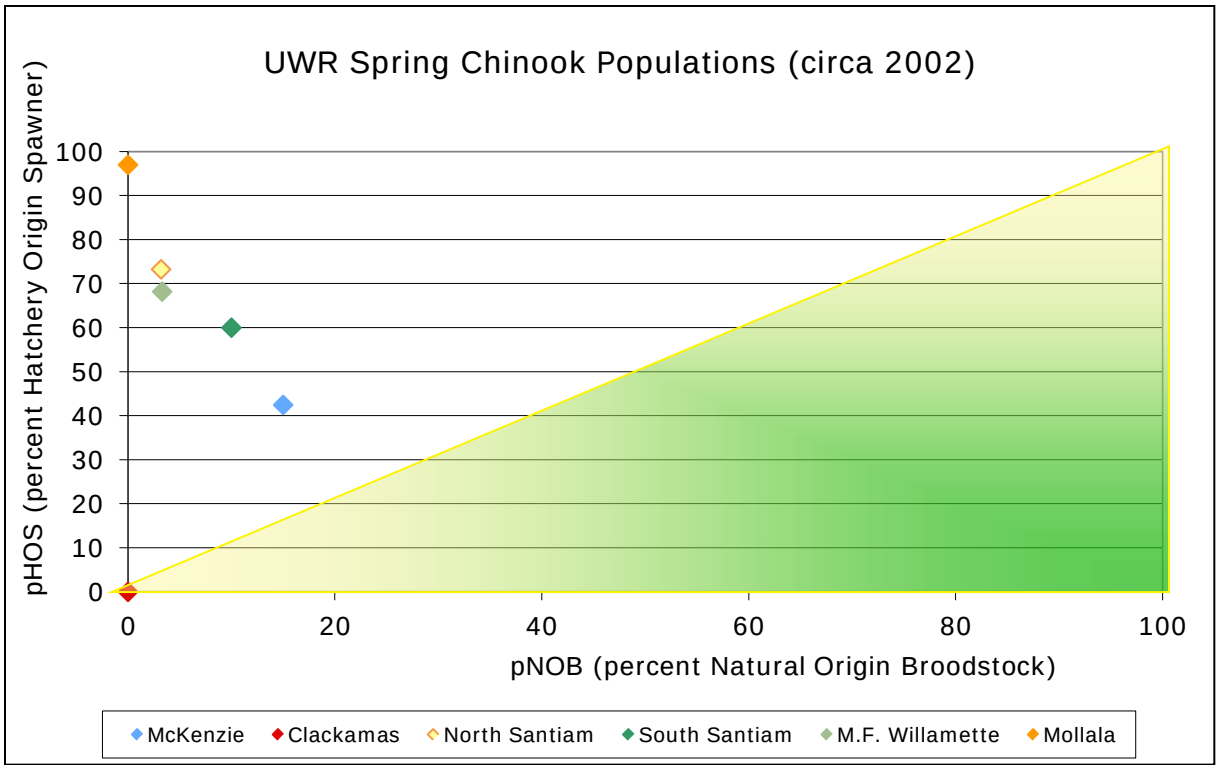


Figure 3.23: Relative percent hatchery origin spawners (pHOS) and percent natural origin broodstock (pNOB) for Willamette River Hatcheries. Where pHOS < pNOB, hatchery populations tend to become more natural over time (green shaded area). Where pHOS > pNOB, natural populations tend to become more domesticated. From UWTRT (2007).

We have utilized the relationship between pNI and fitness to develop a dynamic driver in SLAM that adjusts the productivity/survival of naturally-spawning hatchery-origin fish. In the extreme case of pNI = 0, where there are no natural-origin fish in the hatchery population, hatchery fish would exhibit a 60% fitness reduction; whereas, under a no-hatchery option there would be no reduction.[31]

A linear relationship was plotted and the hatchery discount was applied at the survival from the egg to emergent fry stage. Thereafter for that brood year, naturally-produced fish from both hatchery and natural-origin parents were pooled in the model. pNI was calculated as:

$$\text{pNI} = \frac{p(NOB)}{p(NOB) + p(HOS)}$$

[31] There have been a number of recent studies estimating the relative decline in fitness of artificially propagated fish. Of these, a review by Chilcote et al. (2011) estimated an 87.2% fitness reduction with a pNI=0, and provides an upper bound to the estimates. Other studies report a wide range of estimated reductions, with no consensus on the mode(s) of action or their magnitude. The 60% reduction used in the Chinook salmon SLAM model represents an interim estimate pending further studies.

A running average for pNI was calculated to estimate the overall domestication status of the hatchery population. pNI was initialized using estimates provided by the HSRG for each hatchery program, and the initialize value was weighted to reflect 25-years of hatchery operations at the initial pNI to mimic the gradual process by which pNI would change in the population over several generations. Each year pNI was recalculated based on returning adults (Figure 3.24). This reflects that genetic selection for hatchery conditions or local adaptation is a relatively slow cumulative process and changes in hatchery practices may take several generations to result in observable improvements in fitness. It is likely that locally-adapted gene complexes can be readily disrupted, but require considerable time to reestablish themselves.

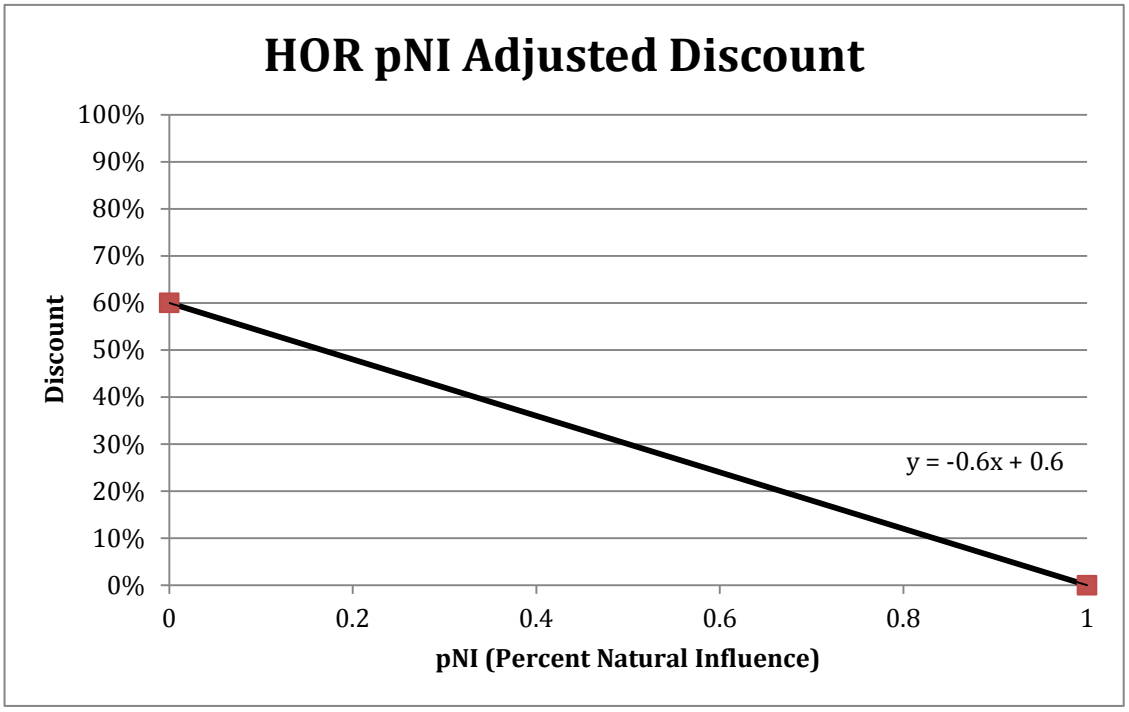


Figure 3.24: Proportional adjustment for egg to fry survival for the progeny of hatchery-origin recruits (HOR) based on the percent natural influence (pNI) estimated for the population.

Initial simulations with SLAM under conditions where pNI was low (< 0.25) still resulted in large numbers of NORs via the steady accumulation of hatchery-derived NORs (an outcome not observed empirically). In order to account for latent hatchery legacy effects a discount is applied to the reproductive success of NOR fish, also based on pNI (Figure 3.25). In the case of NORs, the discount is 20.0% at a maximum (pNI =0). This adjustment reflects the fact that many natural-origin Chinook salmon in the Upper Willamette River have at least one parent or grandparent that was of hatchery origin. In the North Santiam and Middle Fork Willamette River, where over 90% of the naturally-spawning fish are of hatchery-origin, it is very likely that the majority of non-marked spawning adults had at least one hatchery-origin parents.

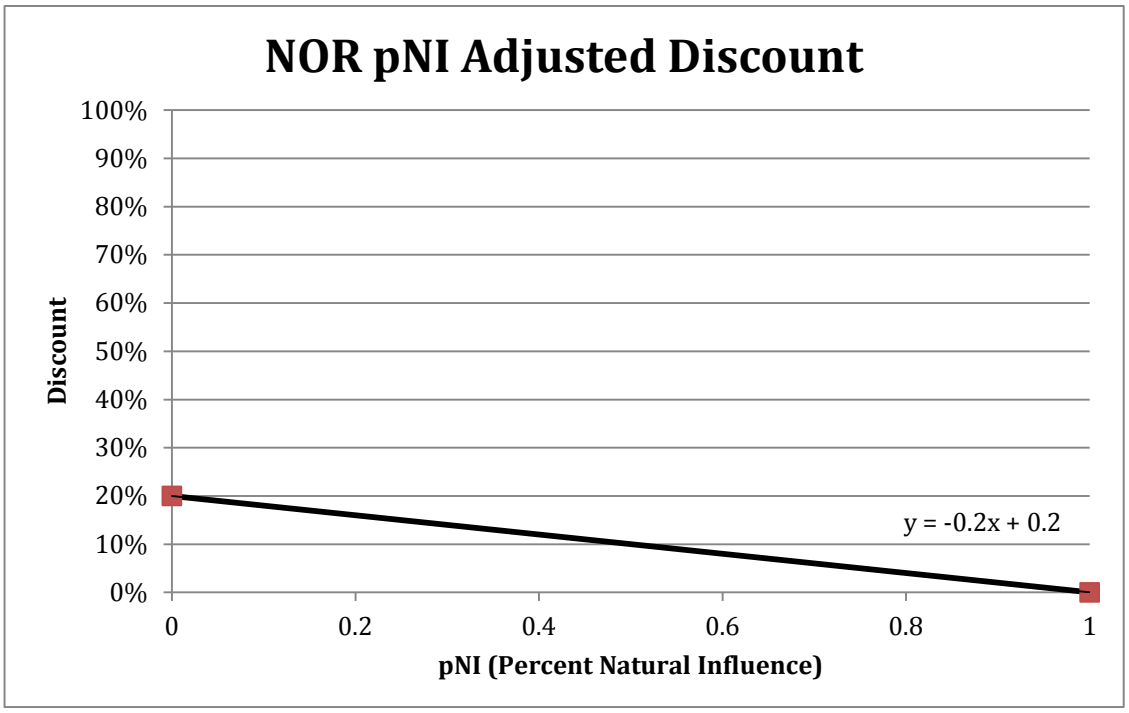


Figure 3.25: Proportional adjustment for egg to fry survival for the progeny of natural-origin parents based on the percent natural influence (pNI) estimated for the population.

3.4.2. VSP Scoring Based on SLAM Outputs

The VSP conceptual approach (McElhany et al. 2000) to identifying and evaluating the status of salmon and steelhead population relies on the assessment of four population parameters: (1) abundance, (2) population growth rate, (3) population spatial structure, and (4) diversity. Technical Recovery Teams (TRTs) in each of the Recovery Domains developed metrics for these parameters, metrics that are often specific to the life history characteristics of each species and quantity and quality of information available. The Upper Willamette River TRT ultimately determined that a weighted measure of the four population parameters best defined the status of DIPs:

$$VSP = \frac{2(Abundance) + 2(\text{Pr}oductivity) + Diversity + Spatial_Structure}{6}$$

VSP scores for abundance and productivity represent different aspects of viability from diversity and spatial structure. Abundance and productivity measures demonstrate the ability of a population to persist, whereas diversity and spatial structure provide confidence that the population can sustain population persistence in the face of future environmental variation. Abundance and productivity metrics are generally derived from abundance time series and were evaluated in combination to estimate population persistence (Figure 3.26). Diversity and spatial structure metrics are quite distinct and evaluated separately. The VSP score

$$VSP = \frac{4(Population_Persistence) + Diversity + Spatial_Structure}{6}$$

VSP scoring is based on the contribution of each parameter toward population persistence (1 – extinction risk). The actual score is a non-linear categorical representation of the probability of population persistence (McElhany et al. 2007).

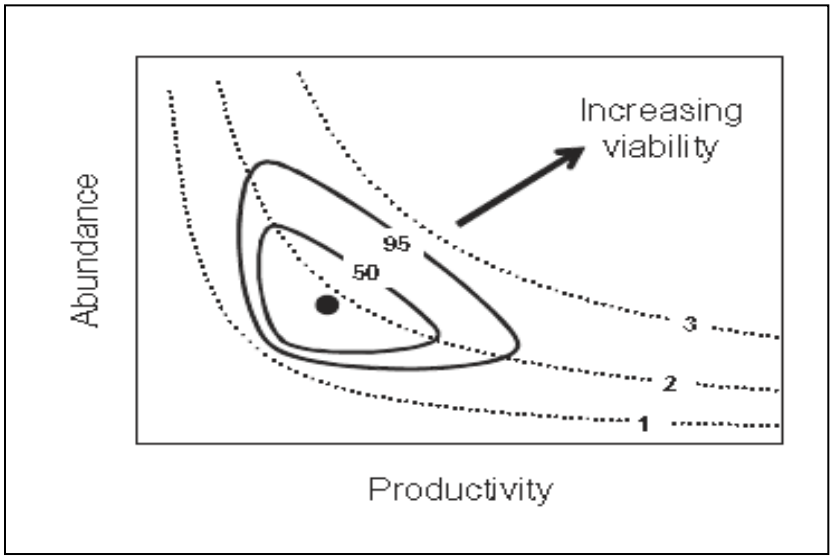


Figure 3.26: Viability as a function of abundance and productivity. The dotted curves depict isopleths of equivalent extinction risk corresponding to different viability categories (1, 2, or 3). For a given abundance, viability increases with increasing productivity, and conversely, for a given productivity, viability increases with increasing abundance. The black dot and solid lines estimate the current risk of extinction and its 50% and 95% confidence ellipses for a hypothetical population.

3.4.3. Scoring Metrics

3.4.3.1. Abundance and Productivity

The population abundance time series produced by the SLAM model can be used to calculate a population persistence or extinction risk estimate. Using the quasi-extinction threshold (QET) risk (all NOR spawners) option in the SLAM model provides an extinction risk (the probability of spawner abundance falling below QET in 100 years, QET was set by the TRT at 250 for the McKenzie (Table 3.20)). Initially, the SLAM was run for 105 years per alternative scenario and the first 6 years excluded from the QET risk estimate to allow for a model "burn in" period, which allowed the initial "startup" variability to stabilize for four generations (Figure 3.27). The extinction risk, in turn, can be converted into a VSP score for abundance and productivity (Table 3.21 and Figure 3.28). QET levels were initially set by the TRT based on basin size. In the Upper Willamette River recovery plan (ODFW and NMFS 2011), population viability was modeled using slightly lower QET (Critical Risk Threshold, CRT) values for South Santiam and Middle Fork Willamette River Chinook salmon populations, 150 adults, than were recommended by the TRT McElhany et al. (2007), 250 adults. We have retained the more conservative (higher) TRT QET levels.

Table 3.20: Critical Risk Thresholds (CRT) levels for Upper Willamette River Chinook salmon and steelhead. From the Upper Willamette River Recovery Plan (ODFW and NMFS, 2011).

Population	CRT	Population	CRT
Clackamas SpCh	150	Molalla StW	200
Molalla SpCh	50	S Santiam StW	200
N Santiam SpCh	150	N Santiam StW	200
S Santiam SpCh	150	Calapooia StW	50
Calapooia SpCh	50		
McKenzie SpCh	250		
Middle Fork Willamette SpCh	150		

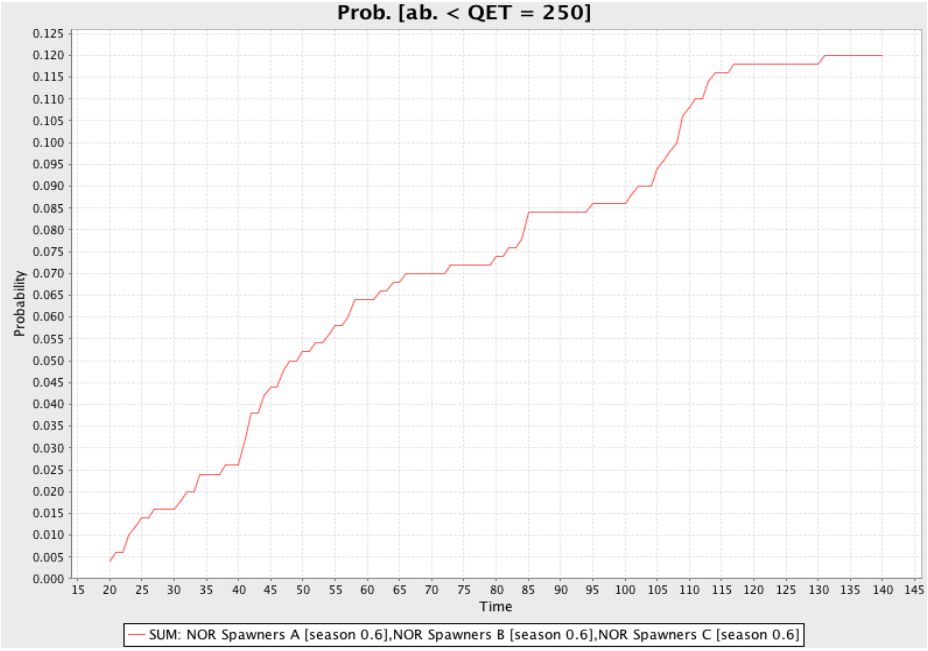


Figure 3.27: Representative output for McKenzie River spring-run Chinook salmon output, with a QET (aka CRT) of 250 and a 4-year running average. The probability of the population dropping to, or below, the QET level is estimated over a 100-year period (from year 20 to year 120 in this scenario). The first 20 years are removed from the estimation to allow the model to equilibrate. The median projection of 500 runs provided the population persistence score (1-QET), which was converted to a population persistence category from 0 to 4 (Table 3.21).

Table 3.21: Persistence and risk equivalents of VSP abundance and productivity scores.

Population Persistence Category	Probability of Population Persistence In 100 Years	Description
0	0–40%	Either extinct of very high risk of extinction.
1	40-75%	Relatively high risk of extinction in 100 years
2	75-95%	Moderate Risk of extinction in 100 years.
3	95-99%	Low (negligible) risk of extinction in 100 years (viable salmon population).
4	>99%	Very low risk of extinction in 100 years.

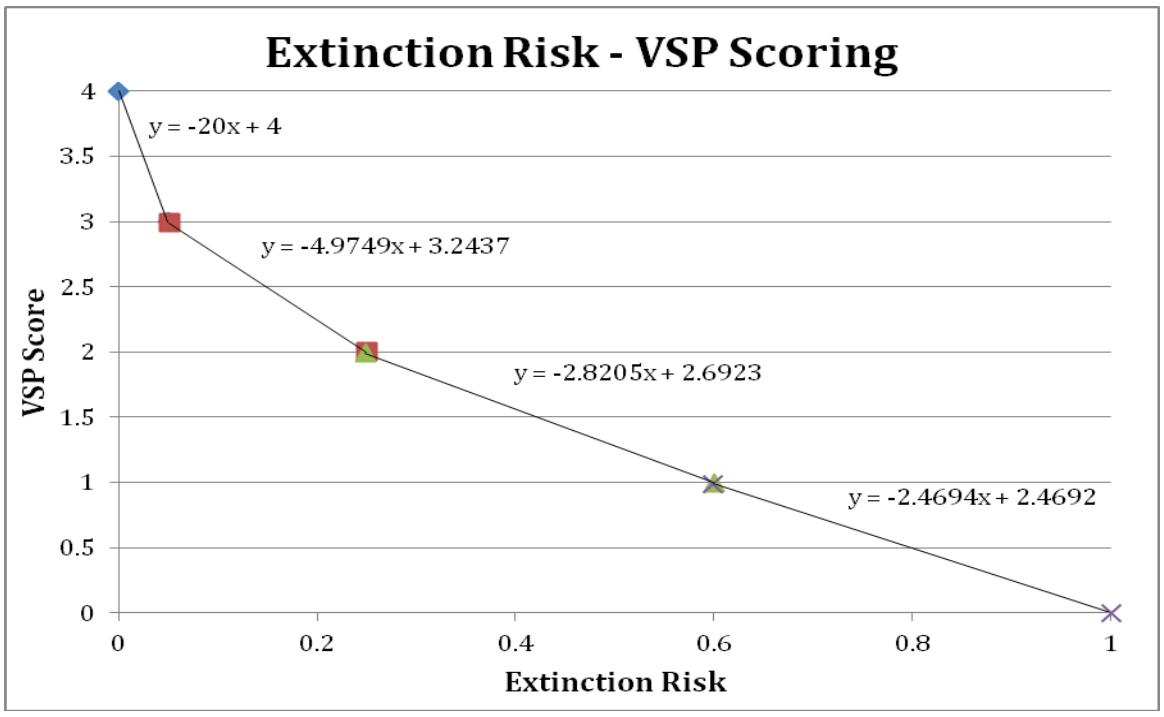


Figure 3.28: Equations for converting SLAM extinction risk to VSP Abundance and Productivity score. Point values are from the UW LCR TRT viability criteria (McElhany et al. 2007).

3.4.3.2. Diversity

The UWLCR TRT identified a number of population metrics that could be used to estimate the contribution of diversity toward population viability. These include both direct measures of life history traits and genetic variation and indirect measures that include potential factors that could impose a selective effect on populations. Few life history traits are being monitored across all of the populations in the Upper Willamette River and as a result there are a limited number of life history traits that can be effectively included. Life history strategies such as juvenile life history or age at maturation represent suites of traits that are coordinated in order to enable completion of one life history trajectory. For most of these life history strategies one would want to know a number of parameters: the mean, mode, and range of occurrences. Additionally, measures of life history characters need to be correlated with freshwater and climatic conditions. Changes in both major and minor traits by themselves are not necessarily indicative of changes in the underlying genes that influence life history diversity. In many cases, phenotypic responses to environmental fluctuations are indicative of a "healthy" population. Variation relative to historical levels may be useful, but given the environmental changes in the Columbia River estuary and mainstem, Willamette River mainstem, and natal tributaries it is unlikely that the distribution of life history strategies would be expected to remain unchanged from historical levels. While one can be fairly confident in asserting that multiple outmigrant strategies are necessary or "desired", it would be riskier to establish quotas on each temporal window. Simply verifying that a population is still capable of expressing a specific life history type may be sufficient if one is confident that a population will express a specific trait when the environmental cues are present. Similarly, monitoring variability rather than some mean or mode in traits, such as spawn timing, may be the more useful measure of some diversity traits.

Life History Traits

Juvenile life history is generally monitored either during juvenile outmigration (at passage structures or outmigrant traps (i.e. screw traps)) or retrospectively from the adult return migration (using scales or otoliths). Juvenile monitoring methods cannot identify differences in juvenile rearing that occur prior to or subsequent to sampling. For example, subyearling migrants counted at a passage structure may continue to rear downstream prior to smolting or may move directly to the ocean. Likewise, analysis of returning adults identifies successful life history trajectories, but may be unable to nuance the difference between a fish that emigrates from its natal tributary as a fry but rears to be a yearling smolt at some other freshwater site prior to ocean entry, and a fish that rears in its natal tributary for an entire year before emigrating as a yearling smolt. Because juvenile life-histories differentially rely on various freshwater habitats, understanding the relative success or failure of juvenile life history trajectories can assist recovery planners in developing freshwater recovery strategies.

Juvenile monitoring may be more useful in indicating the potential for life history variation, while adult monitoring alone cannot identify the relative success of the different life history trajectories. Ideally, both measures are needed to evaluate juvenile life history trajectories; however, in most cases this information is not available in sufficient detail for all tributaries to be useful as a criteria.

Given these constraints VSP scoring for life history traits (specifically juvenile life history traits) in SLAM models focuses on whether multiple strategies are available in significant proportions, enough so that the population could respond to changes in the short and long term without suffering a severe bottleneck in population abundance. Population scores for juvenile life history trajectories would require basin-specific sampling programs for naturally-produced juveniles and adults. Based on Mattson's 1962 work, a simple scoring system for juvenile life history (based on juvenile migrants or adult returns) was employed. Scores are computed annually and averaged across the SLAM time series. For each year deductions are applied against the possible score of 4 when any juvenile life history segment falls below one of the critical values, any deductions that result in scores of less than 0, would be considered 0 (Table 3.22).

In the course of analyzing preliminary SLAM outputs it was observed that the proportion of some juvenile life histories would often fall below the desired thresholds, even in populations that exhibited a substantial positive growth rate. In cases where the proportion of "river migrant juveniles" for any one life history stage fell below the 20% threshold and the absolute abundance of juveniles in that life history trajectory was more than 5,000 no deduction was made. In these cases the VSP goal of preserving a juvenile life history type was met by providing a sufficient number of juveniles to ensure some adult representation.

Table 3.22: Scoring template for three classes of juvenile life history. Each population would have an initial score of 4.0, from which deductions would be applied based on the magnitude any one or more life history stages fell below 20%.

Juvenile Life History Stage	Deduction if proportion falls below…			
	> 20%	>10%	>05%	>01%
1st Spring migrant	-0.5	-1	-1.5	-2
1st Autumn migrant	-0.5	-1	-1.5	-2
2nd Spring migrant	-0.5	-1	-1.5	-2

Artificial Propagation

Hatcheries affect diversity largely through the process of domestication and the introgression of non-adapted hatchery-origin fish into the naturally spawning population. The magnitude of this effect depends on the degree of domestication and the origin (native vs. non-native) of the hatchery broodstock. Additionally, hatchery propagation may produce non-genetic effects affecting the expression of life history traits via non-natural rearing regimes (i.e. non-natural size and time of release). While a concern, the long-term consequences of these practices on diversity are not well understood. Issues related to competition, predation, or disease transmittal by hatchery-origin fish, while important to overall population viability, are not considered in this section. Many of these effects are indirectly included in life-stage specific survivals in the SLAM model during baseline calibration, but not specifically parameterized.

Hatchery influence, whether it is from the inclusion of naturally-produced fish into hatchery broodstocks or the "straying" of hatchery-origin fish onto the natural spawning grounds is believed that have an effect on overall population fitness. It should be remembered that hatchery/domestication influences are one part of a multi-function process, where the effects (domestication, inbreeding, natural and artificial selection) are multiplicative rather than additive over time. Additionally, because the effects of domestication are retained in a fish's genome, it is not possible to eliminate them simply by removing the fish from the hatchery environment. Instead, natural selective forces must reestablish the frequency of locally adapted genes (a process that can easily be protracted over many generations, depending on conditions).

Beyond domestication, the introduction of non-local genotypes (not addressed in the AHA model) is likely to have an erosive effect on locally-adapted life history traits and overall population fitness. For the populations under consideration in the Upper Willamette River, Chinook salmon hatchery broodstocks have been derived from within the ESU and to a certain extent largely from the basin specific to the hatchery. Native winter-run steelhead have not been subject to artificial propagation for almost 15 years; however, in the case of steelhead there is some concern regarding the genetic and ecological influence of introduced summer-run steelhead from the mid-Columbia Region. Overall, given the scale of hatchery production, the low level of natural production, and the quality of much of the currently accessible spawning habitat in the Upper Willamette Rivers, the diversity aspects of hatchery introgression and competition must be included as a potential major factor influencing overall population viability.

The diversity component of the VSP evaluation by the TRT included an AHA model-based metric. In general, the AHA model relies on the proportion of natural influence (pNI), which is based on the relationship between the percent of hatchery origin natural spawners (pHOS) and the percent natural origin broodstock in the hatchery (pNOB), to determine the rate of domestication. The greater the proportion of natural-origin fish utilized as broodstock in the hatchery the slower the rate of hatchery domestication for the broodstock overall. Similarly, lowering the proportion of hatchery-origin fish that spawn in the wild decreases the frequency of "domesticated" genes entering the natural population's gene pool. pNI is calculated as pNOB/(pHOS + pNOB), with values near 1 indicating low levels of domestication and low values (near 0) indicating a strong domestication effect (Figure 3.29). pHOS is primarily a response variable dependent on the level of hatchery production, differential survival between hatchery and natural-origin fish, and homing fidelity by hatchery-origin fish back to their hatchery of origin, while pNOB is dependent on hatchery specific broodstock management plans. Parameters pNI, pHOS and pNOB can be readily generated (in the form of a running harmonic mean) from the SLAM model.

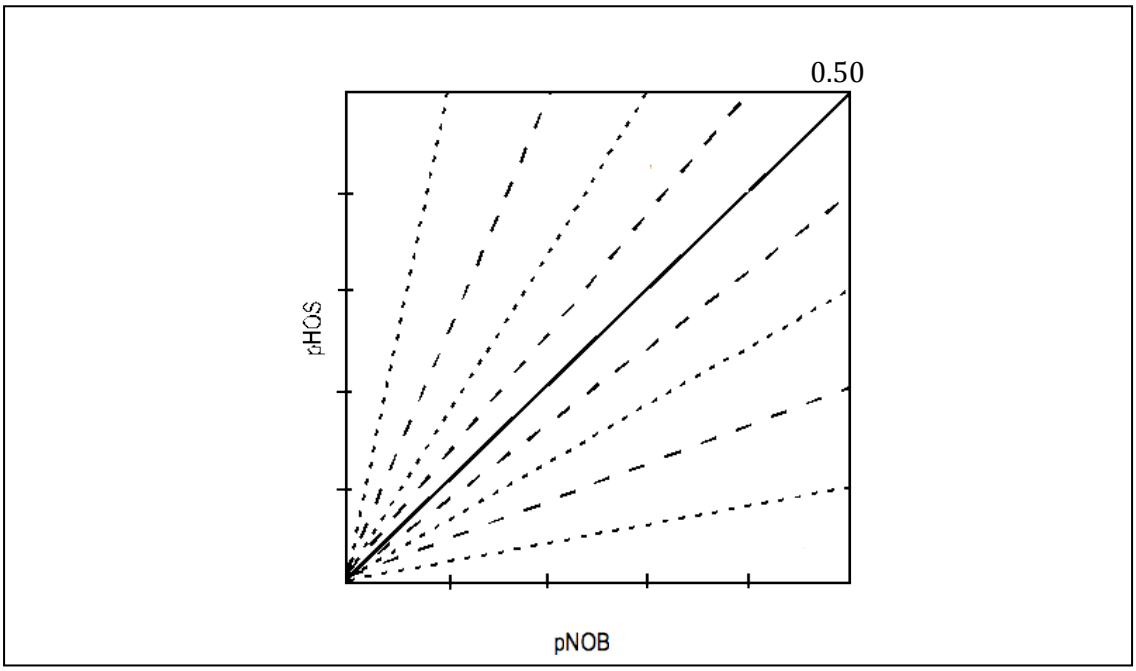


Figure 3.29: Proportion of Natural Influence (pNI) based on the relationship between percent Hatchery Origin Spawners (PHOS) and percent Natural Origin Broodstock (pNOB). The numbers on the outside of the graphic represent the pNI score.

The relative influence of pNI on diversity (expressed as a change in fitness) increases substantially as hatchery operations progress for several generations. In general, the longer fish stay in a hatchery environment rather than in a natural environment, the greater the change in fitness. Short of eliminating hatchery fish from a basin, incorporating natural origin fish into hatchery broodstocks, while minimizing hatchery strays onto the natural spawning grounds provides the highest pNI (Figure 3.29). While using natural-origin fish as broodstock is desirable, it should be noted that "mining" natural populations can result in other diversity concerns: direct selection of temporal portions of the run, or severe reductions in the effective size of the natural spawning population.

A decline in fitness will lower productivity with predictable consequences for the viability of the population. Restoring fitness (local adaptation) is likely be a protracted process, depending on whether hatchery effects can be removed or the influence of hatchery rearing reduced substantially (by placing a larger portion of the population in the wild and/or making hatchery conditions more similar to natural conditions or reducing the duration of hatchery rearing). Furthermore, the more extreme the loss in fitness the more likely that some genetic variation (locally adapted alleles) will be lost completely, making a return to pre-hatchery conditions very difficult.

For those populations where it is possible to estimate a long term pNI value, the loss in fitness can be converted to a Diversity Score for domestication. Few populations have been sufficiently monitored to provide accurate estimates of pNI. Additionally, the relatively recent advent of mass marking requires that estimates of hatchery stray rate and NOB introgression be used. For hatchery programs initiated prior to 1950, many researchers (see Wallis 1961, 1963 regarding Upper Willamette River hatcheries) have assumed that there was a minimal return of hatchery fish and hatcheries were simply mining the natural populations (this may be especially true of steelhead

and coho programs that historically released fish at a very small size). If hatchery survival was historically poor (prior to improvements in feed and rearing protocols), the accumulated decline in pNI and fitness may not be as dramatic as might be estimated assuming UWR hatchery-produced adults returned at current smolt to adult survivals, around 0.5 to 1.5% (see Appendix 3.1). While most salmon and steelhead hatchery broodstocks have been founded and maintained from a variety of sources, in general, transfers within the Upper Willamette River spring-run Chinook salmon ESU have been among populations within the same region. Winter-run steelhead programs in the Upper Willamette River were terminated in the 1990s.

In computing the pNI measure it may be necessary to make a number of assumptions. For many hatcheries that are operated as "isolated" programs the pNI would be near 0 (due to pNOB being 0). It is assumed that isolated programs experience some genetic "leakage" (natural origin fish taken in at the hatchery trap) and a pNI of 0.1 is assumed. Hatchery estimates of pNOB are seldom available. Additionally, where hatchery programs have been dramatically modified or terminated there can be a considerable variation in the pNI over time. The rate will depend on the intensity of selection in the natural environment and the "intactness" of genetic variation in the population. For example, ODFW suspended winter-run steelhead artificial production in the Upper Willamette River in the late 1990s. Monitoring over the next several years should provide valuable information on the recovery rate for local adaptation. This recovery might be reflected in increasing productivity if environmental variability can be accounted for.

In addition to the fitness-derived population persistence score for diversity described above, the TRT developed a simplified scoring metric, based solely on pHOS, the proportion of hatchery-origin fish spawning naturally. It requires a general understanding of the hatchery broodstock origins and annual estimates of pHOS. Where pHOS varies over time, a running average can be computed. pHOS can be influenced by improvements in hatchery homing efficiency by HORs, or by improvements in naturally-spawning NOR productivity. pHOS can also be directly managed in those cases where returning hatchery-origin adults are returned to the river (recycled) for additional sport harvest opportunities. In developing scenarios for SLAM models, it was decided that improvements in the VSP artificial propagation diversity score would be directly influenced by improving the efficiency of hatchery returns and the contribution of NORs to the hatchery broodstock; in the case of the McKenzie River from hatchery returns improved from 82% to 90%, and NOR contribution to the hatchery broodstock would be increased from 1.8% to 5% of the NOR return to the river. When combined with improvements in fish passage (to 72%) at Cougar Dam (and the resulting increase in NORs) the pNI for the McKenzie River populations increases from 31.1% to 91.5%, and pHOS decreases from 19.3 to 2.7%. When pNI is greater than 50%, there is a net improvement in local adaptation in the population. Therefore, the VSP score for pHOS is evaluated differently when the pNI is greater or less 50% (Figure 3.30).

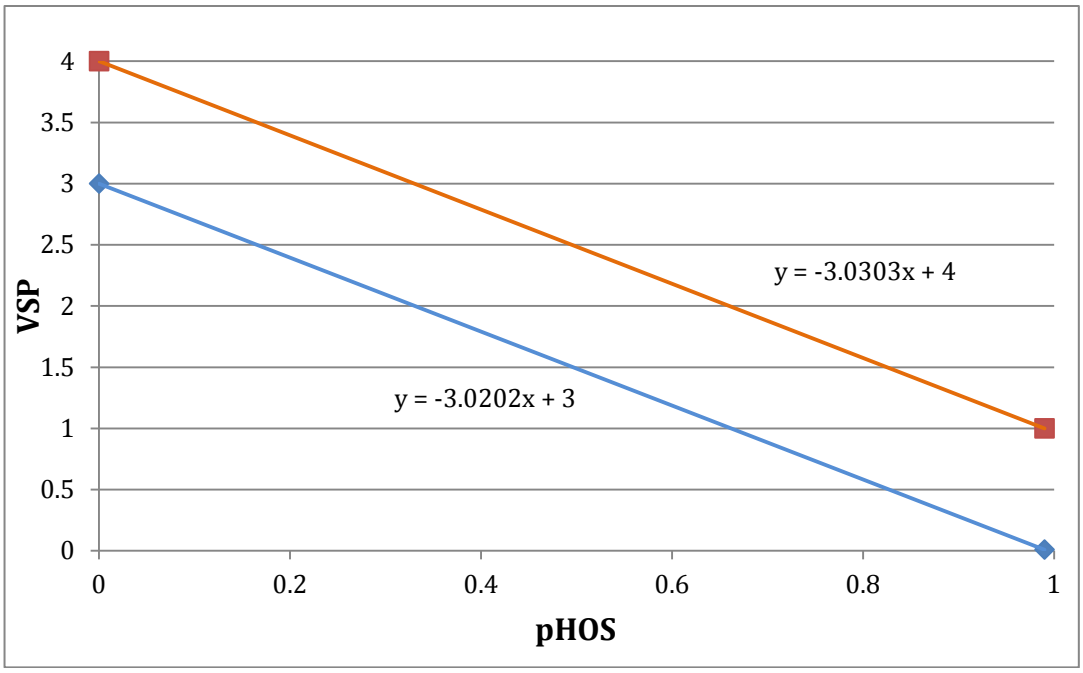


Figure 3.30: Diversity persistence score criteria for populations with different proportions of hatchery-origin spawners (pHOS). Data points are from the UWLCR TRT scoring table (McElhany et al. 2007). The blue line (low pNI) and red line (moderate pNI) describe degree of similarity between hatchery and natural components, for low the pNOB < pHOS (pNI<0.5), for moderate pNOB > pHOS (pNI>0.5).

Other Diversity Metrics

The TRT developed a number of other metrics to evaluate diversity in Upper Willamette River Chinook salmon and steelhead populations. Some of these metrics, genetic variation for example, cannot be derived from the SLAM analysis. Others, such as harvest rate, may influence abundance but not diversity in any substantial way[32]. Many of the other life history traits identified by the TRT as potential criteria for assessing diversity cannot be derived from the existing SLAM model. Out-of-ESU hatchery stray rates are low, especially given the relatively high rate of occurrence of local hatchery strays on the natural spawning grounds. Our understanding of how many potential diversity criteria are related to environmental or demographic factors is not sufficiently informed to be useful in model development or VSP scoring. For the purposes of the SLAM model analysis, it may be largely sufficient to focus on the life history and hatchery outputs to provide a VSP diversity score. For the two diversity metrics described, the harmonic mean of the two metrics is calculated to derive the diversity score.

3.4.4. Spatial Structure

Spatial structure was assessed based on the application of basic principles developed by the TRT (McElhany et al 2007). Quantitative metrics address two of the key spatial structure issues: 1) total quantity of available habitat and 2) spatial distribution of accessible habitat. In addition,

[32] Harvest gear, other than gill nets, may not exert selection on a population's diversity. Seasonal openings may impose temporal selection, more so when the harvest is geographically and temporally near the place and time of spawning. Additionally, freshwater sport harvest only targets hatchery (adipose find clipped) fish and NORs are supposed to be released. In general, harvest effects on diversity are similar across the different scenarios and will have little effect on the relative performance of each alternative.

quantitative scores were adjusted based on qualitative considerations including habitat quality and life-stage specific spatial distribution. TRT spatial structure evaluations were primarily based on the evaluation of maps of accessible habitat developed in the Oregon WLC habitat atlas (Maher et al. 2005). These maps were developed using existing blockage databases and species-specific gradient thresholds. There was no consideration of habitat quality; the maps simply provide an estimate of where fish could go, not necessarily where the habitat can support fish or where fish currently are. In addition, the maps only address adult accessibility; they do not describe life stage specific habitat spatial distribution, such as the arrangement of habitat for juvenile rearing. Despite these caveats, the maps can provide useful information and as they were developed using a consistent protocol comparing current and historical potential distribution for the entire ESU/DPS (Figure 3.31). However, the UWLCR TRT did not rely solely on these maps and incorporated additional information in the final spatial structure evaluations.

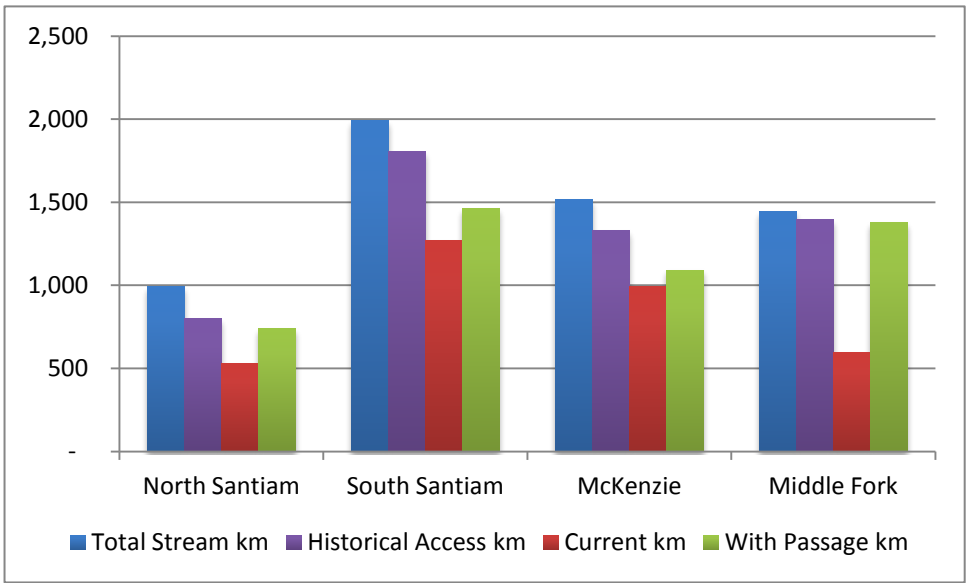


Figure 3.31: Total, historical, and accessible stream kilometers for spring Chinook salmon in Upper Willamette River tributaries (data from Maher et al. 2005).

3.4.4.1. Quantitative Metrics

A primary concern in evaluating spatial structure is whether a population has access to a sufficient quantity of habitat to survive catastrophic events. A viable population should not "put all its eggs in one basket"; for example, utilizing a single spawning reach. The TRT developed metric and threshold guidelines that are a function of both the amount of historically accessible habitat and the size of the watershed (all of the basins considered by the SLAM model fall within the Large watershed classification, except for the North Santiam). These thresholds (Table 3.23) are used in this current status evaluation. Historical accessibility is considered the appropriate reference value because the historic structure was assumed to be viable and the greater the deviation from the historical condition, the greater the risk. These guidelines are not based on any quantitative model, but rather on the professional judgment of the TRT at the time. The TRT included quantitative guidelines, not because they believed there is any quantitative precision in this assessment, but instead to provide a transparent presentation of how they view the relationship between the loss of habitat access and extinction risk.

Table 3.23: Guideline thresholds for relationship between persistence category and percent loss in accessible habitat. Watershed size categories: small <250 km², 250 km² < medium < 500 km², large > 500 km².

Persistence Category	Watershed Size		
	Small	Medium	Large
0	50-100	60-100	75-100
1	25-50	40-60	50-75
2	15-25	20-40	25-50
3	5-15	10-20	15-25
4	0-5	0-10	0-15

Another key consideration is the spatial distribution of habitat loss. The TRT hypothesized that loss of access to an entire stream branch poses a greater risk to a population than a number of smaller losses that would produce the same total amount of habitat lost. The relative size of a stream branch loss can be evaluated as the percent of loss caused by each blockage. We included the following guideline from the TRT viability report: If the largest single blockage results in a >10% loss for small watersheds or a >15% loss for medium and large watersheds, the persistence category is reduced by 0.5. For example, a persistence category 3 would become a 2.5. This metric addresses some of the aspects of the arrangement of the loss in space, but is not a complete evaluation. The natural dendritic structure or "branchiness" of a stream and the exact location of the blockage can also be important. This aspect of spatial structure is difficult to quantify and set a priori thresholds. Therefore, we applied a qualitative evaluation based on consideration of the actual access maps.

3.4.4.2. Qualitative Spatial Considerations

In addition to the two spatial structure metrics described above, we applied adjustments to the scores based on qualitative considerations: habitat quality and life-stage specific spatial distribution (Figure 3.32). For example, in the case of the North Santiam, the addition of habitat above Detroit Dam would result in a significant increase in absolute stream miles, but even more so with regard to a proportional increase in functional habitat.

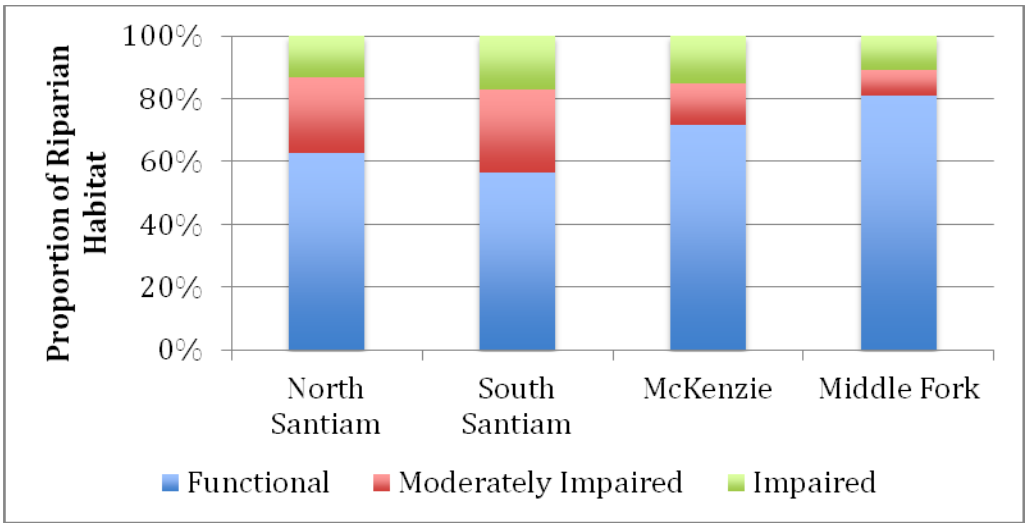


Figure 3.32: Riparian habitat condition and relative occurrence of habitat condition types in Upper Willamette River tributaries (data from Maher et al. 2005).

In addition to the overall condition of habitat in each basin, it is important to evaluate the distribution of those habitat condition types in the basin (Figure 3.33). In the case of the North Santiam Basin, the majority of the habitat above Detroit Dam consists of evergreen forest (Figures 3.34 and 3.35). Functional forest habitat is conducive to the establishment and maintenance of spawning and rearing habitat for Chinook salmon and steelhead. In most cases headwater regions of tributary basins in the Upper Willamette River will contain essential habitat types in moderate to good condition. For example, the spatial structure evaluation for the North Santiam spring-run Chinook salmon was described as follows:

> *Access to large portions of historically productive steelhead habitat has been blocked by Detroit Reservoir. ODFW estimates that 46% of the historically suitable habitat for steelhead is now inaccessible (ODFW 2005). The blocked areas historically included some of the most productive habitats in this system although productive habitat remains in the Little North Santiam River. The watershed score for spatial structure was further reduced to account for habitat declines in the remaining accessible habitat* (McElhany et al 2007, p. 33).

Efforts by the UWLCR TRT and ODFW to evaluate spatial structure in the Upper Willamette for Chinook salmon and winter steelhead considered many of the habitat quality issues discussed here. Differences between Chinook salmon and steelhead spatial structure scores were related to differences in preferential spawning and rearing habitat. Spring-run Chinook salmon prefer mainstem headwater areas for spawning, while winter steelhead spawn in a variety of mainstem and tributary habitats. VSP scores for spatial structure reflected these differences (Tables 3.24 and 3.25).

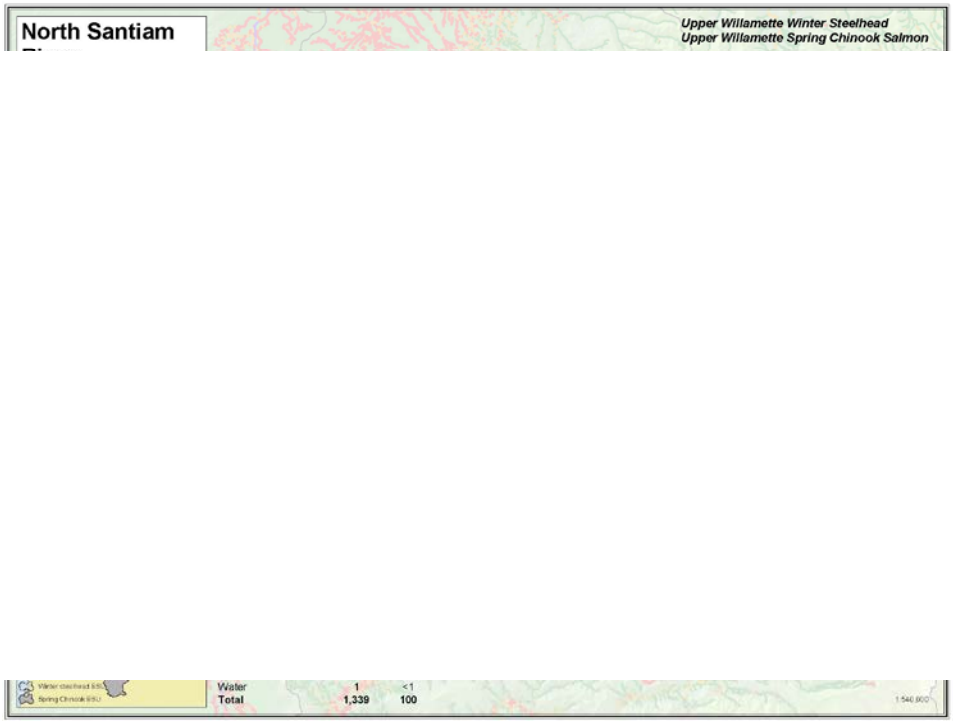


Figure 3.33: Map of the North Santiam River identifying relative levels of stream impairment. In evaluating Spatial Structure it is important to consider that much of the functional stream habitat is above the existing impassable dam (from Maher et al. 2005).

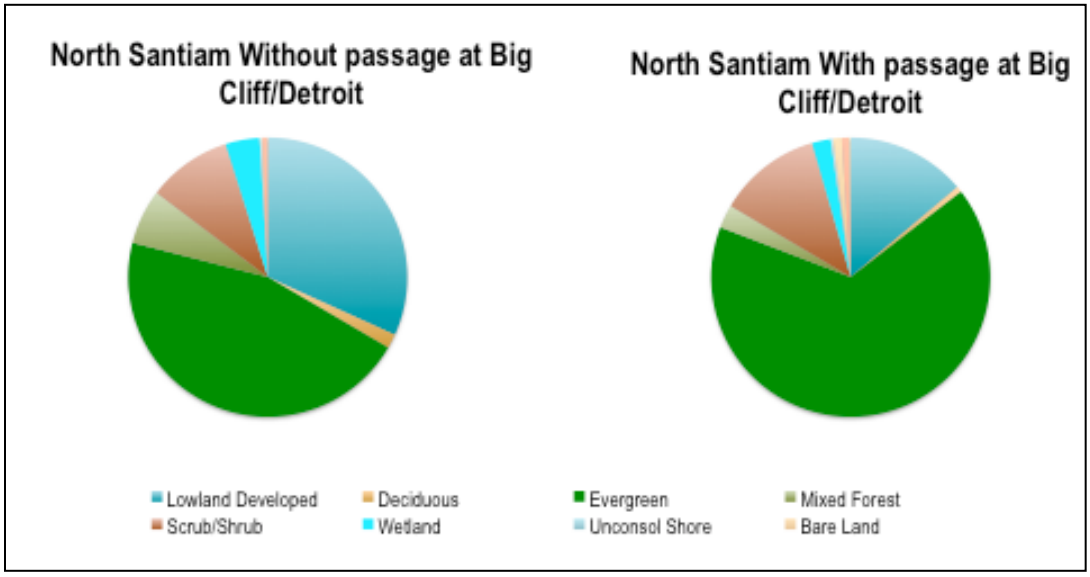


Figure 3.34: Habitat type distribution, as a percentage of total accessible area, in the North Santiam Basin based on fish access with and without passage at Big Cliff/Detroit dams (data from Sheer and Steel 2006).

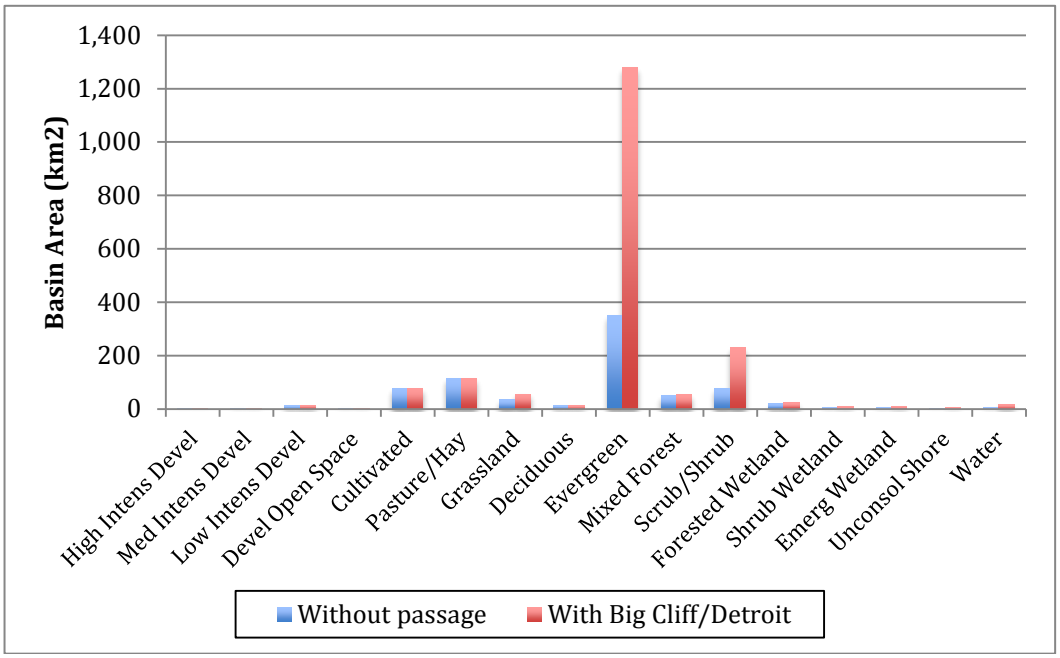


Figure 3.35: Habitat type distribution, area in km^2, in the North Santiam Basin based on fish access with and without passage at Big Cliff/Detroit dams (data from Sheer and Steel 2006).

Table 3.24: VSP spatial structure scores for spring-run Chinook salmon and winter steelhead demographically independent populations in the Upper Willamette River Basin (McElhany et al. 2007, ODFW and NMFS 2011). Scores are based on the proportion and quality of the habitat available above and below the dam and the sustainability (recruit/spawner (R/S) ratio) of the sub-population above the dam.

Upper Willamette	DIP	SS Score Passage (R/S<0.75)	SS Score Passage (0.75<R/S<0.95)	SS Score Passage (R/S>0.95)
Spring Run Chinook Salmon ESU				
	North Santiam (Detroit)	1.5	2.83	3.5
	South Santiam (Foster)	1.0	2.0	2.5
	South Santiam (Green Peter)[33]	2.5	3.17	3.5
	McKenzie (Cougar)	2.0	2.67	3.0
Winter Steelhead DPS				
	North Santiam	1.5	2.83	3.5
	South Santiam (Foster)	2.0	2.33	2.5
	South Santiam (Green Peter)	2.5	3.17	3.5

Table 3.25: VSP spatial structure scores for spring-run Chinook salmon demographically independent populations in the Middle Fork Willamette River Basin (McElhany et al. 2007, ODFW and NMFS 2011). Under some alternatives it is possible for the two reach above Dexter Dam (Middle Fork/North Fork [MF/NF] and Hills Creek [HC]) to have independent R/S ratios. The following matrix was developed to estimate the Spatial Structure score. Additionally, Spatial Structure scores are added independently accounting to R/S replacement above Fall Creek. Scores are based on the proportion and quality of the habitat available above and below the dam and the sustainability (recruit/spawner (R/S) ratio) of the sub-population above the dam.

		Reach E (HC)		
		<0.75	0.75<x<0.95	>0.95
Reach D (MF/NF)	<0.75	0.5	2.00	2.75
	0.75<x<0.95	2.0	2.5	3
	>0.95	2.75	3	3.5
Plus Middle Fork Willamette (Fall Creek)		+0.0	+0.33	+0.5

In general, the inclusion of areas above dams as part of the spatial structure was related to the ability of those areas to contribute to the viability of the population. If areas above barriers were able to maintain a spawner to spawner ratio of at least 0.75[34] (based on a 4-year, one generation average) at the conclusion of the time series (100 years), then that area would be included (see equation below). Thus, the magnitude of this inclusion would depend on the productivity of the habitat above the barrier and the passage efficiency of downstream juvenile passage and upstream adult passage.

[33] Where multiple dams are present – the Spatial Structure score assumes passage at the previously mentioned dam except for Middle Fork (see Table 15).

[34] The 0.75 level was set as a lower threshold rather than a 1.0 spawner to spawner ratio, because many populations (those without barriers) often maintain S:S ratios of less than 1.0 for several years. The intermediate level 0.75<SR<0.95, is meant to suggest a population in transition to becoming sustainable.

$$S/S\ Ratio = averge\ \frac{(NOR\ (above\ Dam))_{t+4}}{HOR(above\ dam)_t + NOR(above\ dam)_t}$$

3.4.5. VSP Scoring

The above sections outline the process of converting SLAM outputs into VSP compatible scores. Many of the SLAM parameters are based on population specific estimates. Other parameters represent estimates of various biological processes (i.e. hatchery domestication). Variability (error) estimates were included for a few parameters to provide some stochasticity to the results. Including error estimates for a large number of parameters had the effect of dampening overall variability (since on average the error estimates would tend to cancel one another out). The precision of any one VSP category score should be viewed with caution and relatively minor differences should be considered as non-significant. VSP scores should be viewed as relative metrics of the different passage/operations alternatives assessed compared to baseline conditions.

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Appendix 3.1. Ocean survival (harvest+escapement) for Chinook salmon released from Upper Willamette River hatcheries.

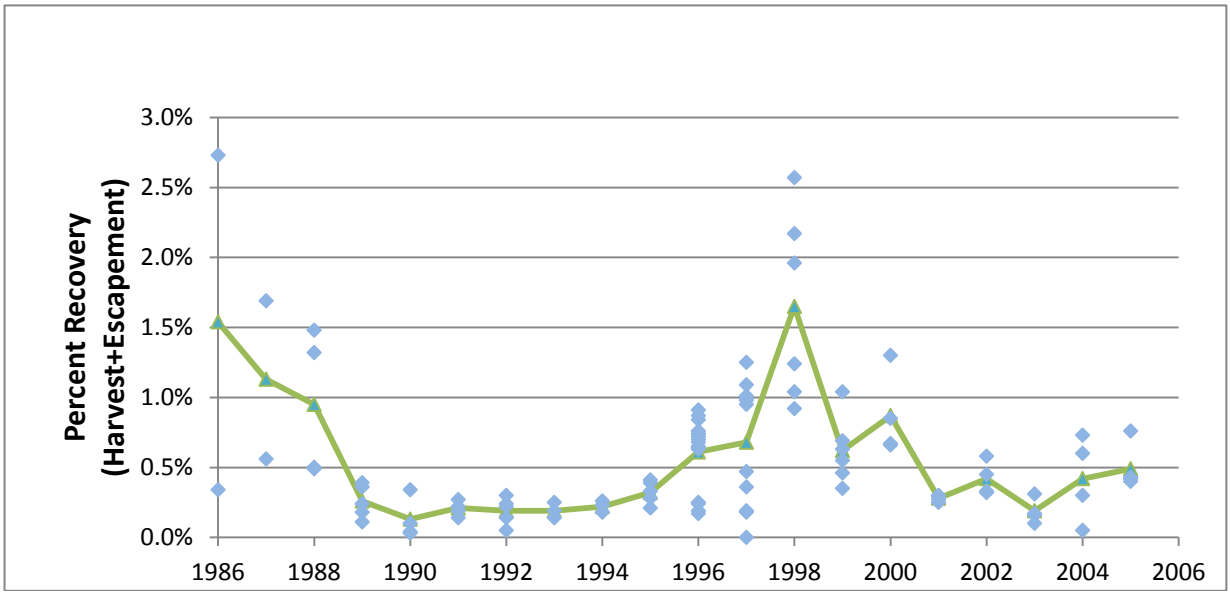


Figure 3.1-1: Percent recovery (smolt to adult) for spring-run Chinook salmon released from the McKenzie Hatchery into the McKenzie River, based on expanded CWT recoveries. Data from Regional Mark Processing Center (RMPC 2012).

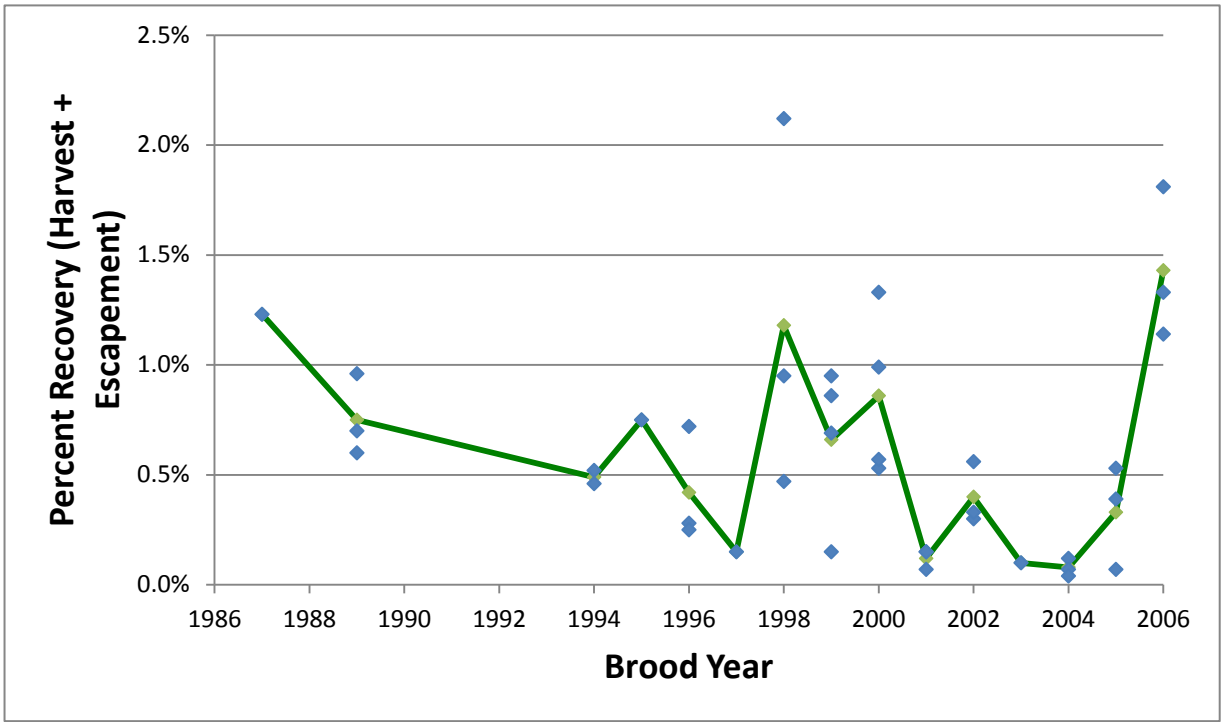


Figure 3.1-2: Percent recovery (smolt to adult) for spring-run Chinook salmon released from the South Santiam Hatchery into the South Santiam River, based on expanded CWT recoveries. Data from Regional Mark Processing Center (RMPC 2012).

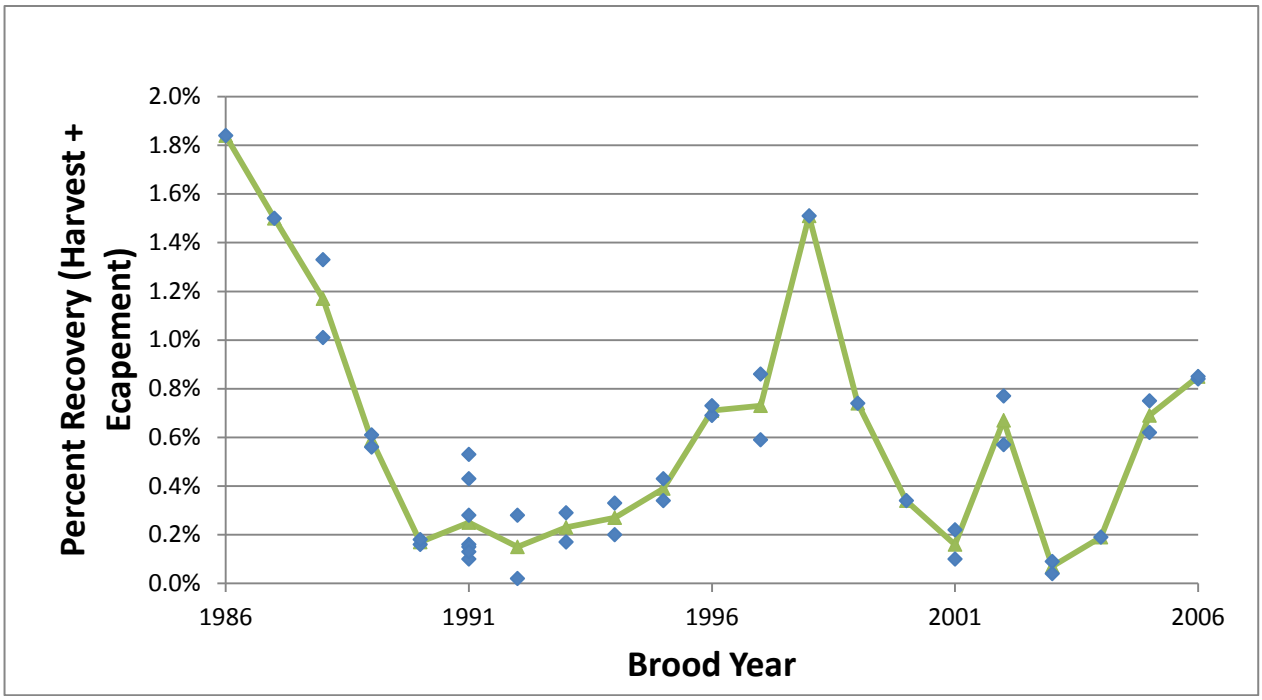


Figure 3.1-3: Percent recovery (smolt to adult) for spring-run Chinook salmon released from the Marion Forks Hatchery into the North Santiam River, based on expanded CWT recoveries. Data from Regional Mark Processing Center (RMPC 2012).

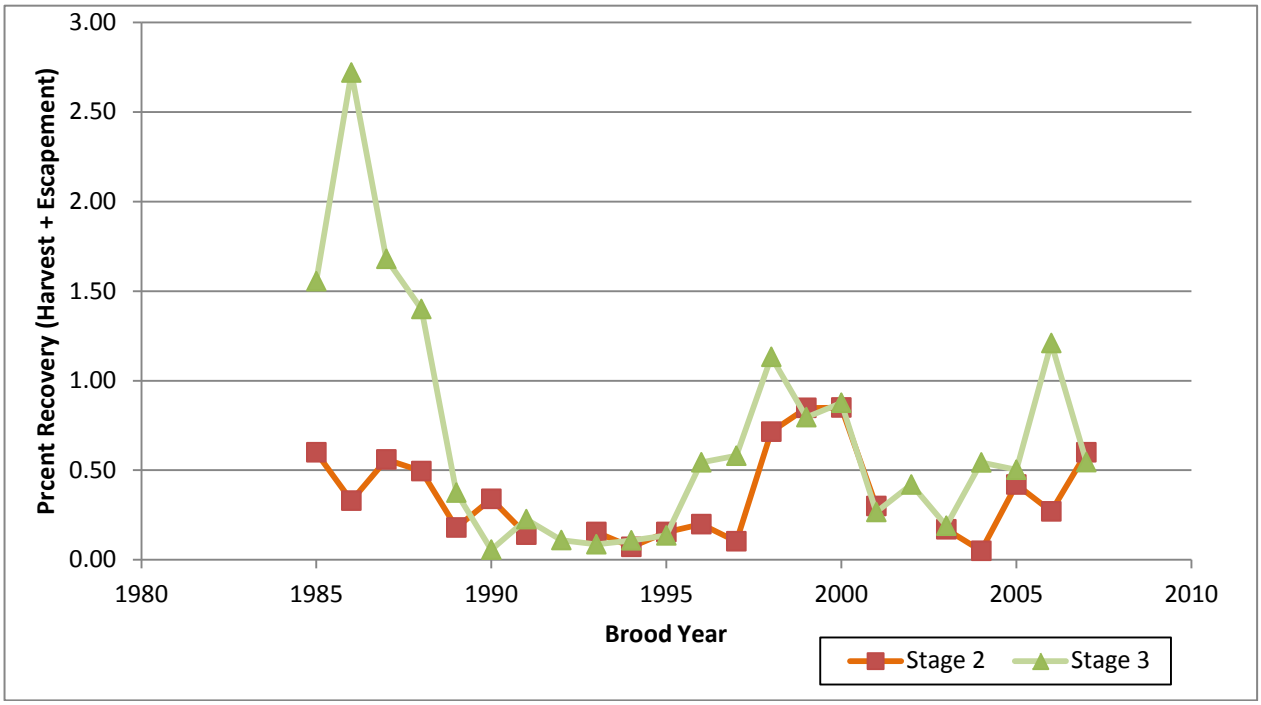


Figure 3.1-4: Percent recovery (smolt to adult) for spring-run Chinook salmon released from the McKenzie Hatchery, based on expanded CWT recoveries. Stage 2: Fall subyearling releases, Stage 3: Spring Yearling releases. Data from Regional Mark Processing Center (RMPC 2012).

Appendix 3.2. Distribution of habitat types in Upper Willamette River tributaries with and without passage at major barriers. Data from Sheer 2013.

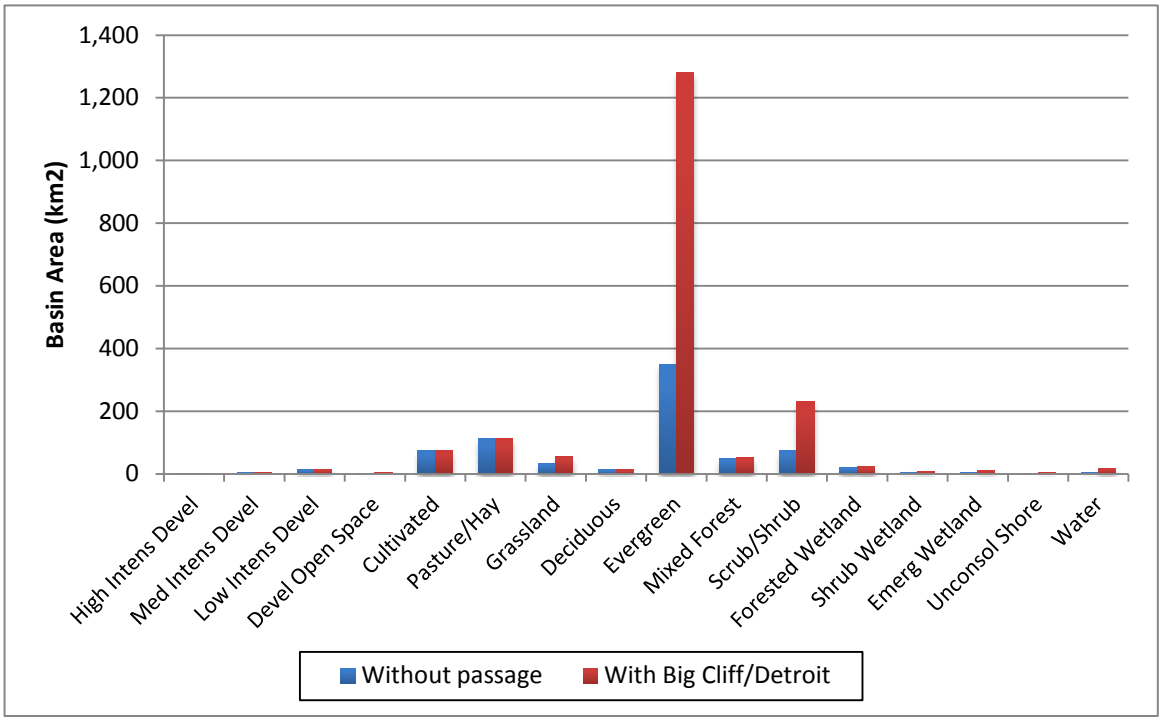


Figure 3.2-1: Habitat type distribution, area in km^2, in the North Santiam River Basin based on fish access with and without passage at Big Cliff and Detroit dams.

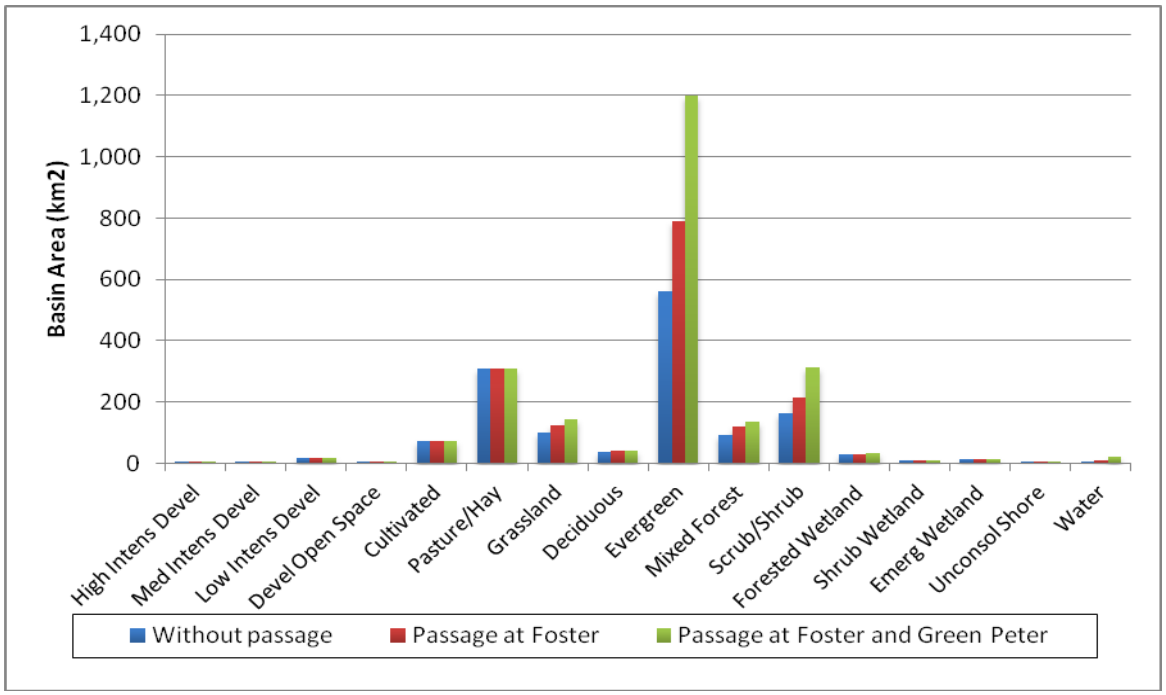


Figure 3.2-2: Habitat type distribution, area in km^2, in the South Santiam River Basin based on fish access with and without passage at Foster and Green Peter dams.

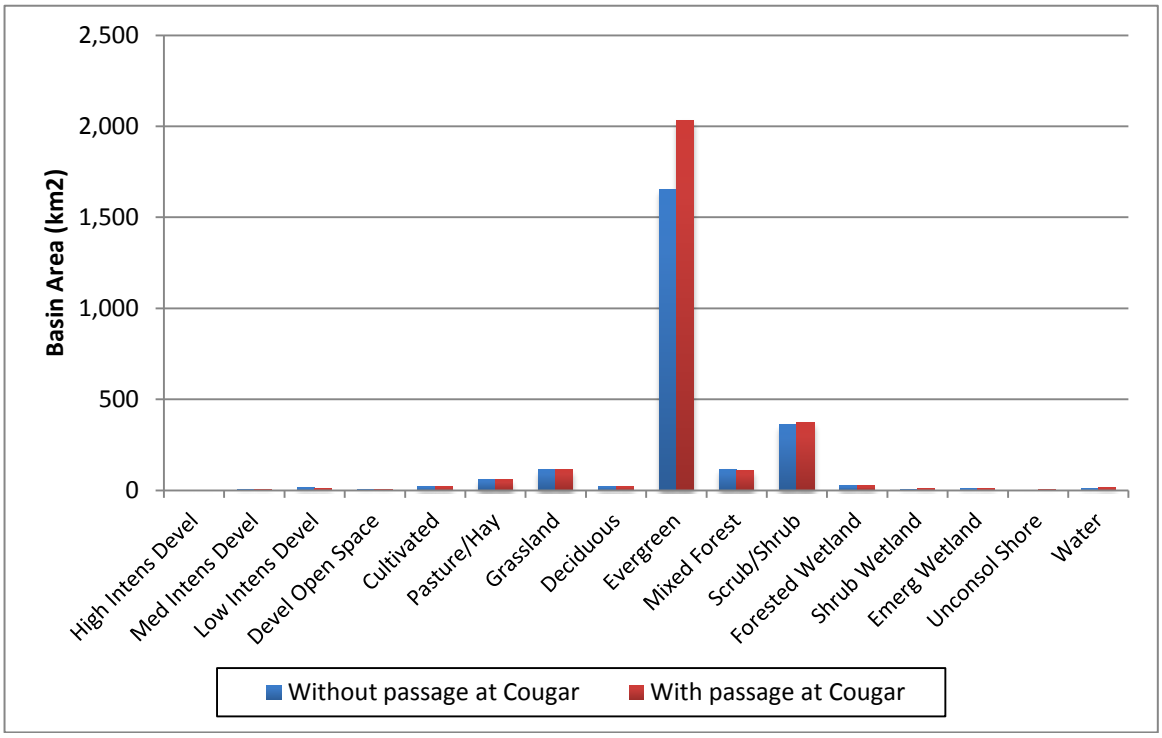


Figure 3.2-3: Habitat type distribution, area in km^2, in the McKenzie River Basin based on fish access with and without passage at Cougar Dam. Does not include areas above Blue River or Trail Bridge Dams.

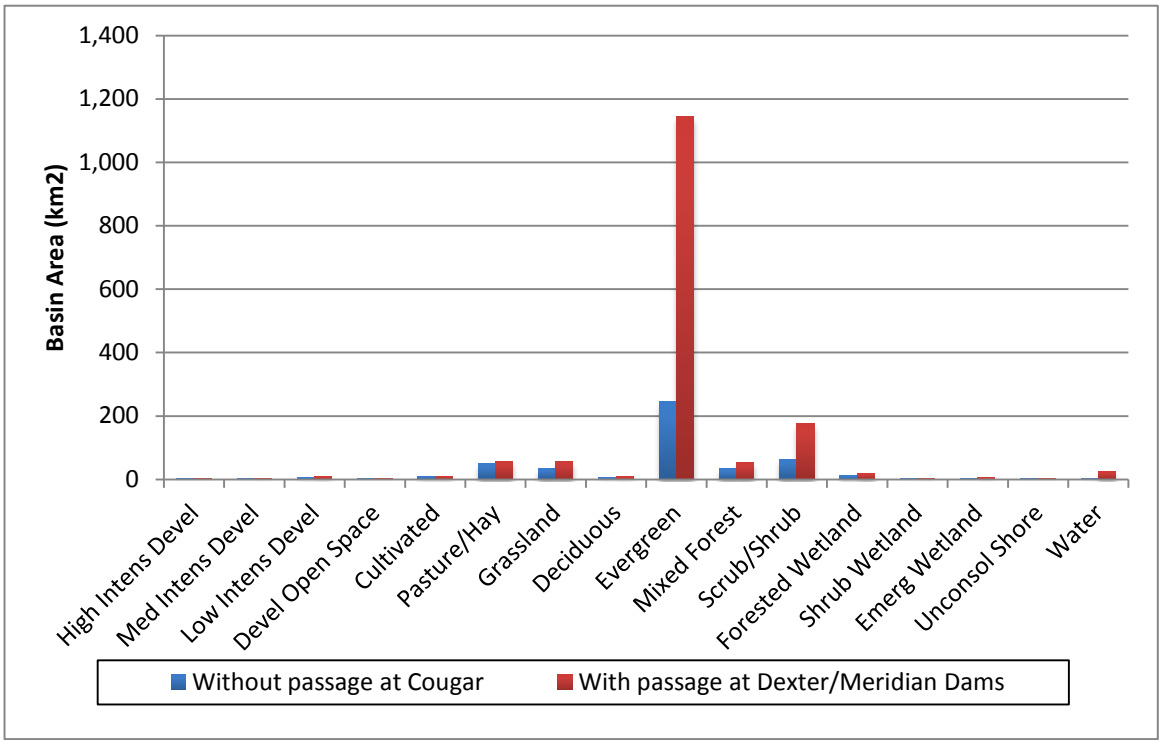


Figure 3.2-4: Habitat type distribution, area in km^2, in the Middle Fork Willamette Basin based on fish access with and without passage at Dexter and Meridian dams. Does not include habitat above Hills Creek or Falls Creek dams.

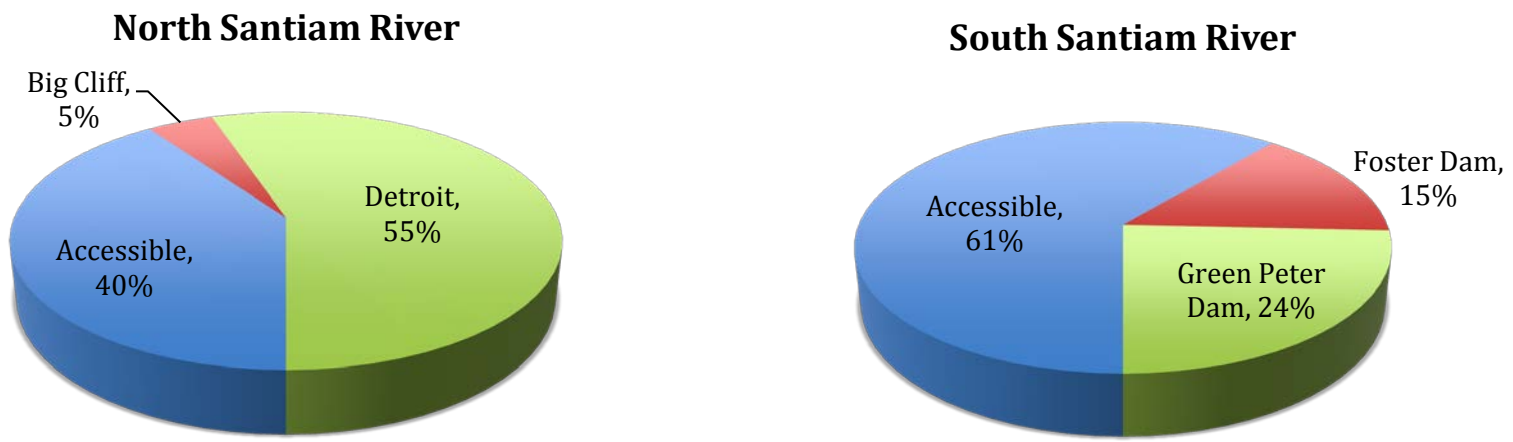


Figure 3.2-5: Distribution of watershed areas above and below barriers in the Upper Willamette River (Sheer and Steel 2006).

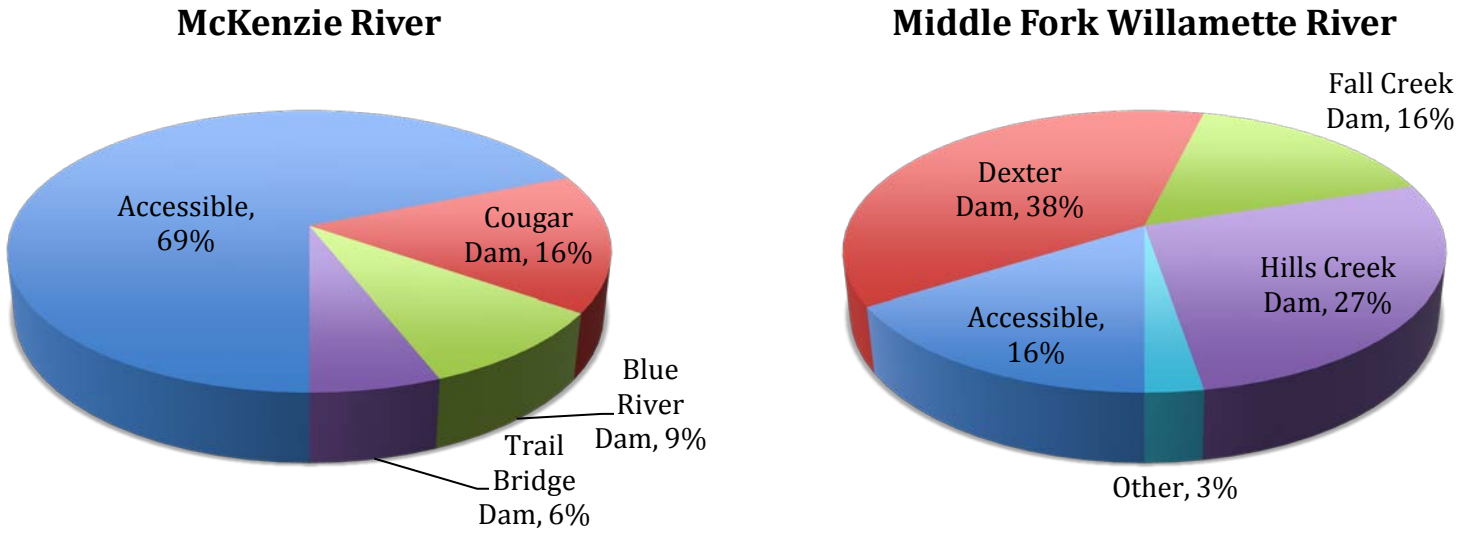


Figure 3.2-6: Distribution of watershed areas above and below barriers in the Upper Willamette River (Sheer and Steel 2006).

Appendix 3.3. Estimates of ocean and freshwater harvest rates (PSC 2012).

Appendix C.96. Percent distribution of Willamette Spring (Willamette River Hatchery) total fishing mortalities among fisheries and escapement.

	Estimated		AABM							ISBM													
Catch	# of	Ages	SEAK			NBC		WCVI		Geo St		Canada			WA/OR coast			Puget Sound		Terminal			
Year	CWTs	Present	Troll	Net	Sport	Troll	Sport	Troll	Sport	Troll	Sport	Troll	Net	Sport	Troll	Net	Sport	Net	Sport	Troll	Net	Sport	Esc.
1979	2296	3,4	Failed	Criteria	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-
1980	6096	3,4,5	5.0%	0.8%	0.2%	7.3%	0.1%	3.2%	0.0%	0.0%	0.0%	0.2%	0.5%	0.0%	0.7%	0.0%	0.8%	0.0%	0.0%	0.0%	0.3%	7.8%	73.1%
1981	8348	3,4,5,6	5.8%	0.4%	0.1%	7.0%	0.0%	1.6%	0.0%	0.0%	0.0%	0.5%	0.1%	0.0%	0.4%	0.0%	0.3%	0.0%	0.0%	0.0%	1.6%	10.5%	71.7%
1982	3963	3,4,5,6	5.8%	1.2%	0.2%	7.5%	0.1%	4.7%	0.0%	0.0%	0.0%	0.1%	0.4%	0.0%	1.3%	0.0%	1.9%	0.2%	0.2%	0.0%	6.9%	23.9%	45.7%
1983	2862	3,4,5,6	18.8%	0.1%	0.0%	13.0%	0.0%	2.0%	0.0%	0.5%	0.3%	0.3%	0.0%	0.0%	2.1%	0.0%	0.5%	0.0%	0.7%	0.0%	5.8%	20.1%	36.0%
1984	4160	3,4,5,6	4.9%	0.2%	0.4%	2.5%	0.1%	2.1%	0.0%	0.0%	0.1%	0.1%	0.1%	0.0%	1.1%	0.0%	0.0%	0.0%	0.2%	0.0%	6.5%	25.8%	55.8%
1985	2900	3,4,5,6	7.1%	0.2%	0.0%	0.5%	0.0%	0.5%	0.0%	0.0%	0.0%	0.2%	0.0%	0.0%	0.3%	0.0%	0.0%	0.2%	0.0%	0.0%	16.1%	27.2%	47.7%
1986	760	3,4,5,6	4.3%	0.4%	0.0%	7.2%	0.0%	6.1%	0.7%	0.0%	0.0%	0.7%	2.5%	0.0%	0.0%	0.0%	0.8%	0.0%	0.0%	0.0%	8.4%	20.5%	48.4%
1987	805	3,4,5,6	18.0%	0.0%	1.0%	15.0%	0.0%	1.4%	1.2%	0.0%	0.0%	1.1%	1.0%	0.0%	3.1%	0.0%	0.0%	0.0%	0.6%	0.0%	5.3%	23.5%	28.7%
1988	2163	3,4,5,6	12.0%	0.4%	0.6%	7.7%	0.0%	3.7%	0.0%	0.0%	0.0%	0.7%	0.0%	0.0%	2.5%	0.0%	0.2%	0.0%	0.0%	0.0%	6.9%	27.7%	37.5%
1989	2784	3,4,5,6	5.7%	0.0%	0.3%	2.2%	0.0%	1.7%	0.6%	0.0%	0.7%	0.0%	0.3%	0.0%	1.8%	0.0%	0.2%	0.0%	0.1%	0.0%	12.4%	20.4%	53.6%
1990	2822	3,4,5,6	10.1%	0.8%	0.3%	1.9%	0.4%	2.7%	0.7%	0.0%	0.0%	0.2%	0.6%	0.0%	1.5%	0.0%	0.1%	0.0%	0.0%	0.0%	16.0%	26.7%	38.0%
1991	3027	3,4,5,6	4.3%	2.0%	0.7%	2.1%	0.0%	0.4%	0.2%	0.0%	0.3%	0.0%	0.2%	0.0%	0.8%	0.0%	0.2%	0.0%	0.0%	0.0%	6.0%	42.7%	40.1%
1992	2879	3,4,5,6	7.1%	6.5%	0.2%	1.9%	0.2%	3.1%	0.2%	0.0%	0.0%	0.0%	0.2%	0.0%	2.7%	0.0%	0.4%	0.0%	0.6%	0.0%	5.3%	28.3%	43.2%
1993	5367	3,4,5,6	13.0%	0.0%	0.0%	1.5%	0.1%	1.6%	0.2%	0.0%	0.0%	0.0%	0.0%	0.0%	1.7%	0.0%	0.1%	0.0%	0.0%	0.0%	0.8%	42.0%	38.9%
1994	5050	3,4,5,6	5.8%	1.0%	1.1%	0.9%	0.1%	0.9%	0.0%	0.0%	0.0%	0.3%	0.2%	0.0%	0.2%	0.0%	0.1%	0.0%	0.1%	0.0%	5.0%	38.7%	45.7%
1995	4482	3,4,5,6	5.7%	0.3%	0.4%	1.3%	0.0%	0.5%	0.1%	0.0%	0.0%	0.0%	0.4%	0.0%	0.0%	0.0%	0.0%	0.0%	0.2%	0.0%	0.3%	43.6%	47.2%
1996	3728	3,4,5,6	2.4%	0.0%	0.0%	0.3%	0.0%	0.1%	0.0%	0.0%	0.0%	0.0%	0.1%	0.0%	0.1%	0.0%	0.0%	0.0%	0.1%	0.0%	0.8%	34.4%	61.7%
1997	2275	3,4,5,6	4.5%	0.0%	0.0%	0.7%	0.0%	0.0%	0.0%	0.0%	0.0%	0.0%	0.0%	0.0%	0.4%	0.0%	0.0%	0.0%	0.0%	0.0%	0.8%	16.4%	77.2%
1998	1592	3,4,5,6	5.8%	0.3%	0.3%	0.0%	0.0%	0.1%	0.0%	0.0%	0.0%	0.0%	0.0%	0.0%	0.1%	0.0%	0.0%	0.0%	0.4%	0.0%	0.4%	17.1%	75.6%
1999	1853	3,4,5,6	9.4%	0.0%	0.9%	0.0%	0.0%	0.0%	0.9%	0.0%	0.0%	0.0%	0.0%	0.0%	0.0%	0.0%	0.2%	0.0%	0.0%	0.0%	0.8%	14.6%	73.2%
2000	7121	3,4,5,6	14.2%	0.1%	1.0%	0.2%	0.8%	0.4%	0.4%	0.0%	0.0%	0.0%	0.0%	0.0%	0.3%	0.0%	0.3%	0.0%	0.0%	0.0%	2.3%	28.8%	51.0%
2001	35086	3,4,5,6	1.7%	0.0%	0.1%	0.1%	0.1%	0.5%	0.1%	0.0%	0.0%	0.0%	0.0%	0.0%	0.3%	0.0%	0.0%	0.0%	0.1%	0.0%	3.8%	24.6%	68.6%
2002	19966	3,4,5,6	2.3%	0.1%	0.1%	1.1%	0.1%	0.7%	0.1%	0.0%	0.0%	0.0%	0.0%	0.0%	0.9%	0.0%	0.3%	0.0%	0.0%	0.0%	15.6%	20.8%	58.0%
2003	6975	3,4,5,6	6.1%	0.0%	0.1%	0.5%	0.2%	2.6%	0.2%	0.0%	0.0%	0.0%	0.0%	0.0%	0.3%	0.0%	0.2%	0.0%	0.0%	0.0%	1.5%	16.2%	72.2%
2004	7087	3,4,5,6	3.9%	0.5%	0.1%	0.7%	0.0%	5.9%	0.0%	0.0%	0.0%	0.0%	0.0%	0.0%	1.8%	0.0%	0.0%	0.0%	0.0%	0.0%	6.3%	21.0%	59.7%
2005	3045	3,4,5,6	3.3%	0.0%	0.1%	0.3%	0.3%	5.7%	0.0%	0.0%	0.0%	0.0%	0.0%	0.0%	1.1%	0.0%	0.1%	0.0%	0.1%	0.0%	5.2%	16.2%	67.7%
2006	2009	3,4,5,6	4.3%	0.0%	0.0%	0.4%	0.8%	4.5%	0.0%	0.0%	0.0%	0.0%	0.0%	0.0%	1.4%	0.0%	0.0%	0.0%	0.3%	0.0%	7.9%	25.2%	55.0%
2007	1610	3,4,5,6	5.5%	0.3%	0.0%	0.0%	0.0%	1.4%	0.0%	0.0%	0.0%	0.0%	0.0%	0.0%	0.8%	0.0%	0.0%	0.0%	0.0%	0.0%	4.9%	18.6%	68.4%
2008	2266	3,4,5,6	1.9%	0.1%	0.1%	0.5%	0.0%	1.2%	0.0%	0.0%	0.4%	0.0%	0.0%	0.0%	0.2%	0.0%	0.0%	0.1%	0.0%	0.0%	20.3%	12.9%	62.3%
2009	4101	3,4,5,6	4.0%	0.0%	0.0%	0.3%	0.4%	0.9%	3.1%	0.0%	1.3%	0.0%	0.0%	0.0%	0.4%	0.0%	0.2%	0.0%	0.5%	0.0%	8.6%	20.1%	60.2%
2010	8797	3,4,5,6	4.1%	0.0%	0.3%	0.7%	0.4%	0.8%	0.1%	0.0%	0.0%	0.0%	0.0%	0.0%	2.9%	0.0%	0.3%	0.0%	0.2%	0.0%	5.3%	44.4%	40.4%
1979-2010	5354		6.7%	0.5%	0.3%	2.8%	0.1%	2.0%	0.3%	0.0%	0.1%	0.1%	0.2%	0.0%	1.0%	0.0%	0.2%	0.0%	0.1%	0.0%	6.1%	24.5%	54.9%
1979-1984	5086		8.0%	0.5%	0.2%	7.5%	0.1%	2.7%	0.0%	0.1%	0.1%	0.2%	0.2%	0.0%	1.1%	0.0%	0.7%	0.0%	0.2%	0.0%	4.2%	17.6%	56.5%
1985-1995	3004		8.5%	1.1%	0.4%	3.8%	0.1%	2.1%	0.4%	0.0%	0.1%	0.3%	0.5%	0.0%	1.3%	0.0%	0.2%	0.0%	0.1%	0.0%	7.5%	31.0%	42.6%
1996-1998	2532		4.3%	0.1%	0.1%	0.3%	0.0%	0.1%	0.0%	0.0%	0.0%	0.0%	0.1%	0.0%	0.2%	0.0%	0.0%	0.0%	0.2%	0.0%	0.7%	22.6%	71.5%
1999-2010	8326		5.1%	0.1%	0.2%	0.4%	0.3%	2.1%	0.4%	0.0%	0.1%	0.0%	0.0%	0.0%	0.9%	0.0%	0.1%	0.0%	0.1%	0.0%	6.9%	22.0%	61.4%

Appendix 3.4a. Basin and reach capacities (eggs) used in spring-run Chinook salmon SLAM models. Egg capacity was based on approximately 50% of the estimated historical adult spawning capacity (e.g. Parkhurst et al. 1950).

Tributary	Reach	SLAM Reach	Mean Capacity (eggs)	Adult Spawners (@ 2250 eggs)
North Santiam River				
	Blw Bennett Dam	A	300,000	133
	Btwn Bennett and MCF	B	5,000,000	2222
	Blw Detroit	A,B,F	5,800,000	2578
	Little North Santiam River	C	1,500,000	667
	Breitenbush River	D	6,000,000	2667
	Upper North Santiam	E	12,500,000	5556
	MCF to Detroit Dam	F	500,000	222
South Santiam River				
	Blw Lebanon Dam	A	150,000	67
	Thomas/Crabtree Creek	B	1,500,000	667
	Lebanon to Foster Dam	C	4,000,000	1778
	Wiley Creek	D	500,000	222
	South Santiam above Foster Dam	E	7,000,000	3111
	South Santiam	A,B,C,D,E	12,150,000	5400
	Quartzville Creek	F	2,000,000	889
	Middle Santiam River	G	4,500,000	2000
McKenzie River				
	Blw Leaburg Dam	A	1,250,000	556
	Above Leaburg Dam	B	8,000,000	3556
	Above Hendrick's Bridge	A,B	9,250,000	4111
	Above Cougar Dam	C	17,000,000	7556
Middle Fork Willamette River				
	Below Dexter Dam	A	150,000	67
	Lower Fall Creek	B	500,000	222
	Upper Fall Creek	C	2,000,000	889
	Fall Creek	B,C	2,500,000	1111
	Above Dexter/Lookout Pt Dams	D	20,000,000	8889
	Above Hills Creek	E	10,000,000	4444
	North Fork Willamette		20,000 adults	NA
	Upper Middle Fork		10,000 adults	NA

Appendix 3.4b. Basin and reach capacities (eggs) used in steelhead SLAM models. Basin-wide egg capacity was based on Chinook reach capacity (Appendix 3.4a above) and adjusted to a relative historical steelhead:Chinook salmon ratio (80% Smith, 1898). Within each basin allocation to specific reaches was based on observed redd distribution.

Tributary	Reach	SLAM Reach	Mean Capacity (eggs)	Adult Spawners (@ 2250 eggs)
North Santiam River				
	Blw Bennett Dam	A	50,000	22
	Btwn Bennett and MCF	B	3,000,000	1333
	Blw Detroit	A,B,F	3,300,000	1467
	Little North Santiam River	C	2,500,000	1111
	Breitenbush River	D	4,000,000	1778
	Upper North Santiam	E	10,000,000	4444
	MCF to Detroit Dam	F	250,000	111
South Santiam River				
	Blw Lebanon Dam	A	50,000	22
	Thomas/Crabtree Creek	B	1,500,000	667
	Lebanon to Foster Dam	C	2,500,000	1111
	Wiley Creek	D	1,500,000	667
	South Santiam above Foster Dam	E	5,000,000	2222
	South Santiam	A,B,C,D,E	11,050,000	4911
	Quartzville Creek	F	2,000,000	889
	Middle Santiam River	G	4,500,000	2000

Appendix 3.5. Historical estimates of Upper Willamette River salmon and steelhead escapement.

Upper Willamette River Spring-Run Chinook Salmon ESU

Historically, the Willamette River Basin provided sufficient spawning and rearing habitat for large numbers of spring-run Chinook salmon. The predominant tributaries to the Willamette River that historically supported spring-run Chinook salmon include the Molalla (RKm 58), Calapooia (RKm 192), Santiam (RKm 174), McKenzie (RKm 282), and Middle Fork Willamette Rivers (RKm 301)—all drain the Cascade Range to the east (Mattson 1948, Nicholas 1995). There are no direct estimates of the size of the Chinook salmon runs in the Willamette River Basin prior to the 1940s. Wilkes (1845) estimated that the fishery at Willamette Falls could yield up to 800 barrels (122,000 kg) of salmon. Collins (1892) reported that 16,874 salmon (303,732 lbs.) were shipped to Portland from the Willamette Falls fishery in April and May 1889. This estimate would not include tribal harvest or harvest that was shipped to markets other than Portland. McKernan and Mattson (1950) presented anecdotal information that the Native American fishery at Willamette Falls may have yielded 908,000 kg of salmon (100,000 fish @ 9.08 kg). Mattson (1948) estimated that the spring Chinook salmon run in the 1920s may have been five times the existing run size of 55,000 fish (in 1947) or 275,000 fish, based on egg collections at salmon hatcheries. Additionally, much of the early historical information on salmon runs in the Upper Willamette River Basin comes from state and federal hatchery reports.

Mattson (1948) provided estimates of the relative distribution of the spring-run Chinook salmon migrating over Willamette Falls. Apportioning historical returns (275,000) above the falls based on this distribution yields: Molalla River (5%) 13,750; Santiam River (34%) 93,500 or North Santiam River (60% of Santiam River total[35]) 56,100 and South Santiam River 37,400; Calapooia River (1%) 9,500; McKenzie River (40%) 110,000; and Middle Fork Willamette River (21%) 57,750. In addition, there are a number of estimates for historical run size on the Clackamas River. Smith (1895) estimated that 140 tons (12,302 fish) of Chinook salmon were caught in the Clackamas River between April and May of 1893. Much of the run would have already passed upstream in February and March (potentially as much as 50%). If we assume that intensive net fisheries can catch 50 to 75% of the run, an estimate for the Clackamas River spring run Chinook salmon run would range from 32,805 to 49,208. The total estimated historical run for the Upper Willamette River spring-run ESU would be around 325,000.

Upper Willamette River Winter Steelhead ESU

The same flow conditions at Willamette Falls that only provided access for spring-run Chinook salmon also provided an isolating mechanism for this unique run time of steelhead. Late-run winter steelhead enter the Willamette River beginning in January and February, but do not ascend to their spawning areas until late March or April (Dimick and Merryfield 1945). Spawning takes place from April to the first of June. Redd counts for late-run winter steelhead in the Willamette River Basin are conducted in May (Howell et al. 1985). It is generally agreed that steelhead did not historically emigrate farther upstream than the Calapooia (Calapooya) River (Dimick and Merryfield 1945, Fulton 1970). Historically, the character of the Willamette River at Albany changed from a highly braided, relatively shallow system upstream, to a more centralized channel, deep-river system downstream (Benner and Sedell 1997). Returning winter steelhead may have found upstream passage difficult past the confluence of the Calapooia River, whereas spring-run Chinook salmon

1. Author's estimate.

(which delay final maturation until the late-summer/early fall) could hold in mainstem, or off-channel, habitat until passage upstream was possible. Stone (1878) reported that steelhead began arriving at the base of Willamette Falls around Christmas, but were most abundant in April. Additionally, the spawning peak was reported to be in May, with spawning complete by June.

There is limited information with which to estimate the historical abundance of steelhead in the Upper Willamette River. Smith (1898) reported that of the fish taken in the Willamette River (below the falls) the catch consisted of 50% Chinook salmon, 40% steelhead and 10% coho salmon. If the ratio described by Smith (1898) applies to steelhead then approximately 220,000 steelhead would have historically passed over Willamette Falls, based on the estimate of 275,000 spring run fish ascending the falls. Of the four major tributaries that currently and historically supported steelhead the North and South Santiam Rivers are thought to have been the major producers (USFWS 1948). Howell et al. (1985) reported that the relative distribution of steelhead spawning in the Upper Willamette River during the 1960s consisted of 8% in the Calapooia River, 57% in the Santiam River, and 35% in the Molalla River. Allocating the estimated escapement using this proportion yields: Molalla River 77,000; Santiam River 125,400 (North Santiam River (60% of Santiam River escapement) 75,240; South Santiam River (40% of Santiam River escapement) 50,160); and Calapooia River 17,600.

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Appendix 3.6. Work Group[36] parameterization of reservoir life history.

The work group's initial task was to define the three juvenile life-history stages used in the SLAM model. The stages were characterized by the timing of dam passage for each stage and the average fish size at the time of passage. While the temporal migration windows were based on hydrology and thought to be somewhat similar among basins, the size at age was believed to vary considerably among basins. Life-history specific passage timing and size at age characteristics for each basin (population) have important ramifications for survival in the Fish Benefit Workbook (FBW). A second task to address was how each of the passage alternatives might influence juvenile life history.

The three juvenile life-history stages were defined as:

Life History Stage[37]	**Timing at Dam**	**Size at Passage ***
Spring subyearling (aka Fry)	Dec to July (mostly to June)	60 mm
Fall subyearling	Aug to Dec	80-100 mm
Spring yearling	Jan to Jan (mostly to May)	>120 mm

Sizes were relevant to the South Fork McKenzie and North Santiam – presented as averages. Juveniles rearing in Fall Creek Reservoir, Lookout Point Reservoir, and Foster Reservoir were thought to be larger at similar stages.

To facilitate the discussion of juvenile life history trajectories, the Work Group developed a schematic of passage options that was incorporated into the SLAM model. The trajectory of juvenile fish passing through the dam structure was described by three stepwise parameters (Figure 3.6-1). Firstly, of the fish residing in the reservoir what proportion are available to pass through the dam (proportion x in Figure 1). This proportion represents those fish that actively or passively find themselves at the dam forebay or passage structure (also referred to as "available to pass"). Second, of the proportion x, a subgroup will actually enter a passage outlet (this proportion is the dam passage efficiency (DPE)), the remainder (1-DPE) will continue to rear in the reservoir until the next life stage with those fish that were not available to pass (1-x).

This approach was employed because the parameters for DPE and passage survival had already been established through the fish benefit workbook (FBW), thus the workgroup could more clearly focus on the proportion of each life history group that is available to pass. Also, the "recycling" of the 1-DPE proportion of those fish available to pass back into the reservoir resident group, to correct an assumption of the FBW:, that those fish that do not actually pass the structure die.

Conceptually, the development of "available to pass" proportions simplified the analysis of different scenarios by the workgroup. DPE estimates described the attractiveness of passage structures to fish, while the available to pass proportions were largely constant across scenarios, unless the scenario actively changed conditions throughout the reservoir.

[36] The Work Group consisted of biologists from BPA, NMFS, Oregon Fish and Wildlife, USACE, USFWS, and USGS, in addition to consultants for several of these agencies. Six meetings were held, with the composition of the group varying between meetings. Formal minutes were not taken.

[37] Life history stage identifies the age and size of the juvenile Chinook salmon at the time of dam passage – not the timing of ocean entry.

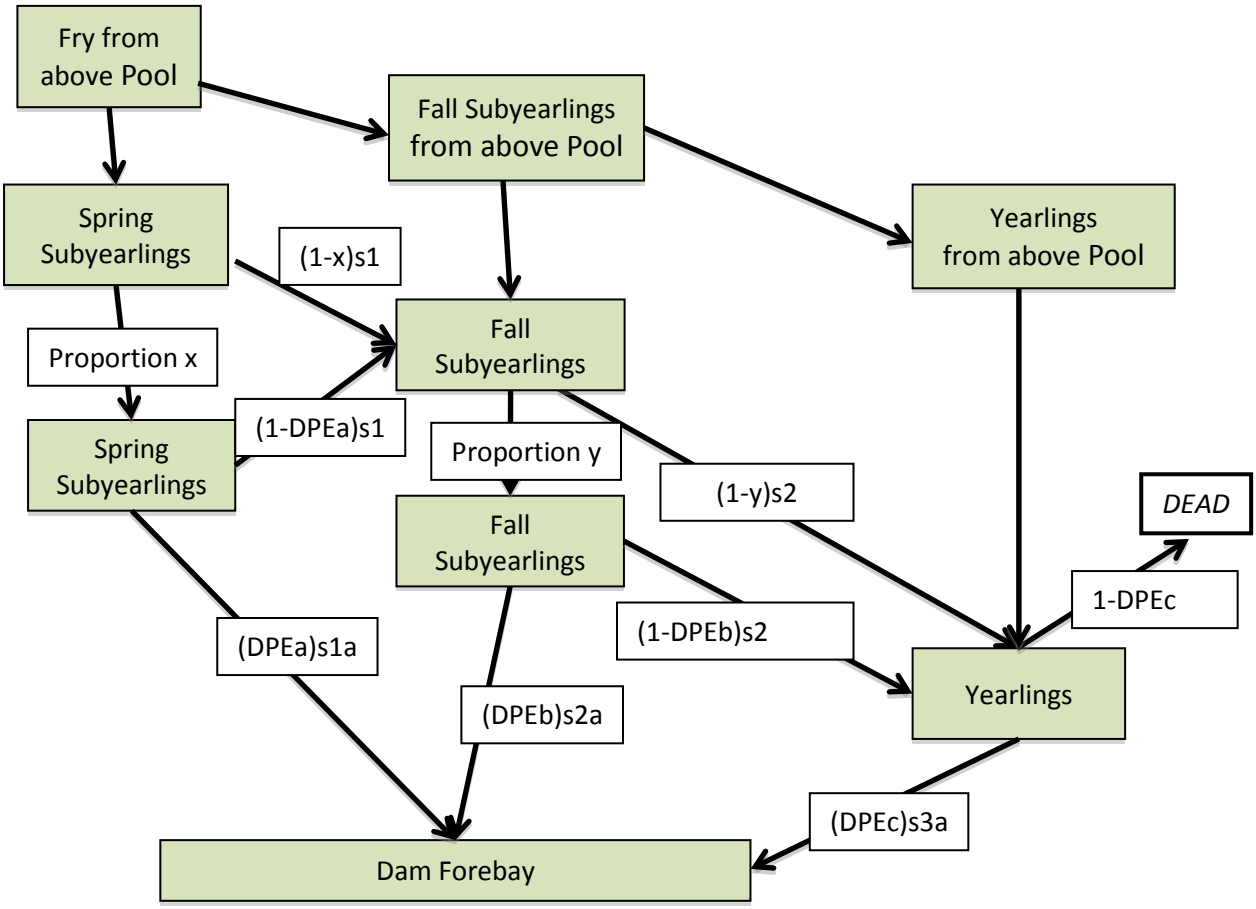
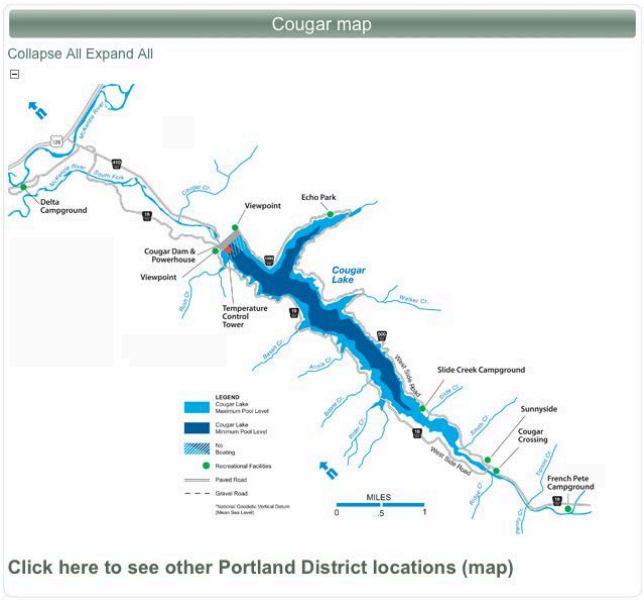


Figure 3.6-1: General schematic of life history trajectories for Chinook salmon passing through a reservoir and dam structure. Proportions x and y describe the fraction of the cohort that becomes available to pass the dam, dam passage efficiency (DPEa, DPEb, and DPEc) describes the fish that actually do pass (enter a passage structure) at each life history stage. S^1,S^2, and S^3 describe reservoir survival from 1. Spring subyearling to fall subyearling, 2. Fall subyearling to yearling, and 3. Yearling to yearling, respectively. . S^{1a},S^{2a}, and S^{3a} describe the in reservoir survival pending passing the dam (e.g. within the same life history stage).

McKenzie River



Cougar project data

Dam length	1,600 ft	487.7 m
Height	452 ft	137.8 m
Elevation (NGVD*)	1,700 ft	518 m
Lake length	6 mi	9.7 km
Area when full	1,280 ac	518 ha

*National Geodetic Vertical Datum

Figure from http://www.nwp.usace.army.mil

Of the Upper Willamette River populations, McKenzie River Chinook salmon are the most intensively studied. Cougar Dam provides both juvenile fish passage and temperature control. Much of the information related to juvenile life history strategies comes from screw trap work below Cougar Dam, juvenile trapping at Leaburg Dam, seining at Harrisburg, and sampling at Willamette Falls. Except where fish are specifically tagged (PIT tag or acoustic tag) it is not possible to separate Cougar-origin juveniles from those originating from those originating in the mainstem McKenzie River (for Leaburg Dam studies) or other basins (for Harrisburg and Willamette Falls samples). A drawback to these tagging studies is the fact that tags could only be put in larger hatchery-origin juveniles (> 65mm).

Proportions of Life History Stages Emigrating from the Reservoir

In determining the life history trajectories of juvenile fish in Cougar reservoir results from screw trap sampling below the dam proved most useful. The group opinion was that the proportion of spring subyearlings (fry) that left the reservoir to pass the dam was small (3 to 10%), similar to the DPE estimate from the FBW.

In determining the fate of subyearling fry that successfully pass Cougar Dam, there was some discussion about rearing capacities downstream of Cougar Dam and whether dam passage was indicative of a greater propensity to begin smoltification and emigration to the ocean. Based on Leaburg Dam juvenile sampling of paired release studies, spring subyearlings emigrating past the dam, ultimately entered the estuary/ocean as:

Spring subyearling (Fry)	10% (10-33%)
Fall subyearling	60% (40-60%)
Spring yearling	30% (10-30%)

Under baseline conditions a higher proportion of fall subyearling juveniles in the reservoir exited through the dam. Of these fish, 75-90% of the fall subyearling fish passing the dam continued moving to the estuary, while 10-25% continued rearing downstream of the dam until the yearling life history stage before moving to the estuary.

Fall subyearlings passing the dam, entered the estuary (pre-smolt) as:

Fall subyearling	75-90%
Spring yearling	10-25%

Reservoir Survival

Reservoir survivals were estimated using screw trap data from both head of reservoir and below Cougar Dam sampling sites. In general, because of the relatively cold conditions in the reservoir the growth of fish is slower than in other reservoirs, which results in juveniles being subject to predation for a longer interval. Overall, there was general agreement on an average reservoir survival from spring subyearling to fall subyearling of 20%, although this could vary annually from 15 to 30%. The survival from fall subyearlings to yearlings was lower (40-90%). The wide range of estimates provided by the workgroup was based in part on whether one was considering survival from midpoint in each of the temporal windows or over a minimum or maximum time span.

Alternate Scenarios

The discussion about the alternate scenarios focused on two basic biological questions. Did conditions in the reservoir change considerably enough under the scenario to alter the subsequent life-history trajectory of the juvenile fish? Did conditions below the dam change considerably enough to alter the life history trajectory of the fish? To the first question, the general consensus was no, the method of egress did not necessarily change the probability of a fish to rear or continue emigrating downstream. It was thought that the probability of fish finding the outlet did not change their life history. Alternatively, downstream flow conditions might stimulate outmigration behavior or simply move fish downstream. In all other cases, there was no change envisioned for any of the parameters in related to the juveniles moving through Cougar Reservoir or migrating below Cougar Dam.

North Santiam River – Detroit/Big Cliff Dams

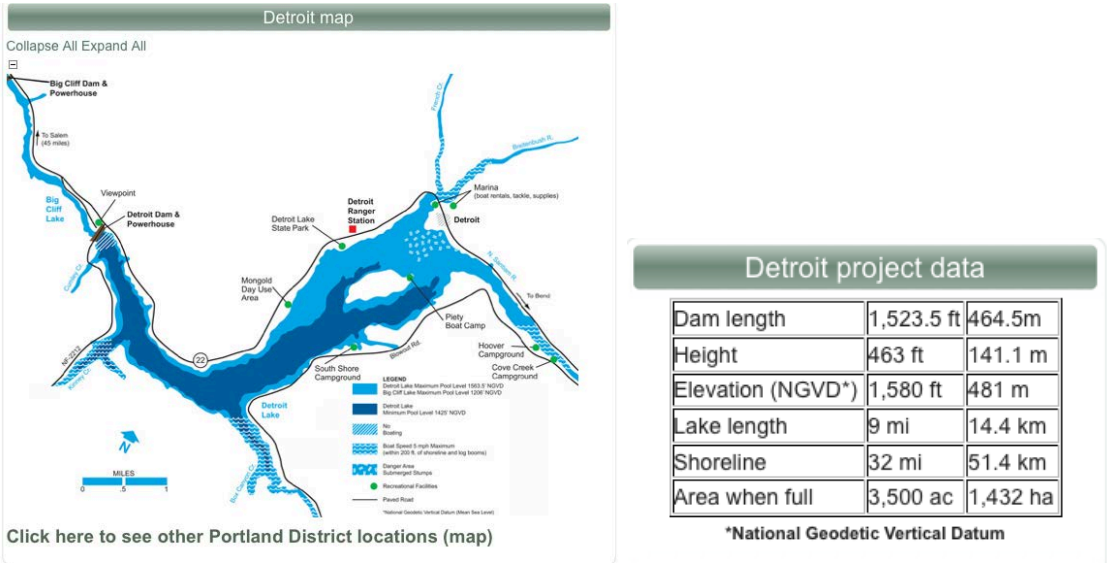


Figure from http://www.nwp.usace.army.mil

As a default, the parameters for reservoir survival, passage, and post-passage life history trajectories, were taken from values assigned to the McKenzie River (Cougar Reservoir). This was due, in part, to the relative availability of data for the McKenzie compared to the other populations in the Willamette Basin. The subsequent parameter assignments for the North Santiam and other basins was based on identified differences between Cougar Reservoir and the other reservoirs. In the case of Detroit Reservoir, it was thought that temperatures were slightly warmer overall. Fish were detected moving out of the Breitenbush River a month or so earlier than observed at the head of Cougar Reservoir (South Fork McKenzie River). Much of the available information related to fish movements in the North Santiam were acquired prior to the initiation of temperature control operations around 2009; therefore some caution should be used to applying older dam passage studies. Additionally, aside from the tailrace of Detroit Dam, there were no sampling stations downstream of the dam.

Proportions of Life History Stages Emigrating from the Reservoir

Based on the observation that very few spring-subyearling juveniles were sampled in screw traps below Detroit Dam, the group estimated that only 1-5% of the spring subyearlings in the reservoir would attempt to pass the dam. This was also based on low flow velocities in the reservoir, even at low conservation pool. Although the proportion of spring subyearling juveniles emigrating through Detroit Dam was slightly less than that determined for Cougar Dam, the proportion of fall subyearling juveniles attempting to emigrate was slightly higher 75-90%, with 10-25% remaining in the reservoir.

Life History Transitions Post-Dam Passage

It was suggested that the proportion of subyearlings continuing to migrate to the estuary post-dam passage would be higher in the Santiam River populations than in the McKenzie River, in part because of the differences in rearing conditions in the reservoir and the shorter distance from the mouth of the Santiam River to Willamette Falls. Additionally, it was suggested that poor rearing

conditions in the mainstem Willamette River downstream of the Santiam River mouth might induce juveniles to continue emigrating to the estuary. For spring subyearlings passing the dam, the work group determined that these fish ultimately entered the estuary (pre-smolt) as:

Spring subyearling (Fry)	20-50%
Fall subyearling	40-60%
Spring yearling	10-20%

Of the fall subyearlings that pass through Detroit Dam, the percentage that enter the estuary is:

Fall subyearling	70-80%
Spring yearling	20-30%

Reservoir Survival

In comparing juvenile survival in the Detroit Reservoir to Cougar Reservoir, several factors were considered. Predation mortality was thought to be higher overall in the Detroit Reservoir and predation effects were greatest for juveniles less than 100 mm, after which competition with kokanee and other fish might limit survival. Rainbow trout stocked in Detroit Reservoir were thought to prey on Chinook salmon fry, although this source was considered relatively small. Relative to juveniles in Cougar Reservoir, fish in Detroit Reservoir were exposed to high predation levels, but grew rapidly to a size where predation was less of an issue.

Survivals

Spring subyearling to fall subyearling: 15% (15-30%)
Fall subyearling to Yearling: 40-90%

Alternate Scenarios

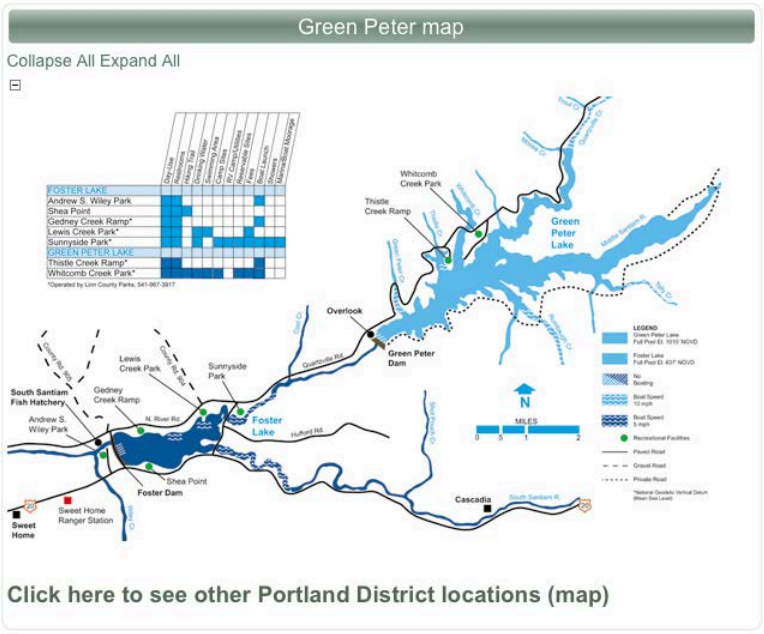
The discussion of conditions in Detroit Reservoir under different passage alternatives did not suggest that the method of egress changed the probability of a fish emigrating downstream. It was thought that the probability of fish finding the outlet did not change their life history. Alternatively, down stream flow conditions might stimulate outmigration behavior or simply move fish downstream. Specifically, the delayed refill operation might raise the proportion emigrating from 3-10% slightly to 6-15%. In all other cases, there was no change envisioned for any of the parameters in related to the juveniles moving through Detroit Reservoir or migrating below Detroit Dam.

Of the fall subyearlings that pass through Detroit Dam, the percentage that enter the estuary is:

- Fall subyearling (drawdown and delay refill scenarios): 75-85% compared to 70-80% (Detroit Baseline).
- Spring yearling: 15-25% compared to 20-30% (Detroit Baseline).

Other than these changes – there were no scenario-specific changes in the reservoir parameters.

South Santiam River



Foster project data

Dam length	4,565 ft	1,391.4 m
Height	126 ft	38.4 m
Elevation (NGVD*)	702.5 ft	214.1 m
Lake length	3.5 mi	5.6 km
Area when full	1,220 ac	493.7 ha

*National Geodetic Vertical Datum

Green Peter project data

Dam length	1,500 ft	457.2 m
Height	327 ft	141.1 m
Elevation (NGVD*)	941 ft	99.7 m
Lake length	10 mi	16.1 km
Area when full	3,720 ac	1,505.4 ha

*National Geodetic Vertical Datum

Figure from http://www.nwp.usace.army.mil

Foster Dam

Foster Reservoir is considered to provide good rearing habitat for Chinook salmon. In general, juveniles benefit from the warmer, more productive, waters in the reservoir and are slightly larger than those from other reservoirs in the Willamette Basin at the same age, with the exception of juveniles rearing in Fall Creek Reservoir. These conditions also provide good rearing habitat for those species preying on Chinook salmon juveniles. Additionally, the relative shallowness of the reservoir results in higher flow velocities which were believed to increase the likelihood of juveniles being able to find the egress point and be available to pass.

Proportions of Lfe History Stages Available to Pass from the Reservoir

The proportion of spring-subyearlings available to pass from the reservoir was considerably higher than that for other reservoir systems discussed, 0.60-0.90, even for baseline conditions. Juveniles in the reservoir exhibit rapid growth during their first spring, becoming more mobile in the reservoir (thus more likely to frequent a potential egress point). Although the proportion available was high, it was thought that DPE was limiting for passage through the dam. A similar situation exists for fall subyearlings. Growth is rapid and a high proportion of the fall-subyearling cohort is available to pass (0.35-0.80).

None of the alternate scenarios were thought to substantially affect reservoir conditions and therefore there was no change proposed for the proportions available to pass for both life stages. Differences in passage success for alternatives were thought to be more related to DPE.

Life History Transitions Post-Dam Passage

In determining the fate of subyearling fry that successfully pass Foster Dam, there was some discussion about rearing capacities in the lower South Santiam River. For example, it was thought that the lower gradient conditions below Foster did not provide quality rearing habitat for Chinook salmon; a further inducement to continue moving downstream. Rearing conditions in Foster Reservoir were thought to be good, generally better than in Cougar Reservoir, such that juveniles passing through the dam would be larger than their counterparts in other systems. This faster growth rate may be physiologically linked with parr/smolt transitions.

Based on downstream sampling of juveniles, spring subyearlings passing the dam, entered the estuary (pre-smolt) as:

Spring subyearling (Fry)	20-50%
Fall subyearling	20-60%
Spring yearling	10-20%

The discussion for fall subyearling life trajectories was similar to that for spring subyearlings, that Foster Reservoir produced larger juveniles that would be more likely to continue their outmigration after passing Foster Dam.

Fall subyearlings passing the dam, entered the estuary (pre-smolt) as:

Fall subyearling	80-100%
Spring yearling	0.0-20%

Reservoir Survivals

Predation was considered a major effect influencing juvenile survival in the reservoir. The relative benefits of good growing conditions were weighed against higher predation risks, ultimately the workgroup concluded that the survivals would fall within the range set for Cougar Reservoir juveniles. The work group provided a wide range of survival values, reflecting both uncertainty and annual variation.

The work group estimates of juvenile survivals for life stages in the reservoir were:

Spring subyearling to fall subyearling: 20% (15-30%)
Fall subyearling to Yearling: 40-90%

Alternate Scenarios

Alternatives primarily varied in the level of attraction to those fish that were available to pass; how likely the fish were to enter the passage structure. These differences are incorporated in the DPE estimates as part of the Fish Benefit Workbook.

Green Peter Dam

Green Peter Dam is located upstream of Foster Dam and intercepts flows from Quartzville Creek and the Middle Santiam River. Although fish passage facilities were included in the dam structure, passage operations were suspended several years ago (1988) and they are not currently being used. Therefore, there is limited documentation on the potential behavior and life history characteristics of fish residing in the reservoir. Studies in the 1970s (Wagner and Ingram 1973; Buchanan and Wade 1978) identified a number of issues with juvenile and adult passage in and out of Green Peter Reservoir. In addition to passage structure issues, conditions in Green Peter Reservoir are generally similar to other reservoirs behind high head dams.

Proportions of Lfe History Stages Available to Pass from the Reservoir

The proportion of spring-subyearlings available to pass from the reservoir was estimated to be very low, 0.01-0.05. The large size (both area and volume) of Green Peter Reservoir and the colder temperatures found in Green Peter likely limit the movement of spring subyearlings in the reservoir toward the dam forebay.

Conditions for fall subyearlings were thought to be more conducive to the juveniles becoming available to pass. By the fall juvenile fish are larger, more likely to be offshore in the reservoir, and generally more mobile. The workgroup estimated that a large proportion, 0.75-0.90, would be available to pass. In addition, autumn drawdown would provide better flow through conditions in the reservoir. None of the alternate scenarios were thought to affect reservoir conditions and therefore there was no change proposed in proportions available to pass for both life stages.

Life History Transitions Post-Dam Passage

Juvenile Chinook salmon that pass Green Peter Dam have very limited rearing opportunities available to them in the Middle Santiam River before entering Foster Reservoir. The SLAM model moves these directly into Foster Reservoir, where they are pooled with their appropriate life-history stage cohorts.

For those scenarios that collected juvenile fish at the head of the Green Peter Reservoir or at the Green Peter Forebay (floating surface collector) and transported them below Foster Dam the Foster Dam life history transitions for post-passage were utilized.

Reservoir Survivals

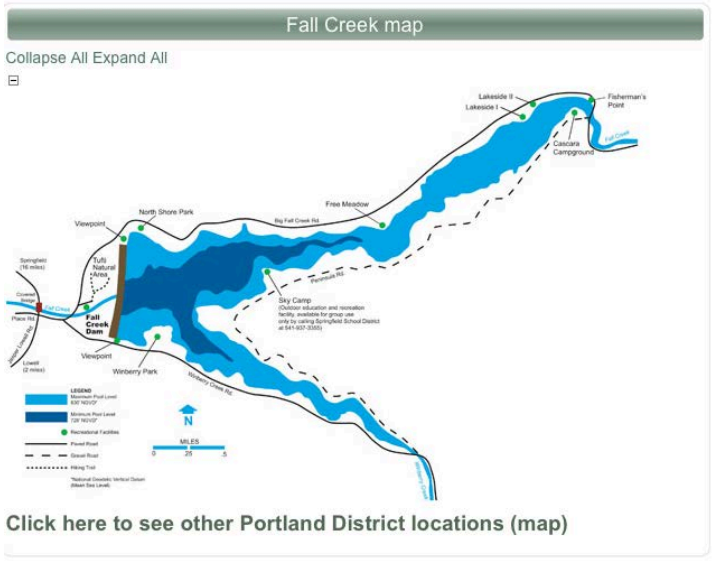
In general, the work group concluded that life-history stage survivals in Green Peter Reservoir were somewhat less than that for other basins. This was due to the colder, slower, growing conditions in the reservoir. Slower growth was thought to result in a protracted susceptibility to predation while in the reservoir.

Spring subyearling to fall subyearling: 20% (15-30%)
Fall subyearling to Yearling: 45-90%

Alternate Scenarios

Alternatives primarily varied in the level of attraction to those fish that were available to pass. These differences were incorporated in the DPE estimates.

Middle Fork Willamette River – Fall Creek Dam



Fall Creek project data

Dam length	5,100 ft	1,554.5 m
Height	180 ft	54.9 m
Elevation (NGVD*)	839 ft	255.7 m
Lake length	6.8 mi	10.9 km
Area when full	1,820 ac	736.5 ha

*National Geodetic Vertical Datum

Figure from http://www.nwp.usace.army.mil

The work group assessment for Fall Creek Reservoir juvenile Chinook salmon focused on the implications of the rapid juvenile growth observed in this large shallow reservoir. Juveniles readily reach 70-80mm by June of their first spring, and well over 100mm by the fall. Another factor considered by the work group was the prevalence of predators in the reservoir, although recent dam operations to maintain a low reservoir elevation during the winter effectively flushed many predators out of the reservoir. Lastly, the baseline scenario was parameterized under the assumption of a continued winter drawdown operation.

Proportions of Lfe History Stages Available to Pass from the Reservoir

In contrast to many of the other reservoirs assessed in the Upper Willamette Basin, the proportion of spring-subyearlings available to pass from the reservoir was considerably higher, 0.75-1.00, even for baseline conditions. There is apparently little rearing habitat in the upper riverine portions of the basin, so spring subyearlings by necessity move quickly to the reservoir. Once there, they exhibit rapid growth during their first spring, becoming more mobile in the reservoir (thus more likely to frequent a potential egress point). Fry migrants are observed below the dam in the late winter and early spring. Under the baseline scenario, the proportion of fry available to pass might decrease during the March to May refill when water flows (releases) are diminished, but increase again in June when flow conditions would be more conducive and the spring subyearlings would be considerably larger (80 mm). Under the delayed refill scenario, early spring flow at low reservoir levels would be extended, providing conditions that would increase the availability of juveniles at the dam forebay (0.90-1.00).

A similar situation exists for fall-subyearlings. Growth is rapid and with the current reservoir drawdown a large proportion of the fall-subyearling cohort is available to pass (0.95-1.00). Since the delayed refill only affects reservoir conditions in the spring, this increase in availability to pass the dam was only applied to the delayed refill scenario.

Life History Transitions Post-Dam Passage

It was suggested that the proportion of subyearlings would be higher in the Fall Creek sub-population than in the McKenzie (used as a default), in part because of the differences in rearing conditions in the reservoir. Flow conditions in the reservoir were likely to result in spring subyearlings passing out of the dam in the early spring at a very small size (< 50mm). Given that juveniles grow more rapidly in Fall Creek reservoir, it is likely that fall subyearlings will be physiologically more ready to move downstream after passing the reservoir.

Spring subyearlings passing the dam, entered the estuary (pre-smolt) as:

Spring subyearling (Fry)	15-35%
Fall subyearling	60% (40-65%)
Spring yearling	25% (10-30%)

Under the delayed refill scenario, the distribution was thought to be more similar to the McKenzie River (Cougar Reservoir) juveniles.

Of the fall subyearling that pass through Fall Creek Dam, the percentage that enter the estuary is:

Fall subyearling	85-100%
Spring yearling	0.0-15%

Reservoir Survival

In comparing juvenile survival in the Fall Creek Reservoir to Cougar Reservoir, several factors were considered. Predation mortality was thought to be higher overall, but growth rate was rapid, providing a size refuge. Under baseline conditions, the survival was thought to be slightly better than that for Cougar Reservoir, but the alternate scenario (delayed refill) was estimated to be similar to the Cougar Reservoir baseline.

Survivals

Spring subyearling to fall subyearling: 30% (20-45%)
Fall subyearling to Yearling: 35-80%

Delayed Refill Scenario

Spring subyearling to fall subyearling: 25% (10-40%)
Fall subyearling to Yearling: 35-80%

Middle Fork Willamette River – Dexter/Lookout Point Dam

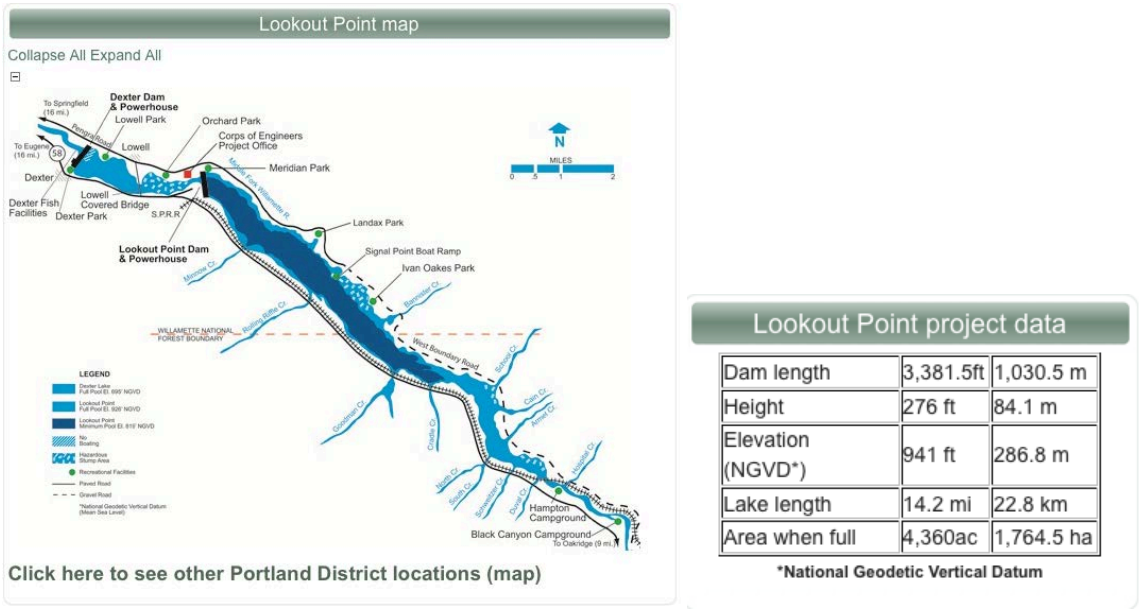


Figure from http://www.nwp.usace.army.mil

In comparing conditions in Lookout Point Reservoir with others in the Upper Willamette Basin, it was generally agreed that this reservoir was more similar to Fall Creek and Foster Reservoir. Growth potential for Chinook salmon juveniles was generally thought to be good. One unique characteristic of this reservoir system was the presence of juvenile rearing habitat in the North Fork of the Willamette River, such that perhaps 20% of the juveniles delayed moving into the reservoir until the fall, in contrast to the 0-10% for juveniles rearing above reservoirs in other basins. Additionally, juvenile residence time in the Dexter reservoir was not considered separately, but survival estimates for Dexter are included in the passage survival estimates in the FBW for Lookout Point Dam.

Proportions of Lfe History Stages Available to Pass from the Reservoir

In general, under baseline conditions relatively few spring subyearlings would be available to pass through exit structures. The work group concluded that between 0.05 and 0.15 of the fish would be available to pass. This proportion would be similar for the alternate scenarios, except the delayed refill alternative that would provide better flow conditions in the reservoir throughout much of the spring. In this case, the proportion was predicted to increase to between 0.10 and 0.30.

Growth potential from the spring to fall life stage periods was thought to be reasonably good, and therefore most of the subyearlings would be large enough to be available to pass (0.70-0.95). None of the alternate scenarios modified reservoir conditions sufficiently to alter life history trajectories from baseline.

Life History Transitions Post-Dam Passage

The work group could not identify any specific downstream conditions that would result in significant differences in the life history trajectories of juvenile Chinook salmon relative to other basins once they had successfully passed through the two dams.

Spring subyearlings passing the dam, entered the estuary (pre-smolt) as:

Spring subyearling (Fry)	10-30%
Fall subyearling	60% (40-65%)
Spring yearling	30% (10-30%)

Under the temperature-control scenario, the increase in summer temperatures due to surface withdrawal could encourage the fish do move farther downstream. Under this alternative the proportions changed slightly.

Spring subyearling (Fry)	10-40%
Fall subyearling	55% (30-60%)
Spring yearling	25% (5-30%)

Of the fall subyearlings that pass through Fall Creek Dam, the percentage that enter the estuary is:

Fall subyearling	70-80%
Spring yearling	20-30%

Reservoir Survival

Spring subyearling survival in Lookout Point Reservoir was thought to be relatively low, primarily due to predation. Fall subyearling survival was similar to that found in other reservoirs (primarily because the juveniles had grown beyond the size where they were susceptible to predation).

Survivals

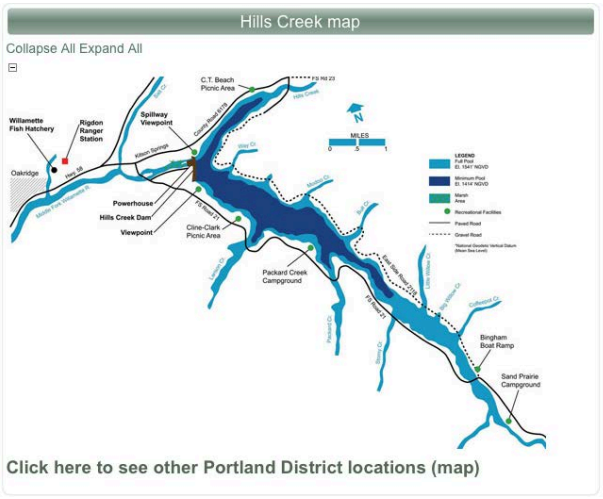
Spring subyearling to fall subyearling: 17.5% (10-40%)
Fall subyearling to Yearling: 35-80%

Delayed Refill Scenario

Under the delayed refill scenario it was thought that reservoir conditions would attract spawning northern pike minnows to areas away from where juvenile Chinook would be.

Spring subyearling to fall subyearling: 22.5% (10-40%)
Fall subyearling to Yearling: 35-80%

Middle Fork Willamette River – Hills Creek Reservoir Dam



Hills Creek project data

Dam length	2,235 ft	681.23 m
Height	304 ft	92.66 m
Elevation (NGVD*)	1,548 ft	471.8 m
Lake length	7.6 mi	14.72 km
Area when full	2,735 ac	1,106.8 ha

*National Geodetic Vertical Datum

Figure from http://www.nwp.usace.army.mil

There was limited discussion regarding the parameters to be used for Hills Creek Reservoir fish survivals and life history trajectories in the SLAM model. Hills Creek Reservoir was similar to other high head dam systems, in particular Cougar Reservoir. Monitoring downstream of Hills Creek Dam suggests that very few spring subyearlings pass through the dam. In the absence of specific estimates for Hills Creek Reservoir, Cougar Reservoir parameters were used.

Appendix 3.7. Temperature and Total Dissolved Gas Effects from Dam Operations

Temperature and total dissolved gas (TDG) levels can have a significant effect on survival at a number of life-history stages. Furthermore, dam passage alternatives can influence both temperature and TDG. Many of these effects on survival have not been widely studied and it was not possible to initially establish parameters. The work group was tasked with estimating the magnitude of temperature and TDG changes, and how these changes could affect survival. In most cases survival effects were presented as a range to underscore uncertainty and to test the sensitivity of changes in the parameters. Much of the workshop discussion was informed by the USACE report Assessment Results for Operational Measures – Appendix B, which provided estimates for both temperature and TDG impacts under different scenarios.

In the current version of SLAM, non-FBW survivals are not correlated with water year type (dry, normal, wet); therefore, adjustments to SLAM survivals were weighted by the occurrence of specific water years. For example, if there is a 3°C increase in temperature during dry years the survival change would be applied as a weighted average to a single survival parameter reflecting that the decrease in survival occurs in only dry years (approximately 20% of the water years). This averaging effect likely results in an underestimation of annual variability (since high and low survivals are likely correlated with water year). The workgroup also considered what proportion of the downstream reach(es) is affected, and at what point the effect is dissipated or diluted.

McKenzie Basin

Cougar Dam has a temperature control structure in place; therefore, in most cases there was no change from baseline temperature-related survivals. In many of the scenarios the Assessment Results for Operational Measures predicted slight rises in TDG, in most cases this amounted to an additional few days at just above the 110% exceedance level and was not thought to result in detectable changes in survival.

Of the alternatives where adjustments in survival were considered, the Drawdown through the RO (Alternative #4) was thought to produce an increase in TDG during the fall incubation period. This was related to the increase in flow through the RO.

In the Delay Refill scenario there was a likely increase in temperature, and in low (dry) water years this increase may be as high at 5°C (9°F). A temperature rise of this magnitude would accelerate incubation and likely result in a decreased survival due to emergence during less than optimal conditions. Based on the relative flow contribution of the South Fork McKenzie and the mainstem McKenzie River, the temperature effect may not carry far downstream into the mainstem. Assuming low water years occur at a frequency of 20%, and within McKenzie SLAM reach B 30% of the redds occur downstream of Cougar Dam, the temperature shift would result in a 5-40% decrease in survival. The range is relatively broad, underscoring the uncertainty in the effect on survival due to altered incubation timing. When the frequency of dry years and the proportion of Reach B affected are factored in, the absolute change in survival is not substantial, but still likely to produce detectable changes in abundance.

Normal survival in Reach B, McKenzie River: 0.425

Weighting—
Year type and frequency: Dry, 0.20
Proportion of Redds in Reach B affected: 0.30
Relative survival effect: 0.05 to 0.40
Absolute survival range: 0.255-0.404

New survival range:
High range: (0.425*(1-(0.2*0.3))+(0.404*(0.2*0.3)= 0.424
Low range: (0.425*(1-(0.2*0.3))+(0.255*(0.2*0.3)= 0.415

Equation Box 1: Computation of change in embryonic survival due to increase in temperature during incubation (resulting in an accelerated incubation/emergence timing).

North Santiam

Current emergence survivals (baseline) reflect operational temperature controls that have been in place since 2007. NOR returns to the North Santiam River from juvenile outmigrations beginning in 2007 have exhibited a nearly two-fold increase, at the same time that total NOR counts at Willamette Falls have been declining. It is also possible that similarly timed improvements to Bennett Dam and juvenile production from above Detroit Dam has contributed to this increase. Baseline parameters for North Santiam Chinook salmon survival in Reach B (below Detroit Dam) were set with recent operational temperature control as the default condition.

In general, temperature and TDG effects from alternate scenarios (structures and operations) were thought to have an impact on Reach F (Detroit Dam to Minto Weir) and Reach B (Bennett Dam to Minto Weir). Temperature changes were thought to exert an influence all the way to the mainstem Willamette River, although the effects would diminish with distance from the dam. TDG effects below Detroit Dam were thought to be dispersed quickly in the Big Cliff Reservoir, while below Big Cliff Dam elevated TDG levels were detected as far downstream as the Minto Weir (the entirety of Reach F).

The group thought it was useful to attempt to model operational temperature changes similar to temperature control structures. Assuming that operational controls produced temperature and TDG effects (both positive and negative) nearly equivalent to a Selective Withdrawal Structure (SWS). This was also thought to be important because many of the alternate scenarios included operational temperature controls. For Detroit Dam, operational temperature changes would result in warmer summer adult holding temperatures but lower egg incubation temperatures. Adult holding temperature increases would be on the order or 3 to 5°C depending on the water year and result in an overall 5°C reduction in incubation temperature. We applied the same basic equation used in the McKenzie alternate scenario with a relative improvement of 0.05 to 0.15 in survival, but affecting the majority of the redds in both Reach B and F (since redd distribution in Santiam River Reach B is disproportionately toward the upstream end of the reach). The range was selected because temperature improvements through operational changes were thought to be less effective than a structural temperature control mechanism.

Normal survival in Reach B, Santiam River: 0.400

Weighting—
Year type and frequency: All, 1.00
Proportion of Redds in Reach B affected: 1.00
Relative survival effect: +0.05 to +0.25
Absolute survival range: 0.405-0.50

New survival range:
High range: (0.5*1.00*1.00) = 0.500
Low range: (0.405*1.00*1.00) = 0.405
- Average 0.4525

Equation Box 2: Estimated average survival and range for egg to emergent survival for North Santiam River Reach B and F under operation temperature controls.

Under a selective withdrawal structure alternative, the temperature of water released would increase during adult holding (summer) period, but this would apparently not be significant enough to alter survivals. Temperatures during incubation would be decreased during wet and normal water years (80%) –the decrease may be 1-4°C, compared to the operational management scenario, with survival improving (5-20%) (Figure 3.7-1). These benefits would be in addition to the existing benefits of operational temperature management. Furthermore, there would be a decrease in TDG with the SWS in place (less spill).

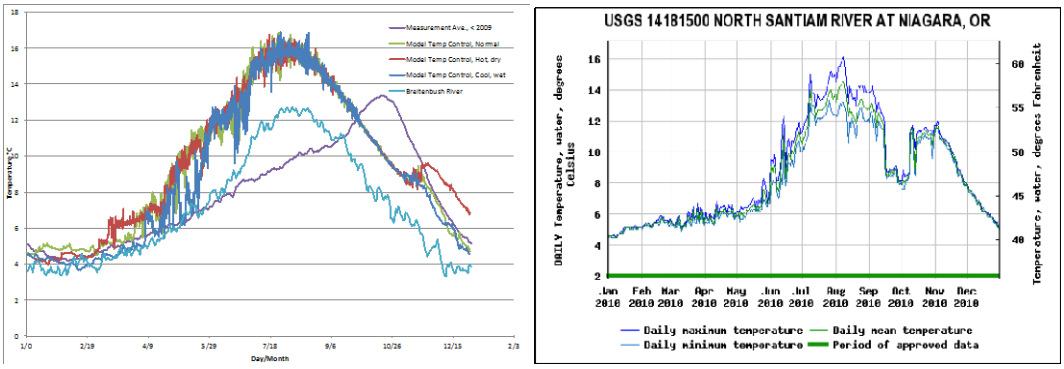


Figure 3.7-1: Comparison of modeled selective withdrawal structure (SWS) temperatures (left) with empirical temperature from operational temperature controls (right).

Normal survival in Reach B and F, Santiam River: 0.453
Selective Withdrawal Structure
Weighting—
Year type and frequency: Wet & Normal, 0.80
Proportion of Redds in Reach B affected: 1.00
Relative survival effect: +0.05 to +0.20
Absolute survival range: 0.475-0.543

New survival range:
High range: (0.453*0.20)+(0.543*0.80) = 0.525
Low range: (0.453*0.20)+(0.475*0.80) = 0.471
- Average 0.498

Equation Box 3: Estimated average survival and range for egg to emergent survival for North Santiam River Reach B and F under the operation of a selective withdrawal structure (SWS). Survivals were computed using the operational temperature controls as the reference for additional improvements under the SWS.

The Deep Drawdown with fish passage through the regulating outlet (OMT: DET_04) provides a lower reservoir level (1370 feet) from 15 November 31 January (although draft down may begin much earlier) so that fish can more easily access the RO. This would increase temperatures (in summer months later in that year, since the reservoir would not be fully refilled) during 50% of the water years simulated. The magnitude of this change (decrease) in survivals is unknown. TDG levels were expected to increase in the early fall and winter due to the need for higher project flows to maintain a low pool, but lower in October and November with Big Cliff reservoir holding much of the flow. Higher TDGs are likely not to affect eggs and embryos in gravel because of depth compensation, but could impact subyearlings emigrating through the Detroit Dam to Big Cliff Dam (Reach F). Reach B (below Minto) might be only marginally affected.

The combined Deep Drawdown and Delayed Refill (OMET:DET_05) from February through May would be expected to produce summer temperatures similar to pre-BIOP conditions (decrease in summer), but warmer during the fall incubation period in all water years. In general, the effect was similar to pre-2007 conditions but may be slightly warmer. TDG levels would be lower, since there would be no spill, and the flow would be through the powerhouse. See Equation Box 1.

Selective withdrawal structure with a floating screen structure would be similar to SWS option in terms of temperature and TDG effects. See Equation Box 3 for details of operational effects.

Glory Hole operations would meet temperature targets, and provide a decrease in temperatures during incubation (having removed warmer surface waters during the summer), similar to the selective withdrawal structure effect. Incubation temperatures could decrease 1-4°C in half the water years. Benefits may not be as good as the selective withdrawal structure alternative. Any increase in TDG would likely degas in Big Cliff Reservoir and during passage through the Big Cliff turbines. Survivals most likely would be similar to Equation Box 2 or slightly less.

Normal survival in Reach B, Santiam River: 0.498
Operational temperature management/Glory Hole

Weighting—
Year type and frequency: 50%
Proportion of Redds in Reach B affected: 1.00
Relative survival effect: -0.05 to -0.20
Absolute survival range: 0.398-0.473

New survival range:
High range: (0.498*0.50)+(0.473*0.50) = 0.486
Low range: (0.498*0.50)+(0.398*0.50) = 0.448
- Average = 0.467

Equation Box 4: Estimated average survival and range for egg to emergent survival for North Santiam River Reach B and F under the "Glory Hole" option. In the equation box above survival was compared to selective withdrawal structure, which the workgroup used as a reference.

South Santiam

Green Peter Dam

Temperature and TDG effects resulting from operational and structural changes to Green Peter Dam were evaluated for their influence on river conditions below Foster Dam and impact the survival of eggs, juveniles, and adults in that reach. Additionally, although there is a free-flowing reach below Green Peter Dam and above Foster Reservoir there appears to be very little spawning in this area and it was not considered in the SLAM model. Baseline conditions were thought to generally apply to alternatives 1, 2, 4 and 7. In alternative 2, there would be some additional flow through the fish horns (200 cubic feet per second (cfs)), but his was not thought to significantly change water temperatures. Under the operational water temperature control scenarios 3 (OMET GPR_01), 5 and 6, temperatures would be controlled using a combination of spillway and powerhouse discharges, similar to those employed at Detroit Dam; however, conditions below Foster Dam would represent the combined inputs from the unregulated South Santiam River above Foster Reservoir and the discharge from Green Peter Dam. Modeled conditions suggest that temperatures during the summer adult holding period would be warmer, especially for alternative 5 (SWS and FSS).

Normal survival in Reach C, South Santiam River: 0.300
Combine spillway, RO, and powerhouse discharges

Weighting—
Year type and frequency: 100%
Proportion of Redds in Reach B affected: 1.00
Relative survival effect: +0.05 to +0.20
Absolute survival range: 0.315-0.36

New survival range:
High range: (0.360*1.00) = 0.360
Low range: (0.315*1.00) = 0.315
- Average = 0.338

Equation Box 5: Estimated average survival and range for egg to emergent survival for South Santiam River for Scenario 3, Reach C.

OTC survival in Reach C, South Santiam River: 0.338
Selective Withdrawal Structure

Weighting—
Year type and frequency: 80%
Proportion of Redds in Reach A affected: 1.00
Relative survival effect: +0.05 to +0.20
Absolute survival range: 0.356-0.406

New survival range:
High range: (0.338*0.20) + (0.406*0.80) = 0.392
Low range: (0.338*0.20) + (0.356*0.80) = 0.352
- Average = 0.372

Equation Box 6: Estimated average survival and range for egg to emergent survival for South Santiam River for Scenarios 6 & 7, Reach C.

Foster Dam

Although Foster Reservoir is not as large nor as deep as Green Peter Reservoir, there is still some water thermal stratification during the summer months. As a result, operational and structural changes at the reservoir may create some temperature changes. Operation of the fish weir or floating surface collector would not result in significant changes in downstream conditions. This also assumes that water is recycled from the floating surface collector. For the selective withdrawal structure alternatives 6 and 7, it was predicted that summer temperatures might rise 2°C and incubation temperatures might decrease up to 3°C. These changes were not as large as in Detroit or Green Peter, so the benefit was predicted to be more similar to operational temperature controls at the other projects.

Normal survival in Reach C, South Santiam River: 0.300
Selective Withdrawal Structure Foster Dam

Weighting—
Year type and frequency: 100%
Proportion of Redds in Reach B affected: 1.00
Relative survival effect: +0.05 to +0.20
Absolute survival range: 0.315-0.36

New survival range:
High range: (0.360*1.00) = 0.360
Low range: (0.315*1.00) = 0.315
- Average = 0.338

Equation Box 7: Estimated average survival and range for egg to emergent survival for South Santiam River for Alternatives 5 & 6, Reach C.

Middle Fork Willamette River

Conditions downstream of the dams in the Middle Fork Willamette River (Reach A) are currently quite poor and natural productivity is thought to be low. There was some concern regarding temperature effects on prespawning adults holding below the dams. These adults would eventually be transported above LOP/Dexter and/or Hills Creek dams. Temperature effects would be correlated with the timing of adult trap and haul operations and the condition of the adult trap (i.e. potential for injury at the current or redesigned facility). Although it would be reasonable to assume that proposed improvements to the adult trap would have a positive effect on the level of pre-spawning mortality (PSM) for transported adults, the workgroup was not able to quantify the magnitude of such benefits. Recent surveys (2013) indicated that current PSM levels were 30-46% above LOP in Reaches D and E.

The work group discussed the impact of changes to operations/structures at either Hills Creek Dam or LOP/Dexter Dam. Changes at either dam were thought to affect conditions in Reach A, below LOP/Dexter Dam, and changes at Hills Creek Dam would only affect a portion of the redds and juveniles in Reach D immediately below the dam and not in the North Fork Willamette River where most of the spawning has been observed.

Lookout Point Dam/Dexter Dam

The baseline for LOP/Dexter Dam included current temperature operations, which have been in effect for the last two years. Because adult returns do not yet reflect the effects of these operational temperature controls, the model was calibrated to pre-OTC conditions and then survivals for Reach A were adjusted accordingly. Therefore assuming OTC continue the new egg-fry survival for Reach A would increase from 0.200 to 0.225. Similarly, summer temperatures would increase up to 4°C, with a resulting increase in PSM.

Normal survival in Reach A, Middle Fork Willamette River: 0.200
Operational Temperature Control

Weighting—
Year type and frequency: 100%
Proportion of Redds in Reach A affected: 1.00
Relative survival effect: +0.05 to +0.20
Absolute survival range: 0.210-0.240

New survival range:
High range: (0.210*1.00) = 0.210
Low range: (0.240*1.00) = 0.240
- Average = 0.225

Equation Box 8: Estimated average survival and range for egg to emergent survival for Middle Fork Willamette River for Scenarios 1,2, 6, & 7, Reach A.

Under the SWS scenario (Numbers 3 & 4) there would be a further improvement in incubation water temperatures , but with minimal additional increase in adult holding temperatures.

OTC survival in Reach A, Middle Fork Willamette River: 0.225
Selective Withdrawal Structure

Weighting—
Year type and frequency: 80%
Proportion of Redds in Reach A affected: 1.00
Relative survival effect: +0.05 to +0.20
Absolute survival range: 0.236-0.270

New survival range:
High range: (0.225*0.20) + (0.270*0.80) = 0.261
Low range: (0.225*0.20) + (0.236*0.80) = 0.234
- Average = 0.247

Equation Box 9: Estimated average survival and range for egg to emergent survival for Middle Fork Willamette River for Scenarios 3 & 4, Reach A.

Finally, under Scenario #5, a Delayed Refill, conditions would resemble those prior to operational temperature controls and SLAM baseline (not OTC baseline) survivals would be utilized. Only in this scenario was there a clear indication that TDG would also increase as more water was routed through the RO.

Hills Creek Dam

Baseline conditions for Hills Creek were thought to be similar to Detroit Dam prior to OTC (pre-2007), with most of the flow being routed through the power house except when capacity was exceeded. Scenarios that included a selective withdrawal structure (SWS) were thought to produce increased summer holding temperatures and lower incubation temperatures (as with other SWS structures). In the case of Hills Creek operations, only a portion (20%) of redds and adults in Reach D (immediately below the Dam) would be impacted. Changes in temperature were also thought to impact conditions in Reach A, below Lookout Point/Dexter Dam.

Baseline survival in Reach D, Middle Fork Willamette River: 0.500
Selective Withdrawal Structure

Weighting—
Year type and frequency: 100%
Proportion of Redds in Reach A affected: 0.20
Relative survival effect: +0.05 to +0.20
Absolute survival range: 0.525-0.600

New survival range:
High range: (0.600*0.20) + (0.500*0.80) = 0.520
Low range: (0.525*0.20) + (0.500*0.80) = 0.505
- Average = 0.513

Equation Box 10: Estimated average survival and range for egg to emergent survival for Middle Fork Willamette River for scenarios with a selective withdrawal structure (SWS) Reach D.

Appendix 3.8. SLAM Upper Willamette River Winter Steelhead Parameterization

In contrast to the process for the parameterization of SLAM for Upper Willamette River Chinook salmon populations, there was less empirical data available to inform the parameterization of the steelhead SLAM models. In most cases these values were based on data from other coastal populations of winter-run steelhead, in others, input from the workgroup was relied upon. This input was often based on unpublished observations or pilot studies undertaken in the North and South Santiam basins.

The workgroup was tasked with parameterizing the life history trajectories of juvenile *O. mykiss* steelhead in the reservoirs, the proportion of each steelhead age class entering the reservoir (0-age, yearling, 2-year-old), and the life history characteristics of returning adults. The age of fish entering the reservoirs is likely related to the amount of rearing habitat available above each reservoir. Much of the information in the literature and from field observations suggests that the majority of returning naturally produced fish emigrated as 2-year olds. Little is known of the timing of in-river migration by different age classes, in part due to the low catch rates in screw traps for larger *O. mykiss*. Finally, there was considerable discussion regarding the presence and contribution of resident *O. mykiss* to steelhead productivity. If the proportion of female steelhead progeny that become resident is substantial it could affect the viability of the population (we are predominately concerned with the number of females as the limiting factor in productivity). In the absence of documented resident contributions to the steelhead population in Upper Willamette Basin tributaries, this life history trajectory was not included. Net sampling of reservoir populations revealed the presence of a small number of larger (greater than 200mm) *O. mykiss.* The sex and origin of these fish was not establish, and if these fish are predominately male or are feral hatchery rainbow trout the potential for resident *O. mykiss* to contribute to the steelhead population could be greatly overestimated. There were a number of studies cited in the discussion where resident rainbow trout had contributed to some extent to the anadromous population; however, in almost all cases the studies concerned summer-run steelhead in the interior Columbia River Basin.

Reservoir Entry

Of the three reservoirs (Detroit, Foster, and Green Peter) relevant to steelhead in the North and South Santiam rivers; Foster Reservoir has been the one most extensively studied. It is also the only reservoir of the three that is currently accessible to steelhead.

Juvenile *O.* mykiss enter Foster Reservoir from July to November and range in size from 50 to 100 mm. In 2012, of the 1400 juveniles captured at the head of Foster Reservoir, approximately 80% were subyearlings (0-age – as determined by size). In general, the workgroup concluded that similar proportions would be found emigrating into Detroit and Green Peter Reservoir. The only adjustments made to the proportions took into account that there was suitable quality and quantity of habitat above the reservoirs in the North Santiam (above Detroit Reservoir) and Middle Santiam (above Green Peter Reservoir) to maintain a sizable number of juveniles to the yearling and two-year-old stages.

At what juvenile life-stage do steelhead enter the reservoir?

Population/Reservoir	0-age (%)	Yearling (%)	2-Year Old (%)
North Santiam	-	-	-
/Detroit	70 (60-80)	10 (8-12)	20 (15-22)
South Santiam	-	-	-
/Foster	85 (70-95)	12 (6-15)	3 (0-5)
/Green Peter	70 (60-80)	10 (8-12)	20 (15-22)

Willamette Falls-Estuary Entry

Historically, two-year old juveniles comprised the majority of outmigrating *O. mykiss* (Massey 1967). Similarly, of the returning adult steelhead nearly all showed scale patterns consistent with ocean entry as two-year-old juveniles (Howell 1985). Current estimates indicated that nearly 80% of the juvenile *O. mykiss* sampled at Willamette Falls were two-year olds. There was little information available to suggest significant differences between the basins.

At what juvenile life-stage do steelhead enter the estuary (smolt)?

Population/Reservoir	0-age (%)	Yearling (%)	2-Year Old (%)
North Santiam	-	-	-
/Detroit	5 (0-7)	20 (18-22)	75 (70-80)
South Santiam	-	-	-
/Foster	5 (0-7)	20 (18-22)	75 (70-80)
/Green Peter	5 (0-7)	20 (18-22)	75 (70-80)

Respawn Rate

Studies in the South Santiam River indicated (from scale analysis) that the repeat spawner rate from 1979 to 1981 ranged from 2 to 4%. Recent analysis of adult steelhead intercepted at Willamette Falls indicated that the repeat spawners rate was substantially higher 8 to 15%. Of those adults that eventual migrated to the Santiam Basin approximately 12% were second time spawners and 3% were third-time spawners. Furthermore, 73% of the repeat spawners were females (although the workgroup set a general sex ratio of 1:4 for the SLAM model). Given this skew in the sex ratio, the fecundity of repeat spawners would be adjusted upward to reflect to deviation from the 50:50 sex-ratio used for first time spawners. Based on an average fecundity of 5,200 eggs per female (repeat spawners are larger and more fecund per unit body weight than virgin spawners), the average fecundity of a repeat spawner would be 4,160 eggs (adjusting for 80:20 female:male sex ratio). There was no basis for differences in these parameters between the two Santiam River steelhead populations.

What is the current rate of return for repeat spawners?

8 to 15%

Population/Reservoir	Male Frequency (%)	Female Frequency (%)
North Santiam		
/Detroit	20%	80%
South Santiam		
/Foster	20%	80%
/Green Peter	20%	80%

SLAM assumes 50:50 sex ratio, repeat frequency will be adjusted to reflect sex bias in repeat spawners.

Reservoir Parameters

The trajectory of juvenile fish passing through the dam structure was described by three stepwise parameters (Figure 3.8-1). Firstly, of the fry originating from the headwaters above the reservoirs, juveniles will emigrate to the reservoir at age 0, 1-year old, or 2-year old. Of the fish residing in the reservoir as age 0 juveniles, a proportion "x" will be available to pass through egress points at the forebay. Whether they are attracted to the egress points is expressed as the DPE for that structure/scenario. The remainder (1-DPE) will continue to rear in the reservoir until the next life stage along with those fish that were not available to pass (1-x). Because of the extended time frame covered in each life history stage, a survival parameter "s1a" is applied to age 0 juveniles that are available to pass, those fish remaining in the reservoir until the yearling stage are subject to a survival "s1". This process is repeated for later life history stages. For two-year-old juveniles, the proportion available is assumed to be 1.00 and those fish that do not pass are assumed to die. It was recognized that some steelhead juveniles may residualize, but no information was available on the contribution of these fish toward steelhead viability. For the SLAM parameterization, it was assumed that the contribution of these resident fish was minimal.

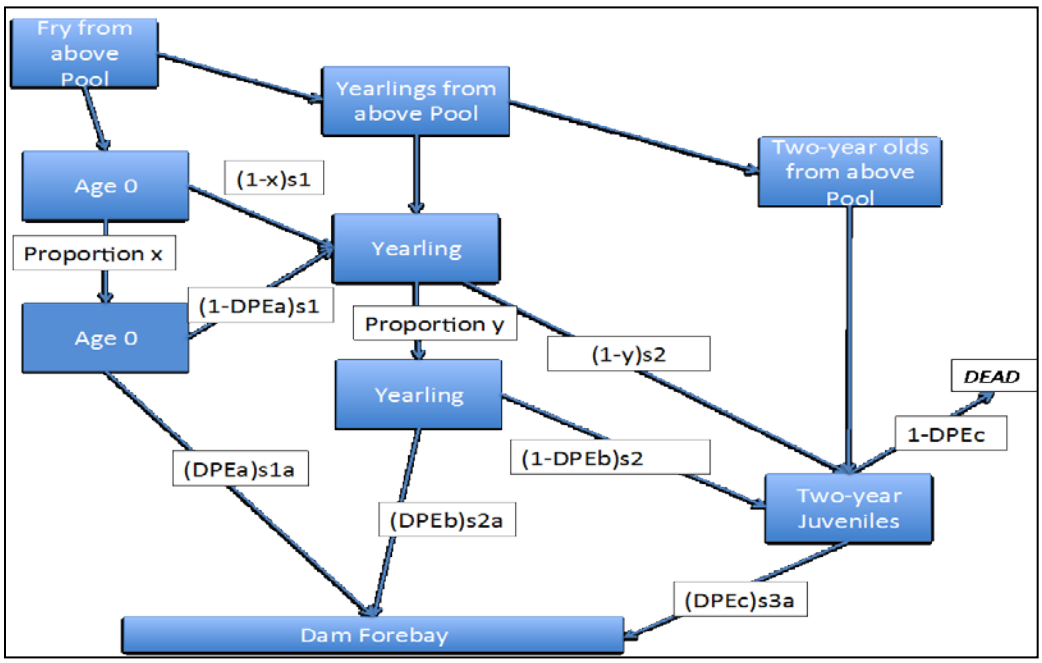


Figure 3.8-1: General schematic of life history trajectories for steelhead salmon passing through a reservoir and dam structure. Proportions x and y describe the fraction of the cohort that becomes available to pass the dam, dam passage efficiency (DPE) describes the fish that actually do pass (enter a passage structure).

Much of the discussion by the workgroup focused on studies undertaken in Foster Reservoir with steelhead. Reservoir conditions were contrasted with those in Detroit and Green Peter reservoirs. Comparisons were also made between the parameters assigned to steelhead and Chinook salmon juvenile life history stages, with steelhead having longer freshwater residence times and obtaining larger body sizes. As with Chinook salmon, for most juvenile age classes the majority of fish were "available to pass" as each life stage. For age 0 juveniles, predation was seen as a major factor influencing survival. Predation on *O. mykiss* in Foster and Green Peter reservoirs was thought to be more intense than in Detroit Reservoir. This was reflected in a slightly higher Age 0 to Yearling reservoir survival (Survival s1) in Detroit, 0.2, compared to Foster and Green Peter Reservoir, 0.15.

In the absence of reservoir specific data, few differences were identified between the reservoirs. Some temperature control scenarios were thought to benefit fish survival by either keeping temperatures lower (slowing the ability of predators, largemouth and smallmouth bass, to intercept juvenile *O. mykiss*), or creating thermal stratification in the reservoir and providing different preferential temperature zones for steelhead juveniles and bass. This improvement was characterized as an absolute increase in survival of 5%. For older juveniles, predation was thought to be less of a factor due to their larger size.

Appendix 3.9. Parameter Work Group Participants

Name	Affiliation
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CHAPTER 4. SLAM MODEL OF MCKENZIE RIVER CHINOOK SALMON

This chapter provides a description of the parameter values being considered in the McKenzie River SLAM model. Below, we provide a short description of the model parameters used in each of five categories (1. Productivity, capacity, & survivals, 2. Splits, 3. Datafiles, 4. Dynamic drivers & influencers, and 5. Initialized). For reference purposes, a map of McKenzie River (Figure 4.1) is provided that highlights each reach used in SLAM. Figure 4.2 shows how the life-cycle model is modeled within SLAM. Lastly, Table 4.1 is a list of definitions corresponding to each box within the life-cycle model, while Table 4.2 is a list of abbreviations used throughout this chapter.

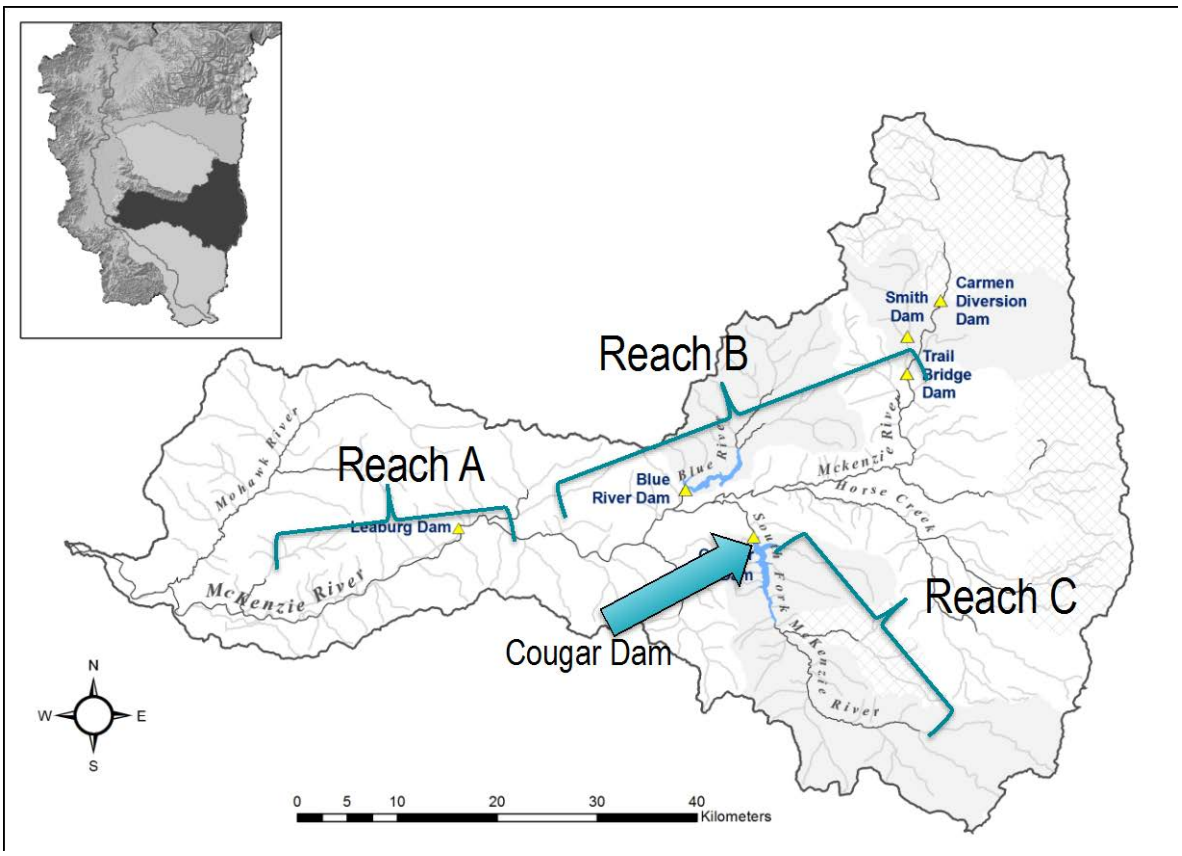


Figure 4.1: Map showing McKenzie River Basin and the three reaches (A, B, and C) that are modeled in SLAM; Reach A corresponds to mainstem McKenzie River downstream of Leaburg Dam, Reach B corresponds to mainstem McKenzie River upstream of Leaburg Dam excluding South Fork McKenzie River upstream of Cougar Dam, and Reach C corresponds to South Fork McKenzie River upstream of Cougar Dam. Map provided by M. Sheer.

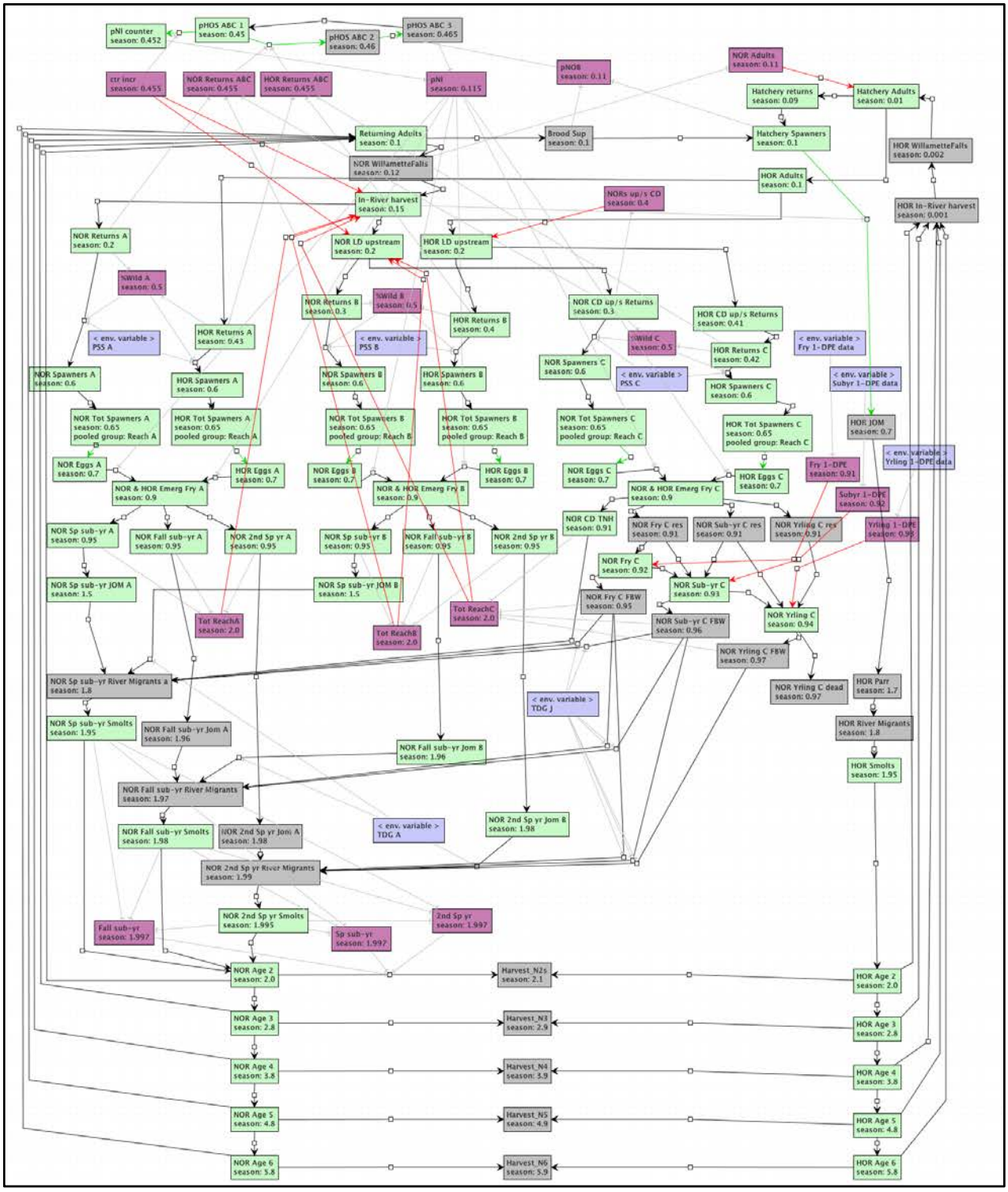


Figure 4.2: SLAM generated flow diagram of McKenzie River Chinook salmon life cycle model. Details of this model are provided in Table 4.1 and subsequent figures in this chapter will emphasize components of this diagram.

Table 4.1: Life history stages and transitions for the McKenzie River Chinook salmon life cycle model (Figure 4.2). Reaches correspond to those in Figure 4.1; Reach A corresponds to mainstem McKenzie River downstream of Leaburg Dam, Reach B corresponds to mainstem McKenzie River upstream of Leaburg Dam excluding South Fork McKenzie River upstream of Cougar Dam, and Reach C corresponds to South Fork McKenzie River upstream of Cougar Dam.

Life Stage	Definition
HOR In-River harvest	Freshwater harvest of hatchery fish
Hatchery Adult	Hatchery origin adults
Hatchery returns	Hatchery fish that return to the hatchery rack
Hatchery Spawners	Adults that spawn in hatchery, including some natural origin adults for brood stock improvement
HOR Adults	Hatchery origin adults that spawn in wild
Returning Adults	Returning adults of natural origin
Brood Sup	Natural origin individuals that are supplied to brood supply at hatchery program
In-River Harvest	Freshwater harvest of natural origin
NOR Returns A	Natural origin adults that return to Reach A
NOR LD upstream	Natural origin adults that are upstream of Leaburg Dam
NOR Returns B	Natural origin adults that return to Reach B
NOR CD up/s Returns	Natural origin adults that return to Reach C
HOR Returns A	Hatchery origin adults that return to Reach A
HOR LD upstream	Hatchery origin adults that are upstream of Leaburg Dam
HOR Returns B	Hatchery origin adults that return to Reach B
HOR CD up/s Returns	Hatchery origin adults that return to Reach C
NOR Spawners A	Natural origin spawners that spawn in Reach A
HOR Spawners A	Hatchery origin spawners that spawn in Reach A
NOR Spawners B	Natural origin spawners that spawn in Reach B
HOR Spawners B	Hatchery origin spawners that spawn in Reach B
NOR Spawners C	Natural origin spawners that spawn in Reach C
HOR Spawners C	Hatchery origin spawners that spawn in Reach C
NOR Tot Spawners A	Natural origin and hatchery origin spawners that spawn in Reach A
HOR Tot Spawners A	Natural origin and hatchery origin spawners that spawn in Reach A
NOR Tot Spawners B	Natural origin and hatchery origin spawners that spawn in Reach B
HOR Tot Spawners B	Natural origin and hatchery origin spawners that spawn in Reach B
NOR Tot Spawners C	Natural origin and hatchery origin spawners that spawn in Reach C
HOR Tot Spawners C	Natural origin and hatchery origin spawners that spawn in Reach C
NOR Egg A	Eggs in Reach A produced by natural origin spawners in Reach A
HOR Egg A	Eggs in Reach A produced by hatchery origin spawners in Reach A
NOR Egg B	Eggs in Reach B produced by natural origin spawners in Reach B
HOR Egg B	Eggs in Reach B produced by hatchery origin spawners in Reach B
NOR Egg C	Eggs in Reach C produced by natural origin spawners in Reach C
HOR Egg C	Eggs in Reach C produced by hatchery origin spawners in Reach C
NOR & HOR Emerg Fry A	Natural and hatchery produced emergent fry in Reach A

NOR & HOR Emerg Fry B	Natural and hatchery produced emergent fry in Reach B
NOR & HOR Emerg Fry C	Natural and hatchery produced emergent fry in Reach C
HOR JOM	Hatchery origin juvenile out-migrants
NOR Sp sub-yr A	Natural origin fry in Reach A that express a Spring sub-yearling life history strategy
NOR Fall sub-yr A	Natural origin fry in Reach A that express a Fall sub-yearling life history strategy
NOR 2nd Sp yr A	Natural origin fry in Reach A that express a 2nd Spring yearling life history strategy
NOR Sp sub-yr B	Natural origin fry in Reach B that express a spring sub-yearling life history strategy
NOR Fall sub-yr B	Natural origin fry in Reach B that express a fall sub-yearling life history strategy
NOR 2nd Sp yr B	Natural origin fry in Reach B that express a 2nd spring yearling life history strategy
NOR CD TNH	Placeholder for a trap and haul program
NOR Fry C res	Natural origin fry in Cougar Dam reservoir
NOR Sub-yr C res	Natural origin sub-yearlings in Cougar Dam reservoir
NOR Yrlings C res	Natural origin 2nd spring yearlings in Cougar Dam reservoir
NOR Fry C	Natural origin fry available to pass Cougar Dam
NOR Sp sub-yr C	Natural origin spring sub-yearlings available to pass Cougar Dam
NOR Yrling C	Natural origin yearlings (i.e., 2nd spring fish) available to pass Cougar Dam
NOR Fry C FBW	Natural origin fry that are passing through Cougar Dam
NOR Sub-yr C FBW	Natural origin sub-yearlings that are passing through Cougar Dam
NOR Yrling C FBW	Natural origin yearlings that are passing through Cougar Dam
NOR Yrling C dead	Natural origin yearlings that fail to pass through Cougar Dam
NOR Sp sub-yr JOM B	Natural origin spring sub-yearlings in Reach B that are juvenile out migrants
NOR Sp sub-yr River Migrants a	Natural origin spring sub-yearlings leaving McKenzie River
NOR Fall sub-yr JOM A	Natural origin fall sub-yearlings in Reach A that are juvenile out migrants
NOR Fall sub-yr JOM B	Natural origin fall sub-yearlings in Reach B that are juvenile out migrants
NOR Fall sub-yr River Migrants	Natural origin fall sub-yearlings leaving McKenzie River
NOR 2nd Sp yr JOM A	Natural origin 2nd spring sub-yearlings in Reach A that are juvenile out migrants
NOR 2nd Sp yr JOM B	Natural origin 2nd spring sub-yearlings in Reach B that are juvenile out migrants
NOR 2nd Spy r River Migrants	Natural origin 2nd spring sub-yearlings leaving McKenzie River
NOR Sp sub-yr Smolts	Natural origin smolts that are spring sub-yearlings
NOR Fall sub-yr Smolts	Natural origin smolts that are fall sub-yearlings
NOR 2nd sub-yr Smolts	Natural origin smolts that are 2nd spring sub-yearlings
HOR Parr	Hatchery origin parr downstream of Leaburg Dam
HOR River Migrants	Hatchery origin juvenile out-migrants leaving McKenzie River
HOR Smolt	Hatchery origin smolts
NOR Age 2	Age 2 natural origin adults

NOR Age 3	Age 3 natural origin adults
NOR Age 4	Age 4 natural origin adults
NOR Age 5	Age 5 natural origin adults
NOR Age 6	Age 6 natural origin adults
HOR Age 2	Second generation age 2 hatchery origin adults, indistinguishable from natural origin age 2 adults
HOR Age 3	Second generation age 3 hatchery origin adults, indistinguishable from natural origin age 3 adults
HOR Age 4	Second generation age 4 hatchery origin adults, indistinguishable from natural origin age 4 adults
HOR Age 5	Second generation hatchery origin age 5 adults, indistinguishable from natural origin age 5 adults
HOR Age 6	Second generation hatchery origin age 6 adults, indistinguishable from natural origin age 6 adults
Harvest_N2	Adults (both natural and hatchery origin) harvested at age 2
Harvest_N3	Adults (both natural and hatchery origin) harvested at age 3
Harvest_N4	Adults (both natural and hatchery origin) harvested at age 4
Harvest_N5	Adults (both natural and hatchery origin) harvested at age 5
Harvest_N6	Adults (both natural and hatchery origin) harvested at age 6

Table 4.2: List of Acronyms and Abbreviations.

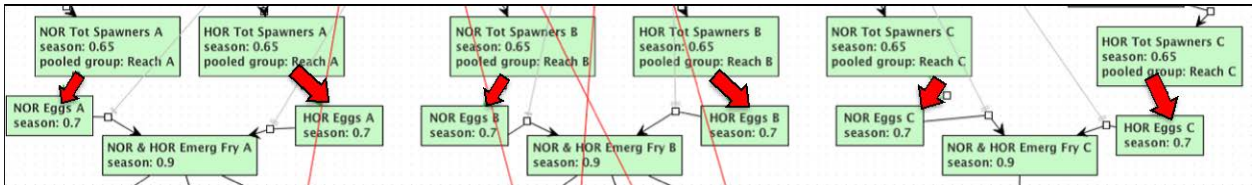
Abbreviation	**Definition**
0+	Juveniles less than one year old
1+	Juveniles older than one year but less than two years old
Beverton-Holt	Beverton-Holt spawner-recruit relationship
CD	Cougar Dam
d/s	Downstream
Harvest_N#	Fishery harvest of age N# fish (# = 2, 3, 4, 5, & 6 for spring Chinook)
FBW	Fish Benefit Workbook
Hockey-Stick	Spawner-recruit relationship in the Hockey-stick shape
HOR	Hatchery origin
HoR	Head of reservoir
JOM	Juvenile out-migrant
LD	Leaburg Dam
NOR	Natural origin
ODFW	Oregon Department of Fish and Wildlife
SE	Standard Error
PSS, PSM	Prespawning survival, prespawning mortality
SLAM	Species Life-Cycle Analysis Modules
u/s	Upstream
TDG	Total Dissolved Gas
DPE	Dam Passage Efficiency
TNH	Trap and Haul

4.1. Productivity, Capacity, & Survivals

This section describes the reproductive capability of spawners within each reach and hatchery, reach-specific capacity, and the proportion of individuals that survive as they move among stages in the life-cycle model (Figure 4.2, Tables 4.1 and 4.2).

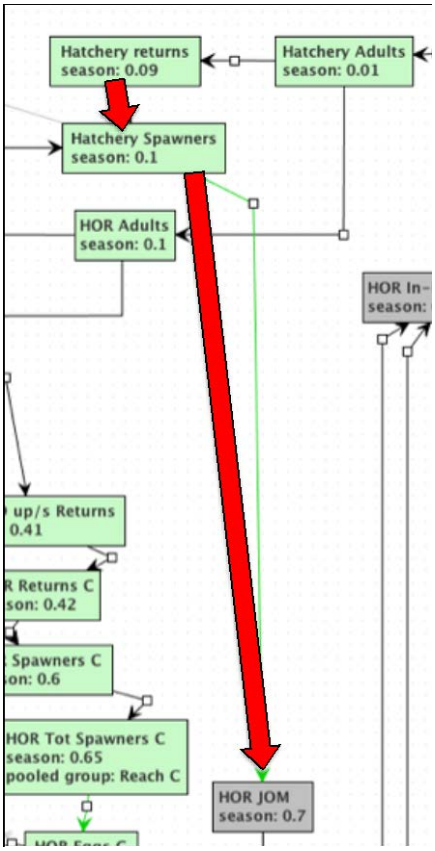
Productivity and capacity parameter values of wild spawning natural and hatchery origin individuals. Within each reach natural and hatchery origin spawners are pooled by reach, and a reach-specific Beverton-Holt capacity function is applied to determine the number of eggs. The Beverton-Holt productivity term is fixed at 0.5 times fecundity, with the assumption that the sex ratio of spawning fish is 50:50. The productivity to 2,250 eggs/individual is a slightly more conservative estimate than the 5000 eggs per female noted by Willis et al. (1995) (see Chapter 3, Fecundity). Egg capacity is stochastic, and each year reach-specific egg capacity is drawn from a normal distribution according to the following parameters (see Chapter 3, Spawner Capacity).

Reach	From	To	Capacity & Productivity	Mean	SD	Min	Max
A	NOR Tot Spawners	Eggs	Capacity	500,000	50,000	250,000	600,000
			Productivity				2,250
B	NOR Tot Spawners	Eggs	Capacity	8,000,000	250,000	2,000,000	15,000,000
			Productivity				2,250
C	NOR Tot Spawners	Eggs	Capacity	17,000,000	500,000	4,000,000	22,000,000
			Productivity				2,250
A	HOR Tot Spawners	Eggs	Capacity	500,000	50,000	250,000	600,000
			Productivity				2,000
B	HOR Tot Spawners	Eggs	Capacity	8,000,000	250,000	2,000,000	15,000,000
			Productivity				2,000
C	HOR Tot Spawners	Eggs	Capacity	17,000,000	500,000	4,000,000	22,000,000
			Productivity				2,000



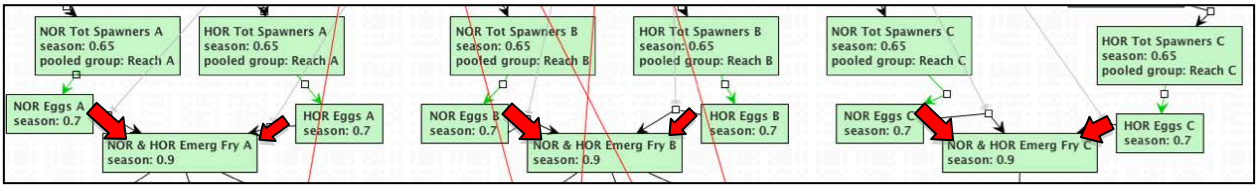
Productivity and capacity parameter values of hatchery spawners. A number of hatchery origin fish (up to 550-750 individuals; see Splits section below) are spawned in the hatchery using a Hockey-Stick capacity function, based on productivity of 1,600 eggs/individual (Willis et al. 1995), to determine the number of hatchery origin juveniles released in the McKenzie River (HOR JOM).

Reach	From	To	Capacity & Productivity	Mean	SD	Min	Max
Hatchery	Hatchery Returns	Hatchery Spawners	Capacity	600	100	550	750
			Productivity				1
Hatchery	Hatchery Spawners	HOR JOM	Capacity	800,000	50,000	750,000	850,000
			Productivity				1,600



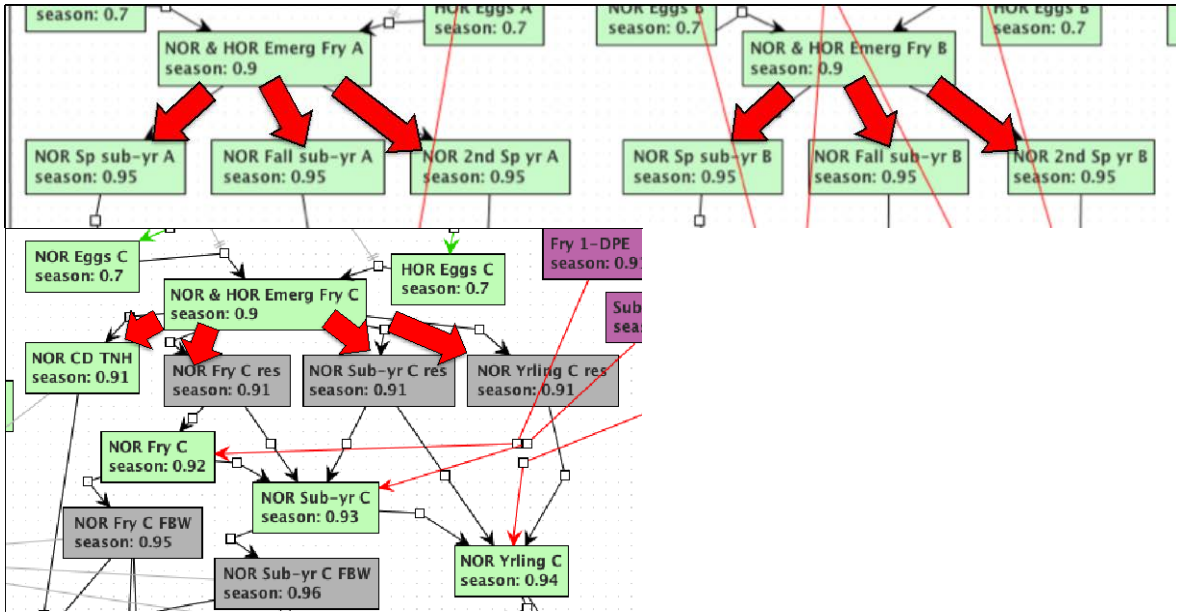
Survival parameter values from Eggs to Emergent Fry stage. The below values correspond to the reach-specific proportion of eggs that survive to become emergent fry (see Chapter 3, Survival):

Reach	From	To	Curve type	Capacity & Productivity	Distribution type	Proportion of fish that survive
A	NOR/HOR Eggs	NOR & HOR Emerg Fry	Linear	Productivity	Constant	0.35
B	NOR/HOR Eggs	NOR & HOR Emerg Fry	Linear	Productivity	Constant	0.45
C	NOR/HOR Eggs	NOR & HOR Emerg Fry	Linear	Productivity	Constant	0.575



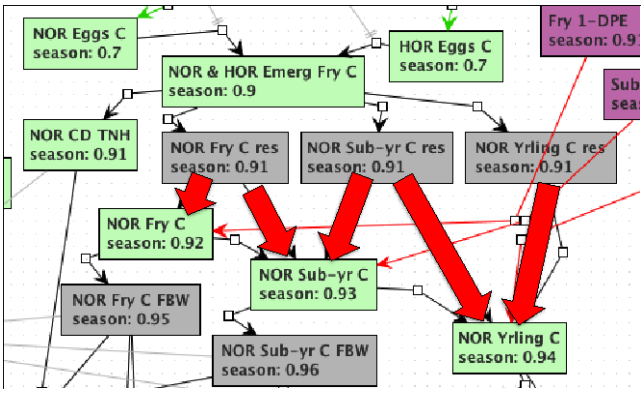
Survival parameter values from Emergent Fry stage to each juvenile life history strategy. The below values correspond to the reach-specific proportion of emergent fry that survive to become spring sub-yearlings, fall sub-yearlings, and 2nd spring yearlings:

Reach	From	To	Curve type	Capacity & Productivity	Distribution type	Proportion of fish that survive
A	NOR & HOR Emerg Fry	NOR Sp sub-yr A	Linear	Productivity	Constant	0.225
		NOR Fall sub-yr A	Linear	Productivity	Constant	0.175
		NOR 2nd Sp yr A	Linear	Productivity	Constant	0.14
B	NOR & HOR Emerg Fry	NOR Sp sub-yr B	Linear	Productivity	Constant	0.275
		NOR Fall sub-yr B	Linear	Productivity	Constant	0.225
		NOR 2nd Sp yr B	Linear	Productivity	Constant	0.17
C	NOR & HOR Emerg Fry	NOR CD TNH	Linear	Productivity	Constant	0.8
		NOR Fry C res	Linear	Productivity	Constant	0.75
		NOR Sub-yr C res	Linear	Productivity	Constant	0.425
		NOR Yrling C res	Linear	Productivity	Constant	0.325



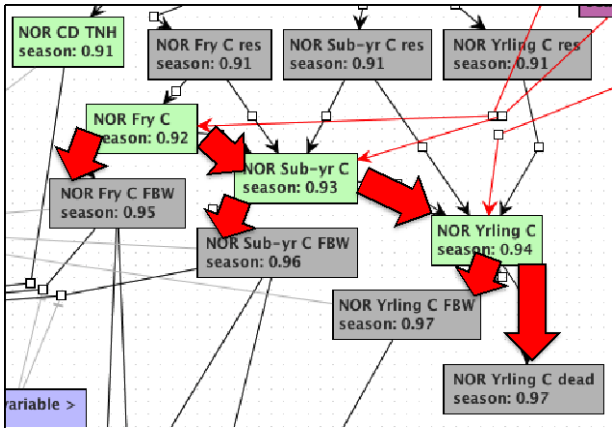
Survival parameter values while in Cougar reservoir for each of three life history strategies. These values are from parameter workshops (see Chapter 3, appendix 3.6).

Reach	From	To	Curve type	Capacity & Productivity	Distribution type	Proportion of fish that survive
C	NOR Fry C res	NOR Fry C	Linear	Productivity	Constant	1
		NOR Sub-yr C	Linear	Productivity	Triangular	0.2 (mean), 0.15 & 0.35 (min & max)
	NOR Sub-yr C res	NOR Sub-yr C	Linear	Productivity	Constant	1
		NOR Yrling C	Linear	Productivity	Uniform	0.4-0.9 (min & max)
	NOR Yrling C res	NOR Yrling C	Linear	Productivity	Constant	1



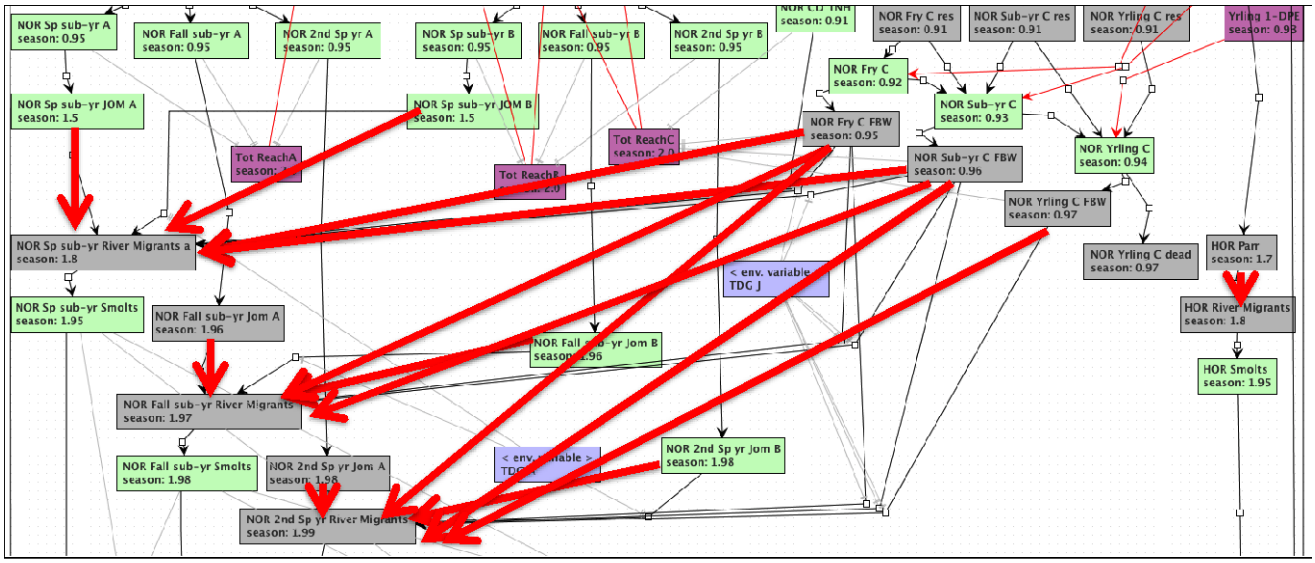
Survival parameter values for each of three life history strategy that rear in the reservoir to the next life history strategy. The survival values listed below that correspond to transitions between life history strategies. These values are from parameter workshops (see Chapter 3, appendix 3.6). Dam passage survival ('Passage survival' in the below table) is one of two data files from the Fish Benefits Workbook, the other being dam passage efficiency (DPE)(Fish Benefits Workbooks User Guide 2014). Dam passage efficiency is the fraction of fish available to pass a dam that actually pass, those that do not pass remain in the reservoir.

Reach	From	To	Curve type	Capacity & Productivity	Distr. type	Proportion of fish that survive
C	NOR Fry C	NOR Sub-yr C	Linear	Productivity	Triangular	0.2 (mean), 0.15 & 0.35 (min & max)
		NOR Fry C FBW	Linear	Productivity	Datafile	Passage survival
	NOR Sub-yr C	NOR Yrling C	Linear	Productivity	Uniform	0.4-0.9 (min & max)
		NOR Sub-yr C FBW	Linear	Productivity	Datafile	Passage survival
	NOR Yrling C	NOR Yrling C dead	Linear	Productivity	Constant	0
		NOR Yrling C FBW	Linear	Productivity	Input file	Passage survival



Survival parameter values from juvenile out migrants (JOM) to River Migrant stage (Willamette River mainstem survival past Willamette Falls). These sets of survivals take the fish past Willamette Falls to the estuary.

Reach	From	To	Curve type	Capacity & Productivity	Distr. type	Proportion of fish that survive
A	NOR Sp sub-yr JOM A	NOR Sp sub-yr River Migrants a	Linear	Productivity	Constant	0.1
	NOR Fall sub-yr JOM A	NOR Fall sub-yr River Migrants	Linear	Productivity	Constant	0.4
	NOR 2nd Sp yr JOM A	NOR 2nd Sp yr River Migrants	Linear	Productivity	Constant	0.525
B	NOR Sp sub-yr JOM B	NOR Sp sub-yr River Migrants a	Linear	Productivity	Constant	0.175
	NOR Fall sub-yr JOM B	NOR Fall sub-yr River Migrants	Linear	Productivity	Constant	0.4
	NOR 2nd Sp yr JOM B	NOR 2nd Sp yr River Migrants	Linear	Productivity	Constant	0.525
C	NOR CD TNH	NOR Sp sub-yr River Migrants a	Linear	Productivity	Constant	0.15
	NOR Fry C FBW	NOR Sp sub-yr River Migrants a	Linear	Productivity	Constant	0.125
		NOR Fall sub-yr River Migrants	Linear	Productivity	Constant	0.375
		NOR 2nd Sp yr River Migrants	Linear	Productivity	Constant	0.575
	NOR Sub-yr C FBW	NOR Sp sub-yr River Migrants a	Linear	Productivity	Constant	0.15
		NOR Fall sub-yr River Migrants	Linear	Productivity	Constant	0.425
		NOR 2nd Sp yr River Migrants	Linear	Productivity	Constant	0.575
	NOR Yrling C	NOR 2nd Sp yr River Migrants	Linear	Productivity	Constant	0.625
Hatchery	HOR Parr	HOR River Migrants	Linear	Productivity	Constant	0.825



Estuary and ocean survival. Juveniles below Willamette Falls have an estuary survival time series applied, and in subsequent ocean years from, from 1, up to 4 ocean years, an ocean survival time series is applied (see Table 4.6 in Parameter variability section).

Survival parameter values associated with ocean and freshwater adult harvest and adult mainstem "loss". Natural origin fish from the McKenzie River experience an average fishing mortality of 9.73% (range of 5.6% - 15.1%; Fisheries Management and Evaluation for 2012 Willamette River spring Chinook 2013) (i.e., 0.903 survival). There is also a loss of fish observed from Willamette Falls to counts within the McKenzie River, which we calculated as an average of 28.4% using data from 1995-2011) (i.e., 0.716 survival;Willis et al. 1996; Foster et al. 1997; Bennett 1998; Lindsay et al. 1998; Ford 2011; Foster & Boatner 2002). Hatchery origin individuals are targeted in mainstem and McKenzie River fisheries. There is 47.6% mortality applied (average of 2006-2011) to account for harvest below Willamette Falls (Fisheries Management and Evaluation

for 2012 Willamette River spring Chinook 2013). This 47.6% mortality is the sum of mortality by recreational fishery at the mouth of the Columbia River to Willamette River (5.2%), lower Willamette recreational fishery (20.8%), mainstem net fishery (9%), and the recreational fishery in the McKenzie River (12.6%). This 47.6% mortality (i.e., 0.524 survival) is comparable to 30.7% and 55% mortality reported by Lindsay et al. (1998) and Ford (2011), respectively. There is also a loss of fish observed from Willamette Falls to counts within McKenzie River Basin, which we calculated as an average of 28.4% using data from 1995-2011 (i.e., 0.716 survival).

Reach	From	To	Curve type	Capacity & Productivity	Distr. type	Proportion of fish that survive
Hatchery	HOR Age 2	HOR In-River harvest	Linear	Productivity	Constant	0.524
	HOR Age 3	HOR In-River harvest	Linear	Productivity	Constant	0.524
	HOR Age 4	HOR In-River harvest	Linear	Productivity	Constant	0.524
	HOR Age 5	HOR In-River harvest	Linear	Productivity	Constant	0.524
	HOR Age 6	HOR In-River harvest	Linear	Productivity	Constant	0.524
	HOR In-River harvest	HOR WillametteFalls	Linear	Productivity	Constant	0.716
NORs	Returning Adults	NOR WillametteFalls	Linear	Productivity	Constant	0.716
	NOR WillametteFalls	In-River harvest	Linear	Productivity	Constant	0.903

4.2. Splits

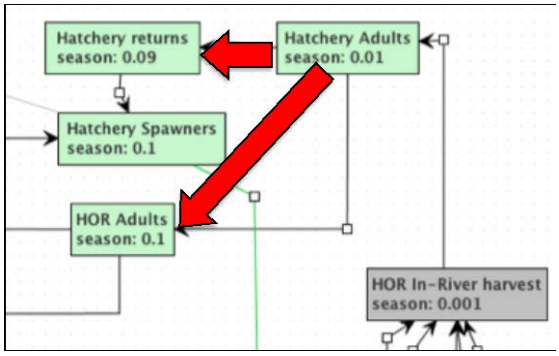
This section describes the proportion of fish directed from an individual life-stage to two or more subsequent life-stages via different pathways (splits).

Proportion of hatchery origin adults (Hatchery Adults) that return to hatchery (Hatchery Returns) or do not return to hatchery (HOR Adults). These proportions are based on abundance of natural origin fish at Willamette Falls. When fewer than 2501 McKenzie River natural origin adults are counted passing above Willamette Falls, 82% of hatchery fish that are returning to freshwater are returned to the hatchery rack (Hatchery returns), while the remaining 18% do not return to the hatchery and spawn in the McKenzie River Basin. When greater than 7875 natural origin fish are counted at Willamette Falls then 95% of hatchery fish that are returning to freshwater will return to the hatchery rack (Hatchery Returns), while the remaining 5% will attempt to spawn in the wild (HOR Adults). When the number of McKenzie River natural origin fish counted at Willamette Falls is between 2501 and 7875 individuals, then a linear relationship (below) sets the rate of return to the rack between 82 – 95%:

$$Proportion\ of\ hatchery\ fish\ that\ return\ to\ rack\ = 0.82\ + (0.18 \times (\frac{NORs\ at\ Willamette\ Falls - 2500}{7500}).$$

From	To	Proportion
Hatchery Adults	Hatchery returns	Split influencer (otherwise use 0.82)
	HOR Adults	Split influencer (otherwise use 0.18)

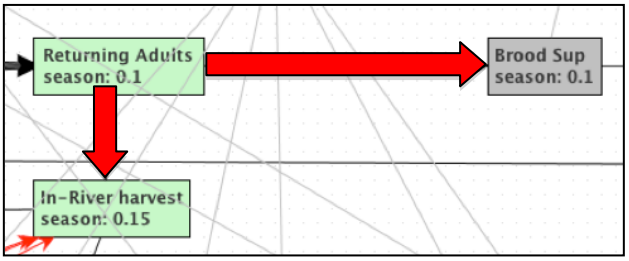
These proportions were based on observations of straying rates from 2001-2011 (Table 1 in DRAFT - Assessment of specific actions to reduce the natural spawning of hatchery Chinook in the McKenzie River (by McKenzie Hatchery Technical Workgroup, March 28, 2012).



Proportion of Returning Adults that are used in the hatchery broodstock program and those that return to each reach. Of the hatchery fish returning to the hatchery, up to 200 are spawned and the remaining continue to a stage where freshwater harvest occurs and they are removed from the model.

From	To	Proportion
Returning Adults	Brood Sup	0.016 (max = 200)
	In-River harvest	0.984

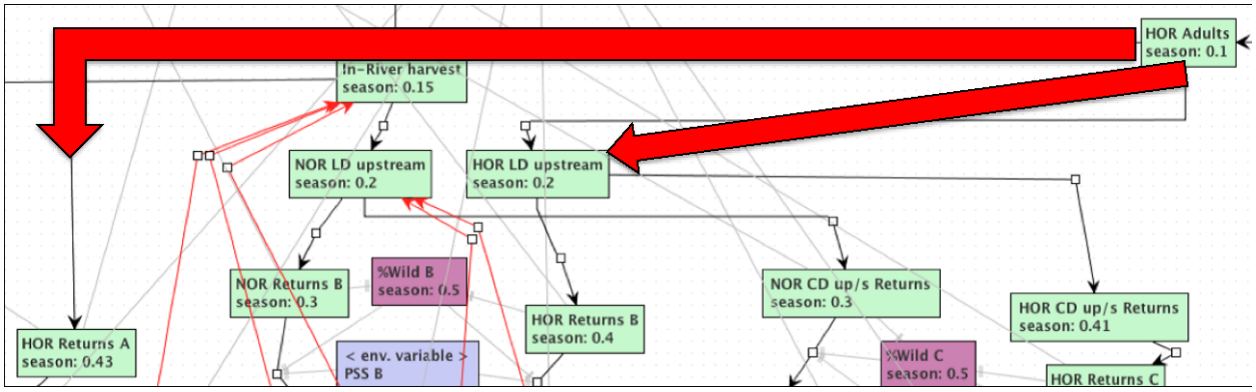
Values taken from Hendrix and Shi (2012) (page 10) and are based on carcass and red counts from Schroeder et al. (2005 and 2007), Kenaston et al. (2009), and Cannon et al. (2010).



Proportion of hatchery origin adults (HOR Adults) that return to Reach A (HOR Returns A) or continue upstream (HOR LD upstream). Of the hatchery-origin adults that do not return to the hatchery, some spawn in Reach A.

From	To	Proportion
HOR Adults	HOR LD upstream	0.894
	HOR Returns A	0.106

Values are taken from Hendrix and Shi (2012) (see page 8) and are based on redd and carcass surveys from Kenaston et al. (2009). Note that Kenaston et al. (2009) report a split of 30% (to HOR Returns A) & 70% (HOR LD upstream), however we retained the adjustments R2 Consultants made to the values to reflect ODFW values & historical information.



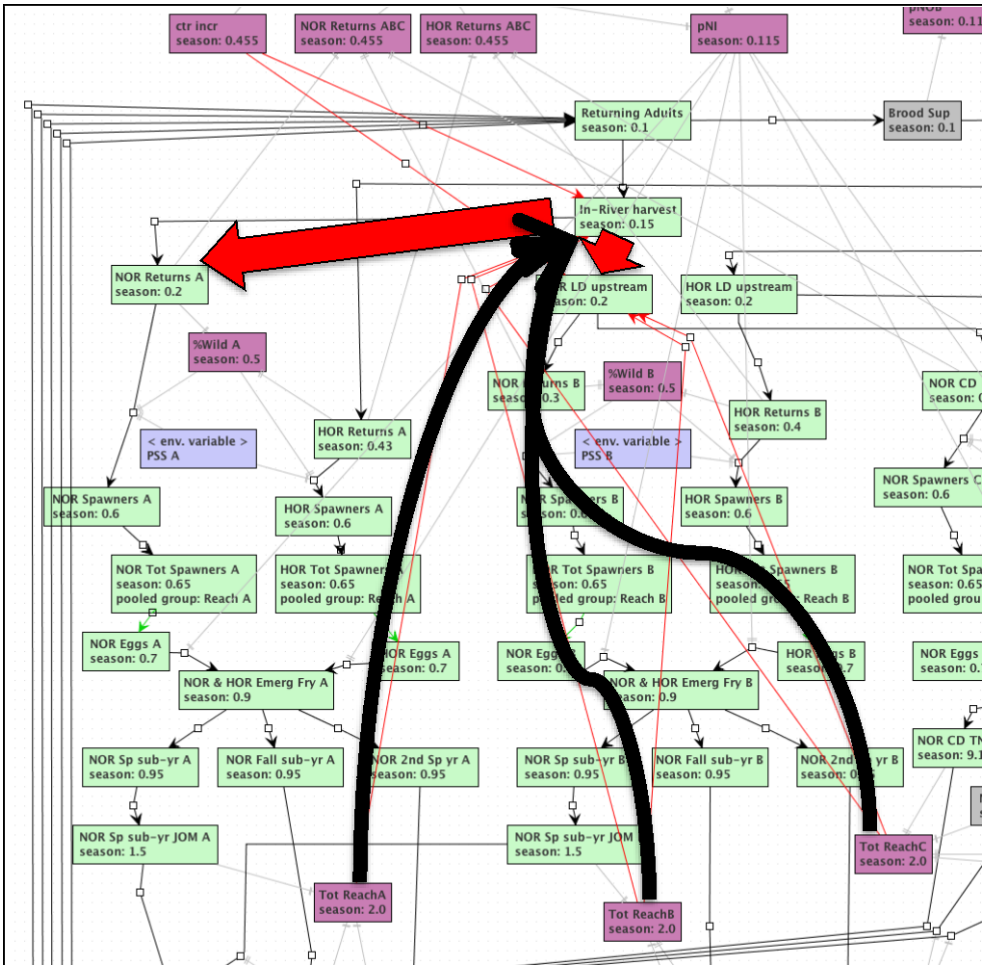
Proportion of Returning Adults that survived freshwater harvest (In-River harvest) to return to Reach A (NOR Returns A) or move upstream of Leaburg Dam (NOR LD upstream). In the process of simplifying the SLAM model structure, we pooled together juveniles from all reaches starting at the estuary stage since estuary/ocean survivals and ocean and mainstem harvest were applied equally to fish from all reaches. Because of homing of adult Chinook salmon to their natal reaches, we reapportioned returning adults in year *t* back to their natal reaches according to the numbers of juveniles produced in year *t* - 4. Specifically, for each simulated year we quantified the proportion of juveniles that exited each reach. These proportions were then used to split Returning Adults (four simulated years later) that survived freshwater harvest (In-River harvest) to those that return to Reach A (NOR Returns A) and those that continue upstream of Leaburg Dam (NOR LD upstream). To achieve this in SLAM we used a tool called a Split Influence, which influences the ratios of a split (McElhany et al. 2012). After the model was initialized with a fixed set of ratios for a split, the Split Influence determined the split from the juvenile counts four years previously:

$$Proportion\ of\ fish\ returning\ to\ NOR\ Returns\ A = \left(\frac{Tot\ ReachA}{Tot\ ReachA + Tot\ ReachB + Tot\ ReachC}\right)$$

Tot ReachA, B, and C correspond to the abundance of reach-specific juvenile outmigrants. This equation was applied for model years 4 and onward. For the first 3 years of model runs we apportioned fish to reaches according to a fixed proportion.

From	To	Proportion
In-River harvest	NOR Returns A	Split influence (otherwise 0.118)
	NOR LD upstream	Split influence (otherwise 0.882)

Values taken from Hendrix and Shi (2012) (page 10) and are based on carcass and red counts from Schroeder et al. (2005 and 2007), Kenaston et al. (2009), and Cannon et al. (2010).



Black lines show that three boxes (Tot ReachA, Tot ReachB, and Tot ReachC) are used to influence the split of fish from In-River harvest to either NOR Returns A or NOR LD upstream. Tot ReachA, Tot ReachB, and Tot ReachC sum all the juveniles that exit Reach A, B, and C, respectively.

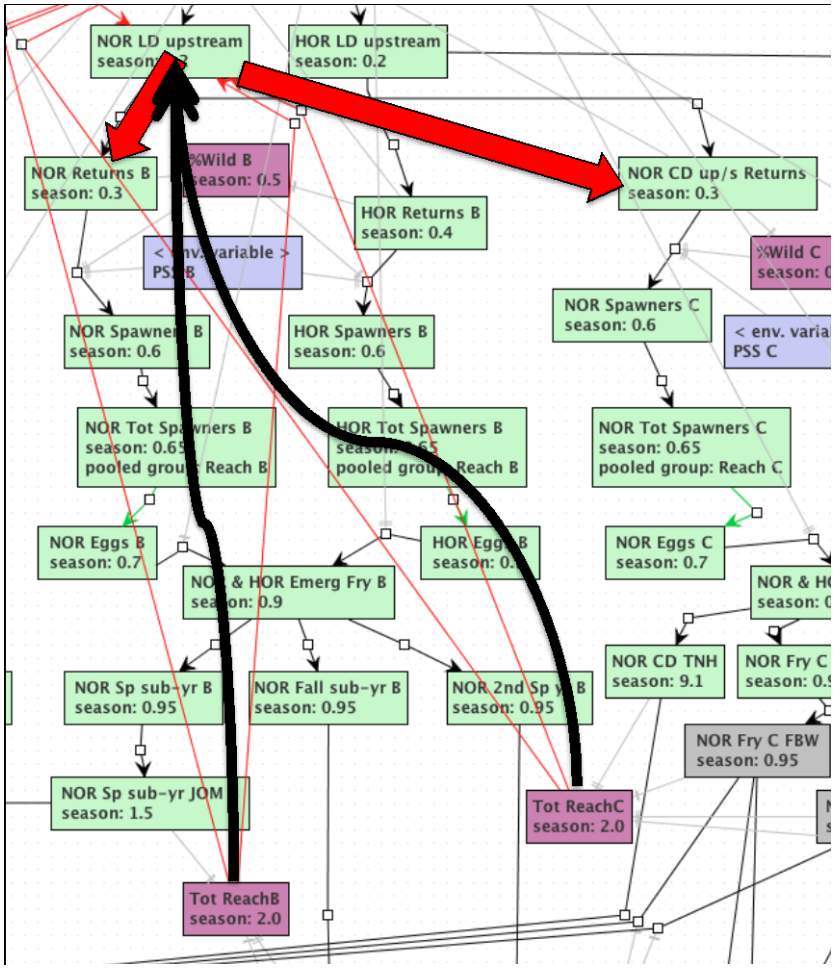
Proportion of NORs above Leaburg Dam (NOR LD upstream) that will return to either Reach B (NOR Returns B) or upstream of Cougar Dam (NOR CD up/s Returns). We followed the same procedure, noted above, to calculate the proportion of adults that return to Reach B or above Cougar Dam) during the simulation run.

$$Proportion\ of\ fish\ returning\ to\ NOR\ Returns\ B = \left(\frac{Tot\ ReachB}{Tot\ ReachB + Tot\ ReachC}\right)$$

Tot ReachB and C correspond to the abundance of juvenile outmigrants, when pooling life history strategies, for each reach.

From	To	Proportion
NOR LD upstream	NOR Returns B	Split influence (otherwise 0.72)
	NOR CD up/s Returns	Split influence (otherwise 0.28)

Values taken from Hendrix and Shi (2012) (page 12).



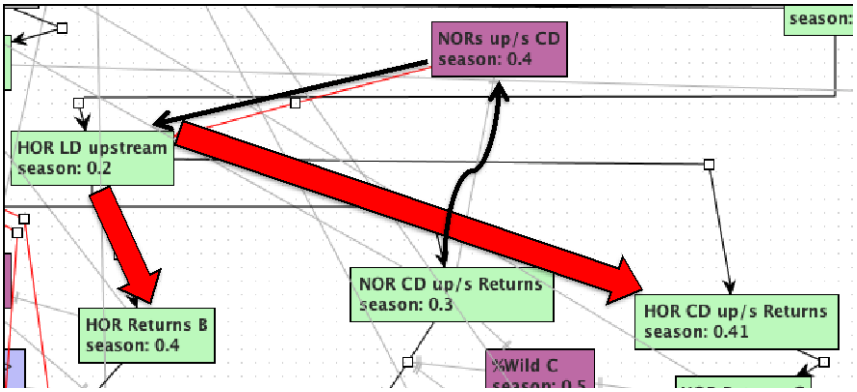
Black lines show that two boxes (Tot ReachB and Tot ReachC) are used to influence the split of fish from NOR LD upstream to either NOR Returns B or NOR CD up/s Returns. Tot ReachB and Tot ReachC sum all the juveniles that exit Reach B and C, respectively.

Proportion of hatchery origin adults upstream of Reach A (HOR LD upstream) that return to Reach B (HOR Returns B) or Reach C (HOR CD up/s Returns). These proportions are based on abundance of natural origin adults that are put above Cougar Dam. Specifically, for each simulated year SLAM determines the abundance of NORs returning to Cougar Dam, which are put into Reach C (above Cougar Dam). When fewer than 200 natural origin fish are counted in Reach C, then 72% of hatchery fish return to Reach B (HOR Returns B) while the remaining 28% are outplanted to Reach C (HOR CD up/s Returns). When greater than 800 natural origin fish are counted in Reach C, then 100% of hatchery fish from Leaburg Dam return to Reach B (HOR Returns B). When the number of natural origin fish in Reach C is between 200 and 800 individuals, then a linear relationship (below) is used to calculate the proportion of hatchery fish in Reach B versus Reach C.

$$Proportion\ of\ hatchery\ fish\ that\ return\ to\ Reach\ B\ = 0.72\ + (0.28 \times (\frac{NORs\ Reach\ C - 200}{600})$$

From	To	Proportion
HOR LD upstream	HOR Returns B	Split influence (otherwise 0.72)
	HOR CD up/s Returns	Split influence (otherwise 0.28)

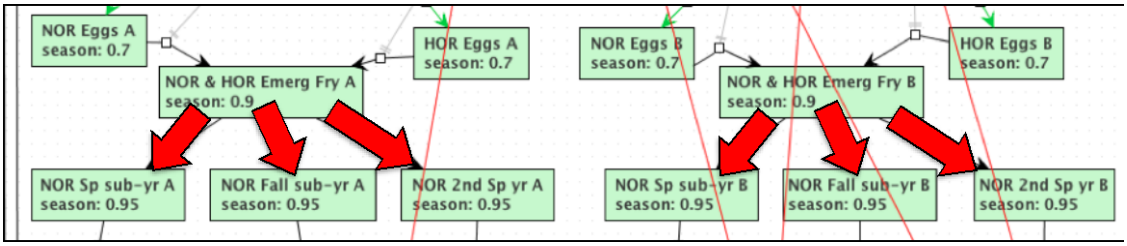
Values taken from Hendrix and Shi (2012) (page 13).



Black arrows show that one box (NOR CD up/s Returns) is used to influence the split of fish from HOR LD upstream to either (red arrows) HOR Returns B or HOR CD up/s Returns. NOR CD up/s Returns corresponds to the number of natural origin fish returning above Cougar Dam.

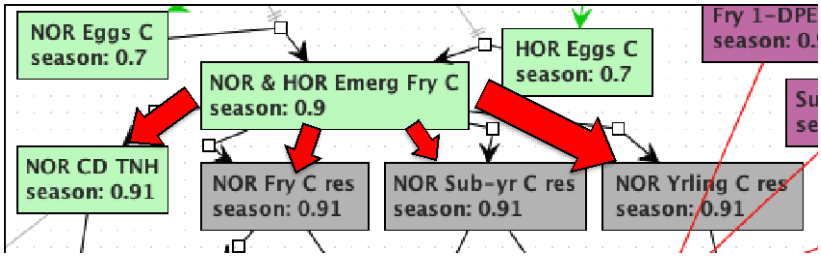
Proportion of emergent fry (NOR & HOR Emerg Fry) within Reach A and B that become spring sub-yearling (NOR Sp sub-yr), fall sub-yearling (NOR Fall sub-yr), and second spring yearling (NOR 2nd Sp yr). The proportions of emergent fry in reaches A and B that followed particular life history trajectories were determined based on Mattson (1962).

From	To	Proportion
NOR & HOR Emerg Fry A	NOR Sp sub-yr A	0.41
	NOR Fall sub-yr A	0.304
	NOR 2nd Sp yr A	0.286
NOR & HOR Emerg Fry B	NOR Sp sub-yr B	0.41
	NOR Fall sub-yr B	0.304
	NOR 2nd Sp yr B	0.286



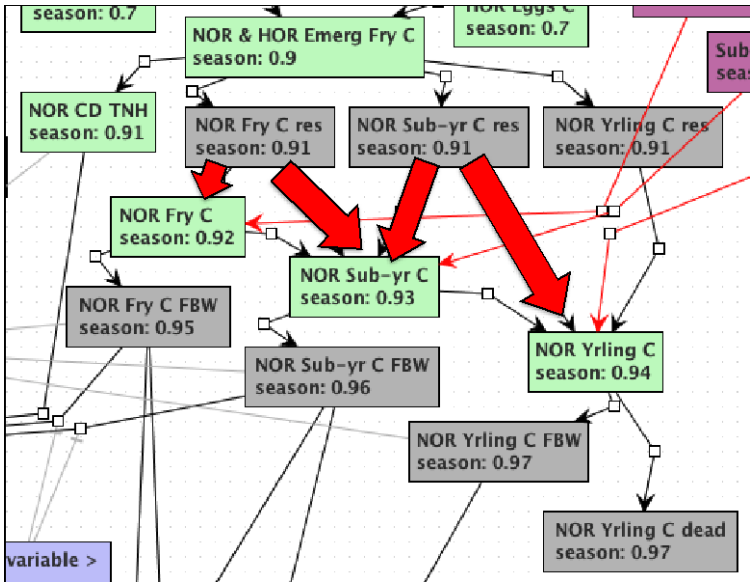
Proportion of emergent fry (NOR & HOR Emerg Fry) within Reach C that become reservoir fry (NOR Fry C res), sub-yearlings (NOR Sub-yr C res), yearlings (NOR Yrling C res) or are transported downstream (NOR CD TNH). In Reach C, above Cougar Dam, the proportions of juveniles of the three life history strategies entering the reservoir were based on data from rotary screw-traps located upstream of Cougar reservoir (ODFW, unpublished data).

From	To	Proportion
NOR & HOR Emerg Fry C	NOR CD TNH	0
	NOR Fry C res	0.94
	NOR Sub-yr C res	0.05
	NOR Yrling C res	0.01



Proportion of reservoir fry and sub-yearlings that remain or change life history strategies. Proportion of fry and sub-yearling in Cougar reservoir (NOR Fry C res and NOR Sub-yr C res, respectively) that remain as fry (NOR Fry C) or rear in the reservoir and become sub-yearlings (NOR Sub-yr C), and remain as sub-yearlings (NOR Sub-yr C) or rear in the reservoir and become yearlings (NOR Yrling C). These values are from parameter workshops (see Chapter 3, appendix 3.6).

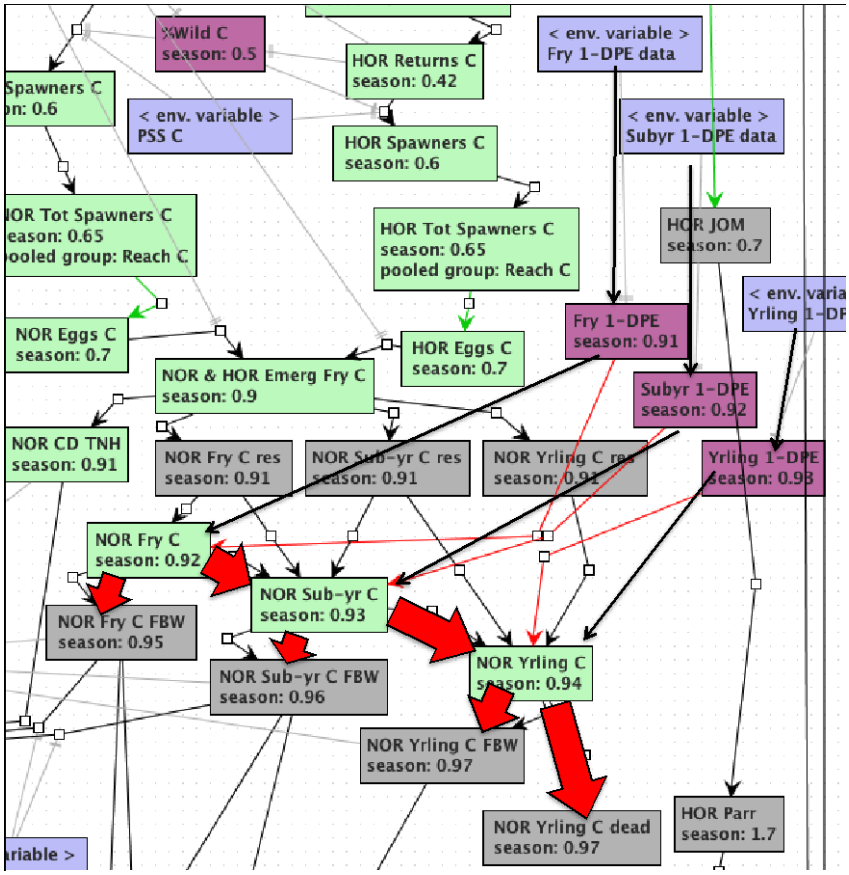
From	To	Proportion
NOR Fry C res	NOR Fry C	0.03-0.1
	NOR Sub-yr C	0.9-0.97
NOR Sub-yr C res	NOR Sub-yr C	0.75-0.9
	NOR Yrling C	0.1-0.25



Proportion of individuals in Cougar reservoir that are available to pass Cougar Dam or unavailable to pass and thus remain rear in the reservoir. Fry in Cougar reservoir (NOR Fry C) that are available to pass Cougar Dam (NOR Fry C FBW) or unavailable to pass and thus remain in the reservoir and become sub-yearlings (NOR Sub-yr C). Proportion of sub-yearlings in Cougar reservoir (NOR Sub-yr C) that are available to pass Cougar Dam (NOR Sub-yr C FBW) or unavailable to pass and thus remain in the reservoir and become yearlings (NOR Yrling C). Proportion of yearlings in Cougar reservoir (NOR Yrling C) that are available to pass Cougar Dam (NOR Yrling C FBW) or unavailable to pass, and are removed from the simulation (NOR Yrling C dead). These

proportions use dam passage efficiency (DPE) estimates that were specific to particular dam project alternatives and were provided by USACE in the FBW.

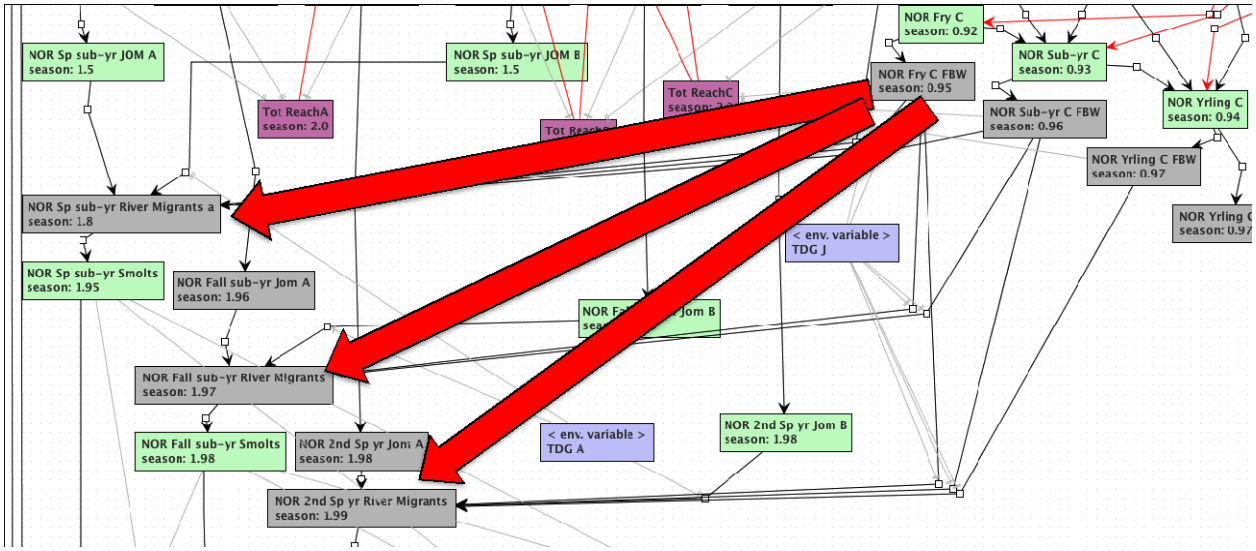
From	To	Proportion
NOR Fry C	NOR Fry C FBW	Split influencer determined by DPE file
	NOR Sub-yr C	Split influencer determined by DPE file
NOR Sub-yr C	NOR Sub-yr C FBW	Split influencer determined by DPE file
	NOR Yrling C	Split influencer determined by DPE file
NOR Yrling C	NOR Yrling C FBW	Split influencer determined by DPE file
	NOR Yrling C dead	Split influencer determined by DPE file



Black arrows represent the split influence from dam passage efficiency data.

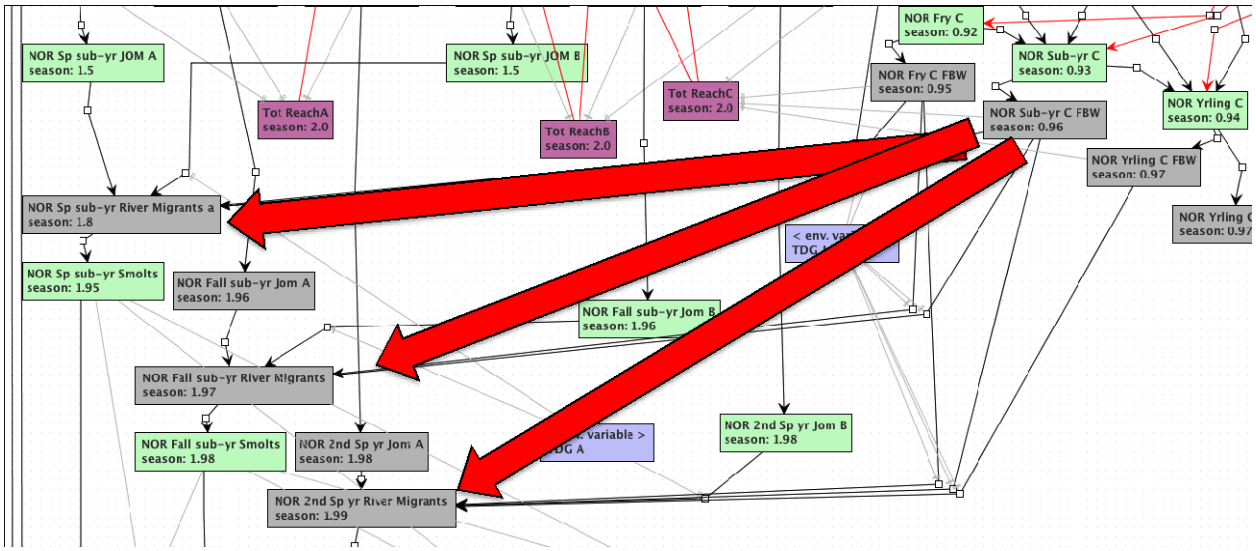
Proportion of fry downstream of Cougar Dam (NOR Fry C FBW) that become spring sub-yearlings (NOR Sp sub-yr C River Migrants a), fall sub-yearlings (NOR Fall sub-yr River Migrants), or second spring yearlings (NOR 2nd Sp yr River Migrants). These values are taken from parameter workshops (see Chapter 3, appendix 3.6).

From	To	Proportion
NOR Fry C FBW	NOR Sp sub-yr River Migrants a	0.1-0.33
	NOR Fall sub-yr River Migrants	0.6 (0.4-0.65)
	NOR 2nd Sp yr River Migrants	0.3 (0.1-0.33)



Proportion of sub-yearlings downstream of Cougar Dam (NOR Sub-yr C FBW) that become spring sub-yearling (NOR Sp sub-yr C River Migrants a), fall sub-yearlings (NOR Fall sub-yr River Migrants), or second spring yearlings (NOR 2nd Sp yr River Migrants). These values are from parameter workshops (see Chapter 3, appendix 3.6).

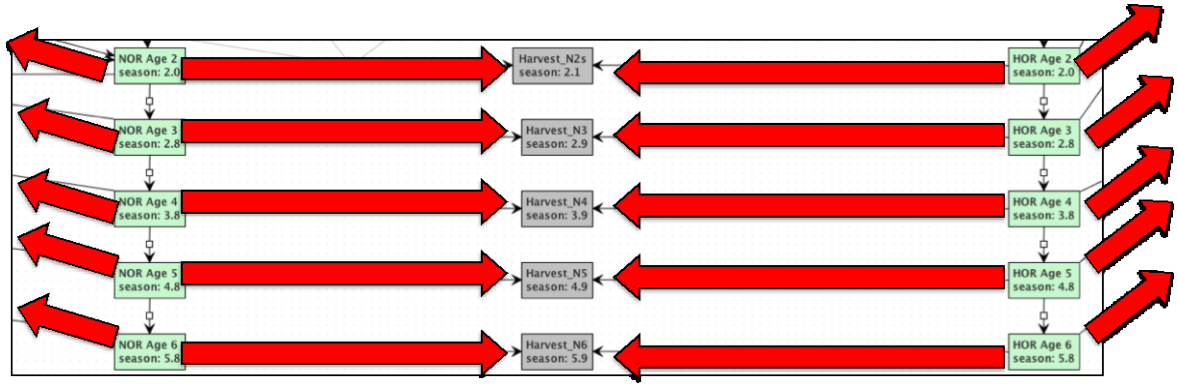
From	To	Proportion
NOR Sub-yr C FBW	NOR Sp sub-yr River Migrants a	0
	NOR Fall sub-yr River Migrants	0.6-0.7
	NOR 2nd Sp yr River Migrants	0.3-0.4



Proportional splits of ocean adults (NOR/HOR Age 2, 3, 4, 5, & 6) that stay in the ocean for another year, are harvested in the ocean, or return to freshwater.

From	To	Proportion
NOR Age 2	NOR Age 3	0.999
	Harvest N2	0
	Returning Adults	0.001
HOR Age 2	HOR Age 3	0.999
	Harvest N2	0
	HOR In-River harvest	0.001
NOR Age 3	NOR Age 4	0.996
	Harvest N3	0.002
	Returning Adults	0.002
HOR Age 3	HOR Age 4	0.996
	Harvest N3	0.002
	HOR In-River harvest	0.002
NOR Age 4	NOR Age 5	0.6
	Harvest N4	0.09
	Returning Adults	0.31
HOR Age 4	HOR Age 5	0.6
	Harvest N4	0.09
	HOR In-River harvest	0.31
NOR Age 5	NOR Age 6	0.03
	Harvest N5	0.09
	Returning Adults	0.88
HOR Age 5	HOR Age 6	0.03
	Harvest N5	0.09
	HOR In-River harvest	0.88
NOR Age 6	Harvest N5	0
	Returning Adults	1
HOR Age 6	Harvest N5	0
	HOR In-River harvest	1

Values taken from Hendrix and Shi (2012) (page 22-31), which are based on ODFW SLAM parameter values and adjusted to fit age composition from ODFW.



4.3. Datafiles

Most parameter values are scalars or are drawn from distributions according to parameters within SLAM, however there are stage transitions within the life-cycle model where survivals or life history splits come from datafiles. For example, dam passage survival and efficiency, and environmental variables like temperature, enter into SLAM as a datafile. The following are the stages or stage transitions that call a datafile with survivals or splits.

4.3.1. Survivals

Stage at which datafile is used	Name of datafile	Name of series
NOR Fry C FBW	Cougar_FBW_Alternatives_toSLAM.csv	Baseline-April 15 2014 FBW-Fry-146yr
NOR Sub-yr C FBW	Cougar_FBW_Alternatives_toSLAM.csv	Baseline-April 15 2014 FBW-Subyr-146yr
NOR Yrling C FBW	Cougar_FBW_Alternatives_toSLAM.csv	Baseline-April 15 2014 FBW-Yrling-146yr
NOR Sp sub-yr Smolts	EstuaryCurrent_modified_1_2013.csv	EstuaryCurrent x 2 (200yrs)
NOR Fall sub-yr Smolts	EstuaryCurrent_modified_1_2013.csv	EstuaryCurrent x 2 (200yrs)
NOR 2nd Sp yr Smolts	EstuaryCurrent_modified_1_2013.csv	EstuaryCurrent x 2 (200yrs)
HOR Smolts	EstuaryCurrent_modified_1_2013.csv	EstuaryHatOr x 2 (200yrs)
NOR HOR Age 2	ChSOcean4thRt_modified_1_2013.csv	ChSAge2 10% down x 2 (200yrs)
NOR HOR Age 3	ChSOcean4thRt_modified_1_2013.csv	ChSAge3 10% down x 2 (200yrs)
NOR HOR Age 4	ChSOcean4thRt_modified_1_2013.csv	ChSAge4 10% down x 2 (200yrs)
NOR HOR Age 5	ChSOcean4thRt_modified_1_2013.csv	ChSAge 5 x 2 (200yrs)
NOR HOR Age 6	ChSOcean4thRt_modified_1_2013.csv	ChSAge 6 x 2 (200yrs)
TDGJ	TDGCougar_modified 12 2012.csv	IRRMBaselineJuvenile x 2 (146yrs) 15%reduction
TDGA	TDGCougar_modified 12 2012.csv	IRRMBaselineAlevinDSCD x 2 (146yrs) 15%reduction
PSS A	McKenzie_Temp_Max7-DADM.csv	Baseline Reach A 200yr max7DADM (based on 5yrs of USGS data)
PSS B	McKenzie_Temp_Max7-DADM.csv	Baseline Reach B 200yr max7DADM (based on 12yrs of USGS data)
PSS C	McKenzie_Temp_Max7-DADM.csv	Baseline Reach C 200yr max7DADM (based on 12yrs of USGS data)

4.3.2. Splits

Stage at which datafile is used	Name of datafile	Recruit stage datafile is applied	Name of series
NOR Fry C res	NOR Fry C res.csv	NOR Fry C	Baseline NOR Fry C
		NOR Sub-yr C	Baseline NOR Sub-yr C
NOR Sub-yr C res	NOR Sub-yr C res.csv	NOR Sub-yr C	Baseline NOR Sub-yr C
		NOR Yrling C	Baseline NOR Yrling C
NOR Fry C FBW	NOR Fry C FBW.csv	NOR Sp sub-yr River Migrants a	NOR Sp sub-yr River Migrants a
		NOR Fall sub-yr River Migrants	NOR Fall sub-yr River Migrants
		NOR 2nd Sp yr River Migrants	NOR 2nd Sp yr River Migrants
NOR Sub-yr C FBW	NOR Sub-yr C FBW.csv	NOR Sp sub-yr River Migrants a	NOR Sp sub-yr River Migrants a
		NOR Fall sub-yr River Migrants	NOR Fall sub-yr River Migrants
		NOR 2nd Sp yr River Migrants	NOR 2nd Sp yr River Migrants

USACE provided R2 Consultants, who in turn provided NWFSC, with the following SLAM datafiles; EstuaryCurrent, ChSOcean4thRt, TDGCougar, and McKenzie_Temp_Max7-DADM. Each of the aforementioned files was expanded by NWFSC by repeating from the beginning, such that the files that were 74 years became 146 years, and those that were 100 years became 200 years. USACE provided Fish Benefits Workbooks datafiles that correspond to dam passage survival (e.g. Cougar_FBW_Alternatives_toSLAM.csv) and dam passage efficiency (e.g., Cougar_1-DPE_Alternatives_toSLAM.csv) (Fish Benefits Workbooks User Guide 2014).

4.4. Dynamic Drivers and Influence Scripts

In some cases we used scripts to influence life stage transitions and splits. These were written in a Java-compatible syntax and are called groovy script. These gave us the ability to dynamically influence splits such as apportioning adults to natal reaches based on juvenile outmigrants four years earlier, or for applying the dam passage efficiency (DPE) to juveniles attempting to pass the dam. Below is a list of boxes where dynamic drivers are applied.

Box where dynamic driver is located	Dynamic driver file name	What does dynamic driver do?
pNOB	pNOB.groovy	Calculates proportion of natural origin broodstock.
NOR Adults	NORs.groovy	Counts the number of NORs at Willamette Falls.
pNI	pNI.groovy	Calculates proportion of natural influence.
NORs up/s CD	NORs.groovy	Counts the number of NORs in Reach C.
HOR Returns ABC	HOR_Returns_ABC.groovy	Calculates total number of hatchery origin adults that returned to Reach A, B, & C.
NOR Returns ABC	NOR_Returns_ABC.groovy	Calculates total number of natural origin adults that returned to Reach A, B, & C.
ctr incr	ctr_incr.groovy	A counter to keep track of the year number being simulated.
%Wild A, B, or C	%Wild.groovy	Calculates percent of natural origin fish with each Reach.
Fry 1-DPE	1-DPE.groovy	Takes proportion from DPE datafile and calculates the proportion of fry that pass dam.
Subyr 1-DPE	1-DPE.groovy	Takes proportion from DPE datafile and calculates the proportion of sub-yearlings that pass dam.
Yrling 1-DPE	1-DPE.groovy	Takes proportion from DPE datafile and calculates the proportion of yearlings that pass dam.
Fall sub-yr	Prop per Strategy-at Smolt.groovy	Calculates proportion of smolts that are fall sub-yearlings.
Sp sub-yr	Prop per Strategy-at Smolt.groovy	Calculates proportion of smolts that are spring sub-yearlings.
2nd Sp yr	Prop per Strategy-at Smolt.groovy	Calculates proportion of smolts that are second spring yearlings.
Tot Reach A & B JOM	Tot ReachAB JOM.groovy	Calculates total number of juveniles that exit Reach A & B that is then used to calculate proportion of juveniles that exit each reach (see Split Influencer below).
Tot Reach C JOM	Tot ReachC JOM.groovy	Calculates total number of juveniles that exit Reach C that is then used to calculate proportion of juveniles that exit each reach (see Split Influencer below).

Stage where influence script is located	Groovy script file name	What does script do?
HOR JOM	HOR JOM.groovy	
NOR or HOR Spawners A, B, & C	PSM.groovy	Calculates prespawn survival by using reach specific temperature and % wild as inputs PSM=((-9.5789)+(%wild * -2.39)+(Temp * 0.5492)); modified from Roumasset (2012) equation.
pHOS ABC 2	pHOS ABC 2.groovy	Calculates proportion of hatchery origin spawners.
pNI counter	PNI counter.groovy	A counter to keep track of the year number being simulated.
pHOS ABC 3	pHOS ABC 3.groovy	Calculates proportion of hatchery origin spawners.
NOR & HOR Emerg Fry A, B, or C	pNI_NORs Eggs to Emerg Fry.groovy	Calculates proportion of eggs that survive.
NOR & HOR Emerg Fry A, B, or C	pNI_HORs Eggs to Emerg Fry.groovy	Calculates proportion of eggs that survive.
NOR Sp sub-yr River Migrants a	TDG.groovy	Calculates proportion of alevins that survive the total dissolved gas.
NOR Fall Sub-yr River Migrants	TDG.groovy	Calculates proportion of alevins that survive the total dissolved gas.
NOR 2nd Sp yr River Migrants	TDG.groovy	Calculates proportion of alevins that survive the total dissolved gas.
Harvest_N2s	Harvest_N2s.groovy	Calculates total number of hatchery and natural origin fish that are harvested.

Split where split influencer is located	Stage where groovy script is located	Groovy script file name	What does split influencer do?
Hatchery Adults	Hatchery returns	Hatchery returns.groovy	Calculates the proportion of Hatchery Adults that return to hatchery.
	HOR Adults	HOR Adults.groovy	Calculates the proportion of Hatchery Adults that stay in river.
In-River harvest	NOR Returns A	NOR Returns A.groovy	Calculates the proportion of natural origin adults that go to Reach A.
	NOR LD upstream	NOR LD upstream.groovy	Calculates the proportion of natural origin adults that go above Reach A.
NOR LD upstream	NOR Returns B	NOR Returns B.groovy	Calculates the proportion of natural origin adults at Leaburg Dam that stay to Reach B.
	NOR CD upstream Returns	NOR CD ups Returns.groovy	Calculates the proportion of natural origin adults at Leaburg Dam that go to Reach C.
HOR LD upstream	HOR Returns B	HOR Returns B.groovy	Calculates the proportion of hatchery origin adults at Leaburg Dam that go to Reach B.
	HOR CD up/s Returns	HOR CD ups Returns.groovy	Calculates the proportion of hatchery origin adults at Leaburg Dam that go to Reach C.
NOR Fry C	NOR Sub-yr C	NOR Sub-yr C.groovy	Calculates the proportion of fry in Cougar reservoir that stay in Cougar reservoir to become sub-yearlings.
	NOR Fry C FBW	NOR Fry C FBW.groovy	Calculates the proportion of fry in Cougar reservoir that attempt to pass Cougar Dam.
NOR Sub-yr C	NOR Yrling C	NOR Yrling C.groovy	Calculates the proportion of sub-yearlings in Cougar reservoir that stay in Cougar reservoir to become yearlings.
	NOR Sub-yr C FBW	NOR Sub-yr C FBW.groovy	Calculates the proportion of sub-yearlings in Cougar reservoir that attempt to pass Cougar Dam.
NOR Yrling C	NOR Yrling C FBW	NOR Yrling C FBW.groovy	Calculates the proportion of yearlings in Cougar reservoir that attempt to pass Cougar Dam.
	NOR Yrling C dead	NOR Yrling C dead.groovy	Calculates the proportion of yearlings in Cougar reservoir that do not pass Cougar Dam.

4.5. Initialization Values

When SLAM begins a simulation not all of the boxes are populated with fish. As a result, the first several simulated years can show large fluctuations in abundance and frequent extinctions. To reduce these fluctuations many of the boxes are initialized with a number of fish at the start of the model. The values used to initialize these boxes were taken from the 100th year in a previous baseline simulation.

Stage	Baseline
Hatchery Adults	3,900
Hatchery returns	500
Returning Adults	2,000
Hatchery Spawners	590
HOR Adults	400
pNOB	100
pNI	231
In-River harvest	40
NOR Returns A	1
NOR LD upstream	39
HOR LD upstream	21
NOR Returns B	37
NOR CD up/s Returns	3
HOR Returns B	18
HOR CD up/s Returns	3
HOR Returns C	3
HOR Returns A	2
pHOS ABC 1	2
pNI counter	20
HOR Returns ABC	1,000
NOR Returns ABC	1,000
ctr incr	20
% Wild A, B, C	500
NOR Spawners A	8
HOR Spawners A	19
NOR Spawners B	350
HOR Spawners B	170
NOR Spawners C	10
HOR Spawners C	20
NOR Tot Spawners A	8
HOR Tot Spawners A	10
NOR Tot Spawners B	350
HOR Tot Spawners B	170
NOR Tot Spawners C	10
HOR Tot Spawners C	20
NOR Eggs A	100
HOR Eggs A	200
HOR Eggs B	5,000
NOR Eggs B	5,000
NOR Eggs C	300
HOR Eggs C	500
NOR & HOR Emerg Fry A	48
NOR & HOR Emerg Fry B	1,600
NOR & HOR Emerg Fry C	200
NOR Sp sub-yr A	30
NOR Fall sub-yr A	14
NOR 2nd Sp yr A	13
NOR Sp sub-yr B	1,300
NOR Fall sub-yr B	530
NOR 2nd Sp yr B	620
NOR CD TNH	-
Fry 1-DPE	70
NOR Fry C	10
Subyr 1-DPE	41
NOR Sub-yr C	10
Yrling 1-DPE	48
NOR Yrling C	10
NOR Sp sub-yr JOM B	1,250
NOR Sp sub-yr JOM A	30
NOR Sp sub-yr Smolts	5,000
HOR Smolts	80,000
NOR Fall sub-yr Jom B	500
NOR 2nd Sp yr Jom B	580
NOR Fall sub-yr Smolts	5,000
Nor 2nd Sp yr Smolts	5,000
Sp sub-yr, Fall sub-yr, 2nd yr	333
Tot Reach A	60
Tot Reach B	2,350
Tot Reach C	100
NOR Age 2	10,000
HOR Age 2	41,000
NOR Age 3	5,000
HOR Age 3	23,000
NOR Age 4	3,000
HOR Age 4	16,000
NOR Age 5	1,500
HOR Age 5	7,000
NOR Age 6	50
HOR Age 6	100

4.5.1. Model Demonstration & Alternative Scenarios

Here we report results from SLAM model runs that evaluated potential population responses to a set of the most recent dam project alternatives (received May 28, 2014) identified by the USACE. Below (Table 4.3) is a list of alternatives that represent various operational and structural modifications to Cougar Dam whose goal is to improve access to Reach C (above Cougar Dam). Each alternative was run in SLAM and estimates were produced of several variables including abundance of natural origin spawners and each life history strategy, and percent wild. Each alternative was run 500 times, and each run is 100 years long. We used 500 runs because output stabilized at this level. USACE provided datafiles of dam passage survival and efficiency (Fish Benefit Workbook), which were time series of 73 years in length, and we duplicated them to produce time series that were 146 years in length. All alternatives were provided by USACE.

Table 4.3: List of alternatives run in the SLAM model of McKenzie River Chinook salmon. Alternatives vary only in terms of dam passage survival, efficiency, and the influence of total dissolved gas (TDG) (it is assumed that trap and haul alternatives will release fish below any TDG influence). Description of each alternative can be found in Appendix D.

	Alternative Description	SLAM output name	Passage survival (average %)			1-DPE (average %)			Trap & Haul releases fish below TDG influence?
			Fry	Sub-yr	Yrling	Fry	Sub-yr	Yrling	
1	Baseline	Baseline	62	44	40	87	65	72	NA
2	Floating Screen Str with Tower	FSS-T	93	92	91	30	30	30	Y
3	Floating Screen Str above 1571	FSS 1571	93	87	76	30	34	43	Y
4	Floating Screen Str above 1571 (40% DPE)	FSS 1571 40	93	85	71	60	60	59	Y
5	Floating Screen Str above 1571 (80% DPE)	FSS 1571 80	93	88	78	20	26	38	Y
6	DrawdownRO	DrawdownRO	61	56	73	85	57	70	NA
7	DelayRefill until June 15	DelayRefill	82	80	73	58	59	59	NA

4.5.2. Parameter Variability

The following tables identify parameters that vary among years in each model run. In all the parameters listed below (except passage survival and estuary and ocean survival) values are randomly selected each model year from the specified distribution and these distributions and parameters defining them do not vary among alternatives (Table 4.4). For any given alternative, passage survival values vary among years of a model run, but do not vary among the 500 model runs (passage survival values are taken from a datafile). Values of passage survival vary among alternatives (Table 4.5). For any given alternative, estuary and ocean survival values vary among years of a model run, but do not vary among the 500 model runs (estuary and ocean survival values are taken from a datafile). Values of estuary and ocean survival do not vary among alternatives (Table 4.6).

Table 4.4: Capacity and survival parameters whose values vary among years in each model run and vary among model runs.

Location in Life Cycle Model	From	To	Curve type	Capacity &/or Productivity	Distribution type	Mean	SD	Min	Max
Hatchery	Hatchery Returns	Hatchery Spawners	Hockey-Stick	Capacity	Normal	600	100	550	750
Hatchery	Hatchery Spawners	HOR JOM	Hockey-Stick	Capacity	Normal	800,000	50,000	750,000	850,000
Reach A Downstream of Leaburg Dam	NOR Tot Spawners	Eggs	Beverton-Holt	Capacity	Normal	500,000	50,000	250,000	600,000
Reach B Above Leaburg Dam (w/o So. McKenzie)	NOR Tot Spawners	Eggs	Beverton-Holt	Capacity	Normal	8,000,000	250,000	2,000,000	15,000,000
Reach C Above Cougar Dam	NOR Tot Spawners	Eggs	Beverton-Holt	Capacity	Normal	17,000,000	500,000	4,000,000	22,000,000
Reach A Downstream of Leaburg Dam	HOR Tot Spawners	Eggs	Beverton-Holt	Capacity	Normal	500,000	50,000	250,000	600,000
Reach B Above Leaburg Dam (w/o So. McKenzie)	HOR Tot Spawners	Eggs	Beverton-Holt	Capacity	Normal	8,000,000	250,000	2,000,000	15,000,000
Reach C Above Cougar Dam	HOR Tot Spawners	Eggs	Beverton-Holt	Capacity	Normal	17,000,000	500,000	4,000,000	22,000,000
Reach C	NOR Fry C res	NOR Sub-yr C	Linear	Productivity	Triangular	0.20		0.15	0.35
Reach C	NOR Sub-yr C res	NOR Yrling C	Linear	Productivity	Uniform			0.40	0.90
Reach C	NOR Fry C	NOR Sub-yr C	Linear	Productivity	Triangular	0.20		0.50	0.35
Reach C	NOR Sub yr C	NOR Yrling C	Linear	Productivity	Uniform			0.40	0.90

Table 4.5: Average, minimum, and maximum passage survival for each alternative and life history strategy. These values vary among years of a model run but do not vary among model runs.

FBW		Average Passage Survival			Min Passage Survival			Max Passage Survival		
Output File name	Alternative	Fry	Sub-yr	Yrling	Fry	Sub-yr	Yrling	Fry	Sub-yr	Yrling
Ch_CGR_1_052814	Baseline-May 28 2014	0.62	0.44	0.40	0.59	0.34	0.29	0.64	0.57	0.51
Ch_CGR_2_052814	FSS-T-May 28 2014	0.93	0.92	0.91	0.85	0.54	0.85	0.97	0.96	0.97
Ch_CGR_3_052814	FSS 1571-May 28 2014	0.93	0.87	0.76	0.85	0.52	0.60	0.97	0.95	0.88
Ch_CGR_3a_052814	FSS 1571 40-May 28 2014	0.93	0.85	0.71	0.85	0.46	0.52	0.97	0.95	0.86
Ch_CGR_3b_052814	FSS 1571 80-May 28 2014	0.93	0.88	0.78	0.85	0.54	0.61	0.97	0.95	0.88
Ch_CGR_4_052814	DrawdownRO-May 28 2014	0.61	0.56	0.73	0.58	0.45	0.61	0.64	0.64	0.82
Ch_CGR_6_052814	DelayRefill-May 28 2014	0.82	0.80	0.73	0.78	0.70	0.70	0.87	0.88	0.76

Table 4.6: Average, minimum, and maximum survival values during estuary and ocean stages. Age-specific time series of estuary and ocean survival were generated by ODFW, and incorporated into SLAM as datafiles.

Stage	Min	Average	Max
Estuary	0.61	0.66	0.70
Ocean 2yr olds	0.22	0.35	0.51
Ocean 3yr olds	0.28	0.46	0.67
Ocean 4yr olds	0.33	0.54	0.78
Ocean 5yr olds	0.42	0.68	0.99
Ocean 6yr olds	0.47	0.76	1

4.5.3. SLAM Output and VSP Scores

For each alternative run in SLAM, four categories of model output are produced; abundance and productivity, proportion of hatchery origin spawners, life history diversity, and spatial structure (see Chapter 3, Parameterization of VSP Criteria). For each of these categories we generate VSP scores, and then use the following equation to produce a Total VSP score:

$$Total\ VSP\ score = \frac{2(Abundance) + 2(Productivity) + Diversity + Spatial\ Structure}{6}$$

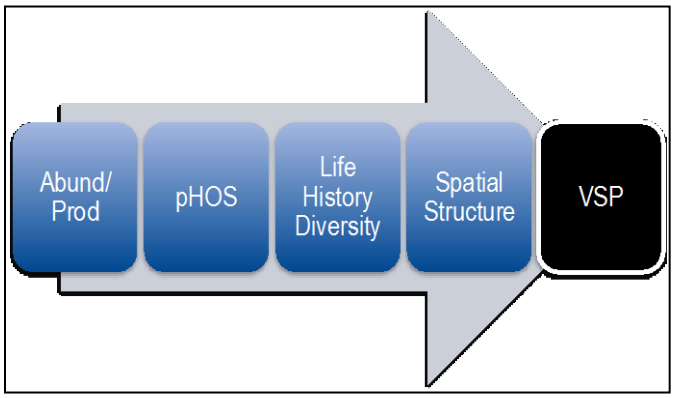


Figure 4.3: Representation of the four components (abundance and productivity, proportion of hatchery origin spawners, life history diversity, and spatial structure) that comprise VSP score.

Abundance and Productivity

Under Baseline (i.e., current) conditions, a median of 1,982 natural origin spawners was estimated for McKenzie River, while the Floating Screen Structure with Tower (FSS-T) alternative was estimated to have a median of 12,954 individuals (Figure 4.4 and Table 4.3).

We estimated the probability quasi-extinction threshold (QET) for each alternative under the following conditions; critical abundance was set as 250 individuals (set by the Lower Columbia/Willamette TRT), a four-year moving average was used over a 100-year period (from year 6 to year 105). We started QET calculation at year 6 because the model was fully initialized beyond this point and reflected system dynamics rather than the influences of starting values. Under Baseline (i.e., current) conditions, QET was estimated as 17% for the McKenzie River, while it was 0.4% for FSS-T alternative (Figure 4.5).

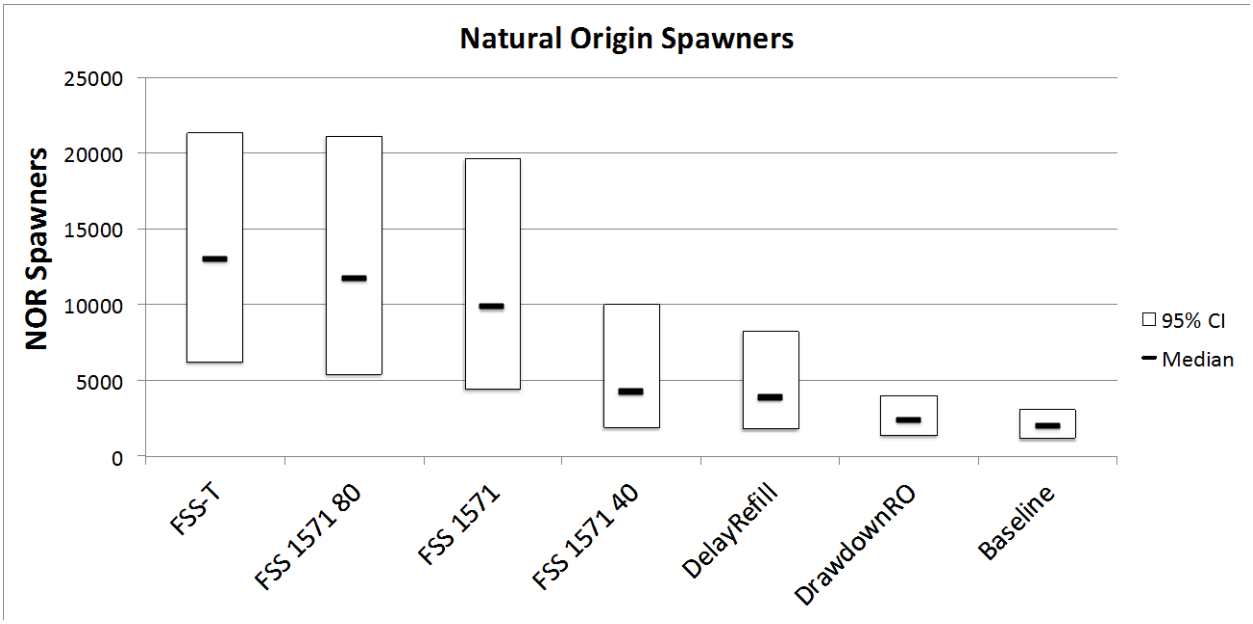


Figure 4.4: Abundance of natural origin spawners among McKenzie River alternatives (see Table 4.3). Median and 95% confidence limits (line and box, respectively) were calculated from the 500 geomeans (1 geomean per run) of abundance, each of which was for a 100-year period.

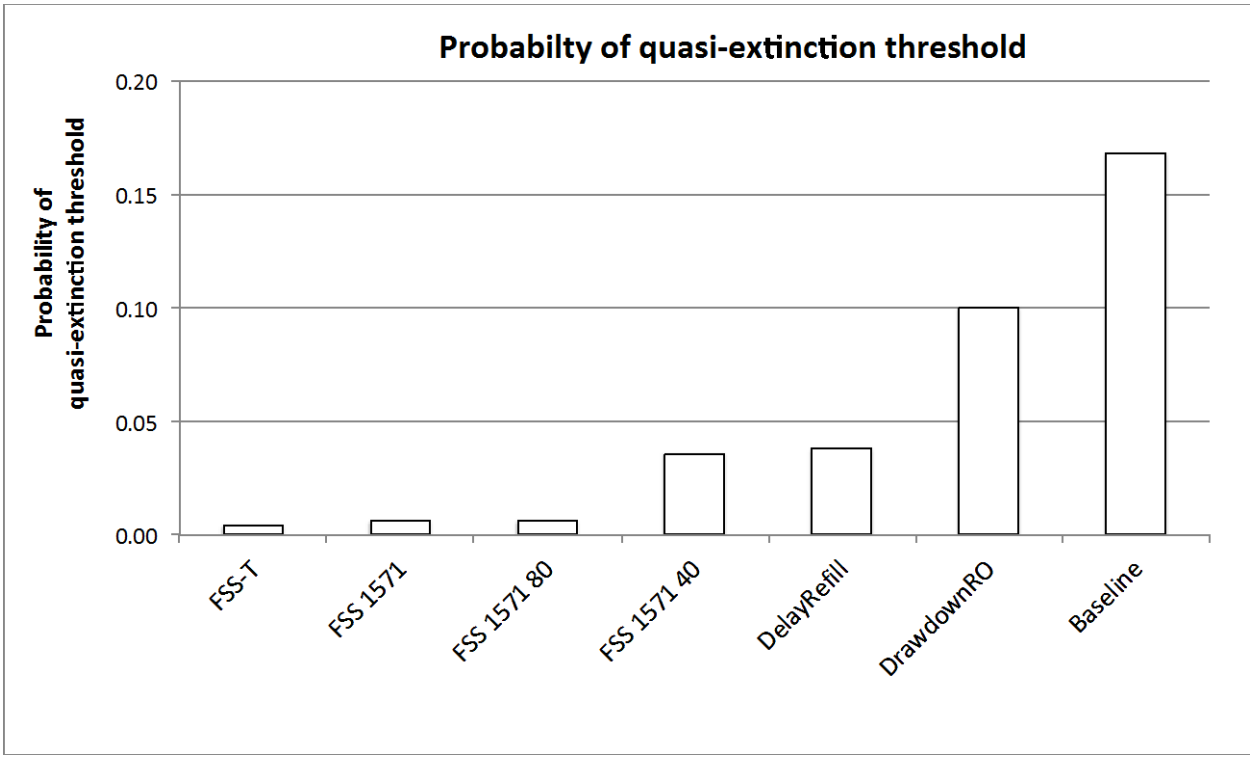


Figure 4.5: Probability of quasi-extinction among McKenzie River alternatives. The maximum value on the y-axis is 0.2 (instead of 1.0) to improve visibility of QET for several alternatives.

Based on a relationship between VSP score and abundance and productivity (see Chapter 3, Parameterization of VSP Criteria), the Baseline (i.e., current) conditions received a median VSP score of 2.5, while all other alternatives (except DrawdownRO) yielded median VSP scores greater than 3.0 (Figure 4.6).

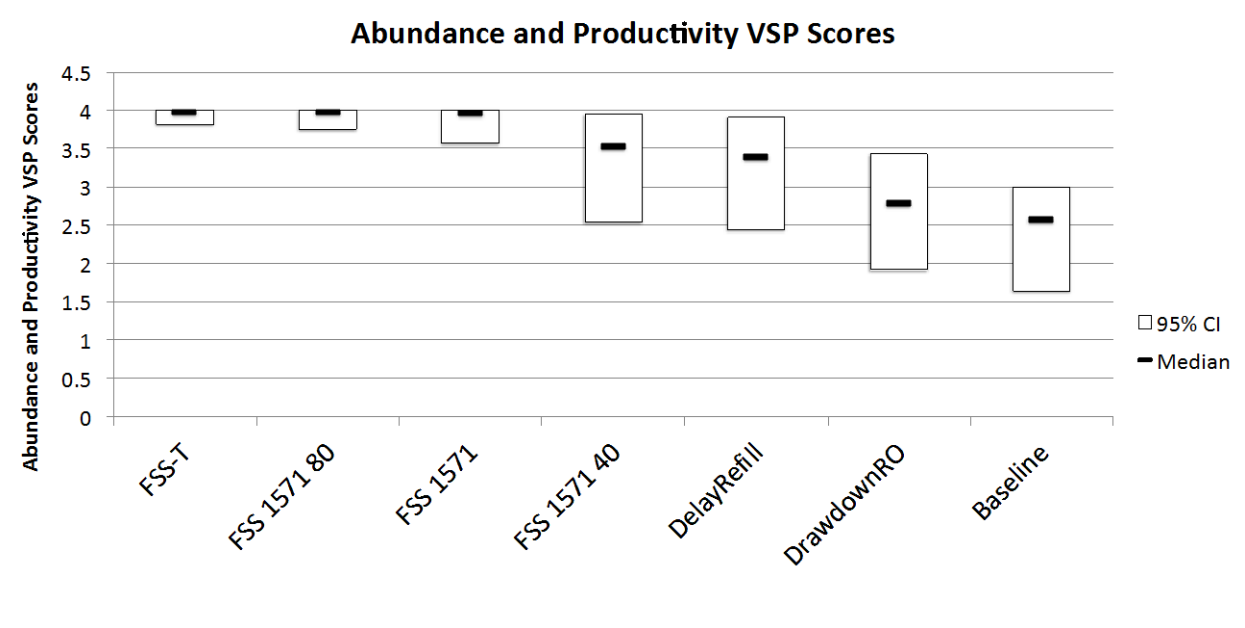


Figure 4.6: Abundance and Productivity VSP scores among McKenzie River alternatives.

Proportion of Hatchery Origin Spawners

Under Baseline (i.e., current) conditions, the median proportion of hatchery origin spawners was estimated as 0.19, while the Floating Screen Structure with Tower (FSS-T) alternative was estimated to have a median of 0.02. This decline in the proportion of hatchery origin spawners for the FSS-T alternative is due to an increase in natural origin spawners that resulted from improved dam passage efficiency and survival relative to the Baseline (Figure 4.7).

The VSP score for proportion of hatchery origin spawners is calculated based on a combination of proportion of natural influence and proportion of hatchery origin spawners (see Chapter 3, Parameterization of VSP Criteria). Under Baseline (i.e., current) conditions, a median VSP score of 2.4 was estimated, while the Floating Screen Structure with Tower (FSS-T) alternative was estimated to have a median of 3.9 (Figure 4.8).

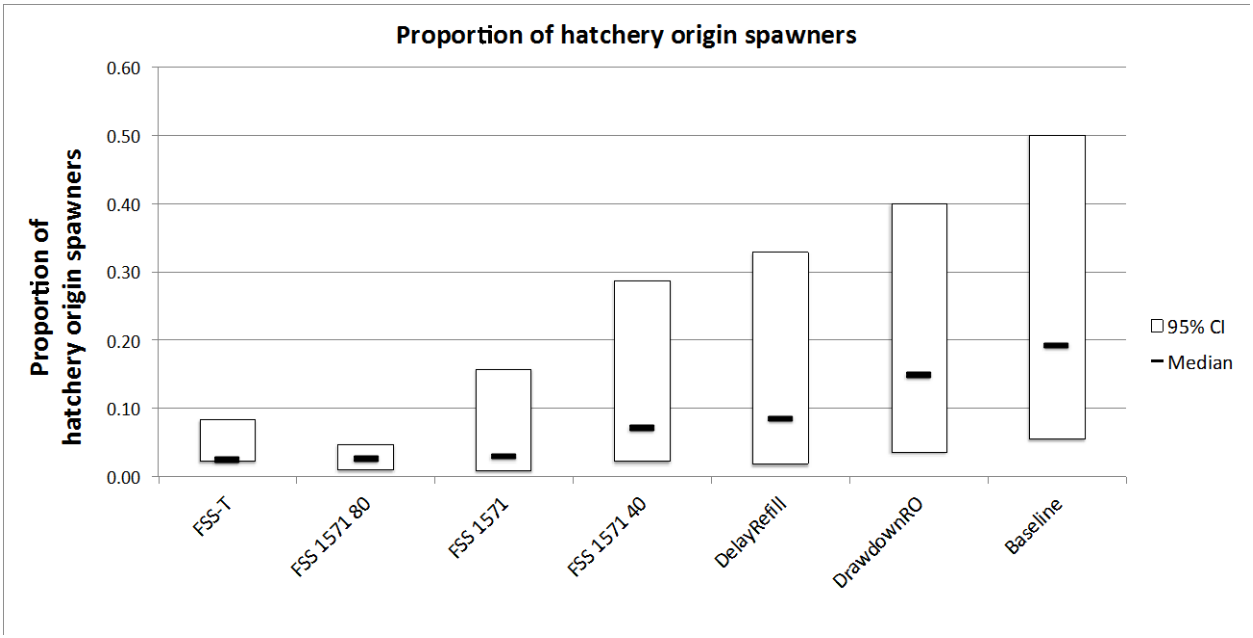


Figure 4.7: Proportion of hatchery origin spawners among McKenzie River alternatives (see Table 4.3). Median and standard deviation are shown (line and box, respectively), which were calculated at the final simulated year using all 500 SLAM trajectories.

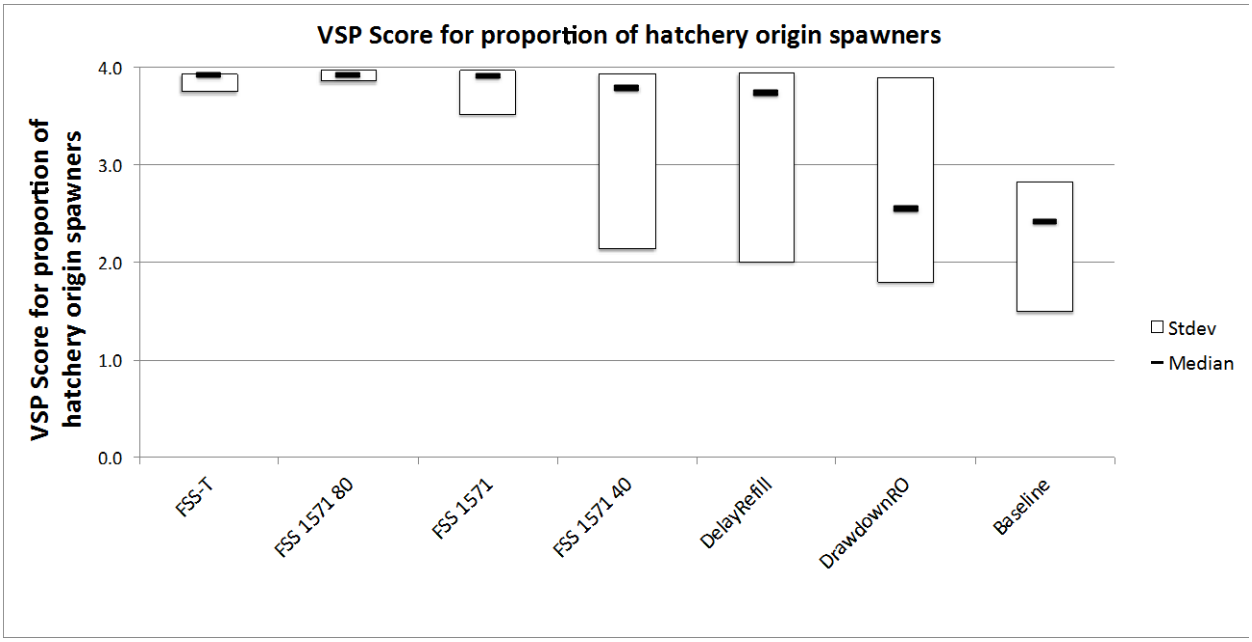


Figure 4.8: Proportion of Hatchery Origin Spawners VSP scores among McKenzie River alternatives. Median and standard deviation are shown (line and box, respectively), which were calculated using the median and standard deviation of PNI and pHOS.

Life History Diversity

Moving from baseline conditions to FSS-T, the number of spring subyearlings increased but not as much as the numbers of fall subyearlings and spring yearlings (Fig. 4.9). The composition of each life history was the most similar to baseline conditions in the DrawdownRO alternative. All alternatives were given a VSP score of 4.0 because each juvenile life history strategy was estimated to represent greater than 20% of the smolts (Figure 4.10).

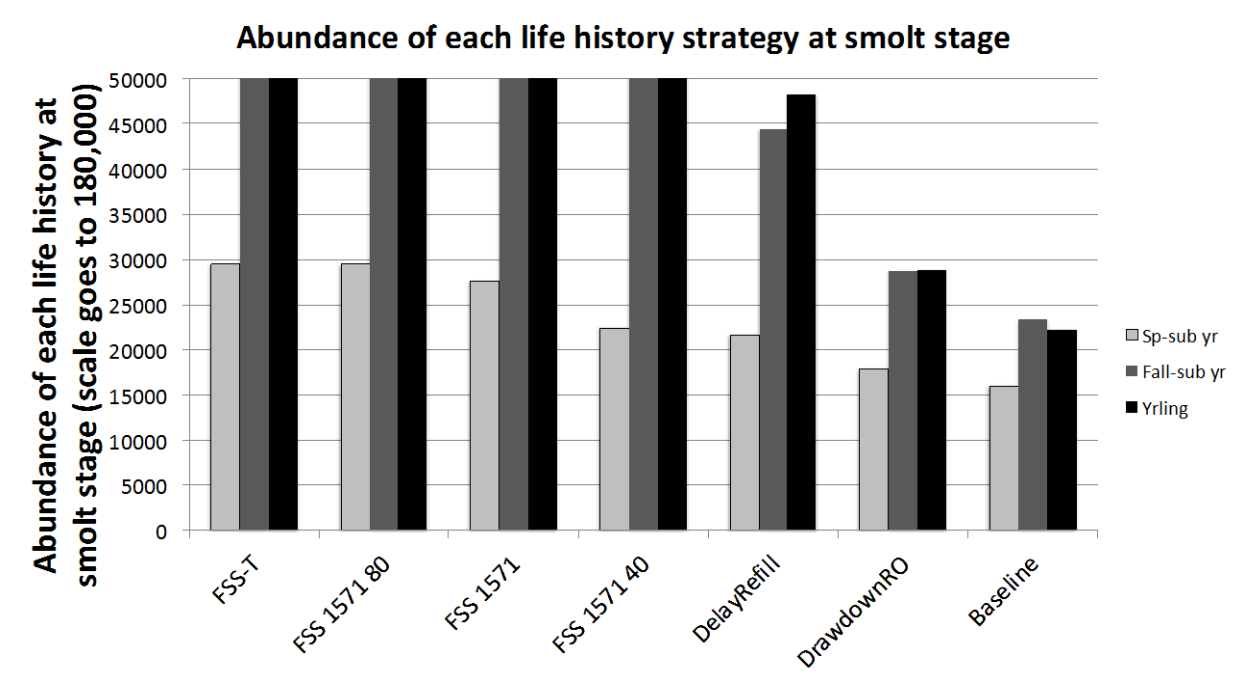


Figure 4.9: Median smolt abundance for each life history strategy among alternatives (see Table 4.3). Median was calculated at the final simulated year using all 500 SLAM trajectories. Standard deviation is excluded to improve clarity.

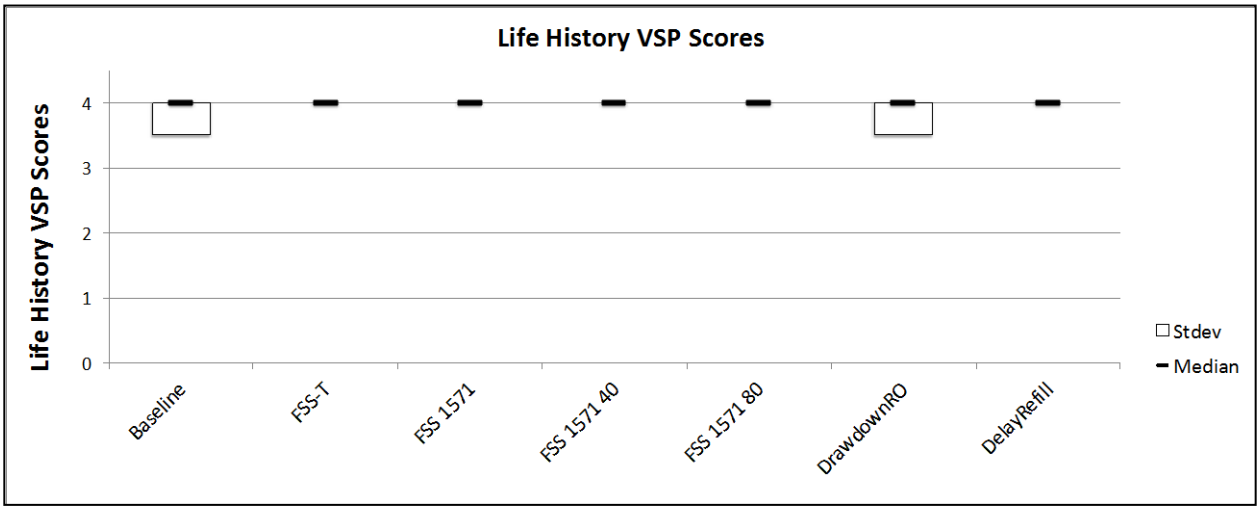


Figure 4.10: Life History Diversity VSP scores among McKenzie River alternatives. Median and standard deviation are shown (line and box, respectively), which were calculated using the median and standard deviation of abundance of smolts among life history strategies.

Spatial Structure

Spatial structure is a measure of population replacement above Cougar Dam. To assess replacement above Cougar Dam (i.e., Reach C) we used recruits per spawner, measured as median returning spawners referenced to the median of the spawning brood that produced them (i.e., the spawner to spawner).

$$Spawner{:}\,Spawner = \frac{Natural\ origin\ spawners\ in\ Reach\ C\ at\ time\ y + 4yrs}{Hatchery\ origin\ spawners\ in\ Reach\ C\ at\ time\ y + Natural\ origin\ spawners\ in\ Reach\ C\ at\ time\ y}$$

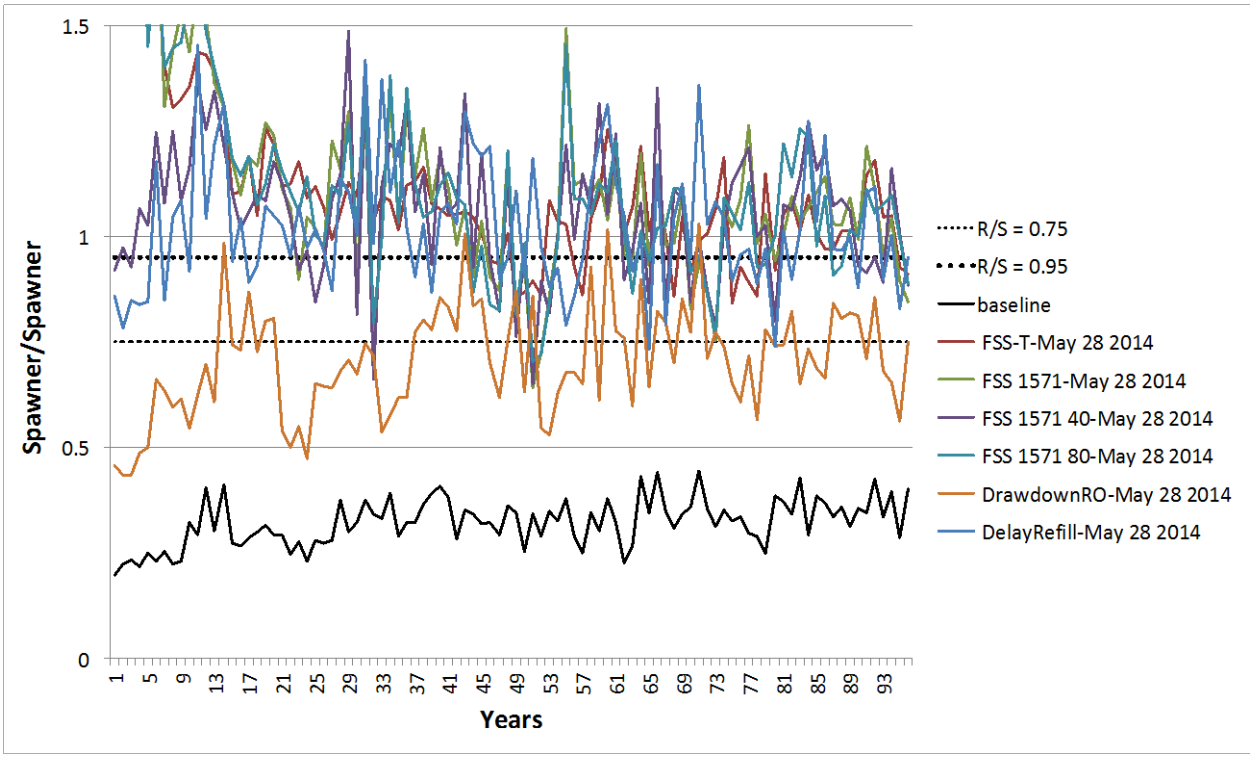


Figure 4.11: Times series of spawner-to-spawner ratio for each McKenzie River alternative. See text above for the equation used to calculate spawner-to-spawner ratio.

For each alternative, we calculated a median spawner-to-spawner ratio over all simulated years. A median spawner-to-spawner ratio that was less than 0.75 (dotted line in Figure 4.11) yielded a VSP score of 2.0 for Spatial Structure, while the median of the ratio between 0.75 and 0.95 (between dotted and dashed lines) yielded a VSP score of 2.67, and the median of the ratio above 0.95 (dashed line) gets a VSP score of 3.0. Under Baseline conditions, the median VSP score for Spatial Structure was 2.0, while it was 3.0 for FSS-T alternative (Figure 4.12).

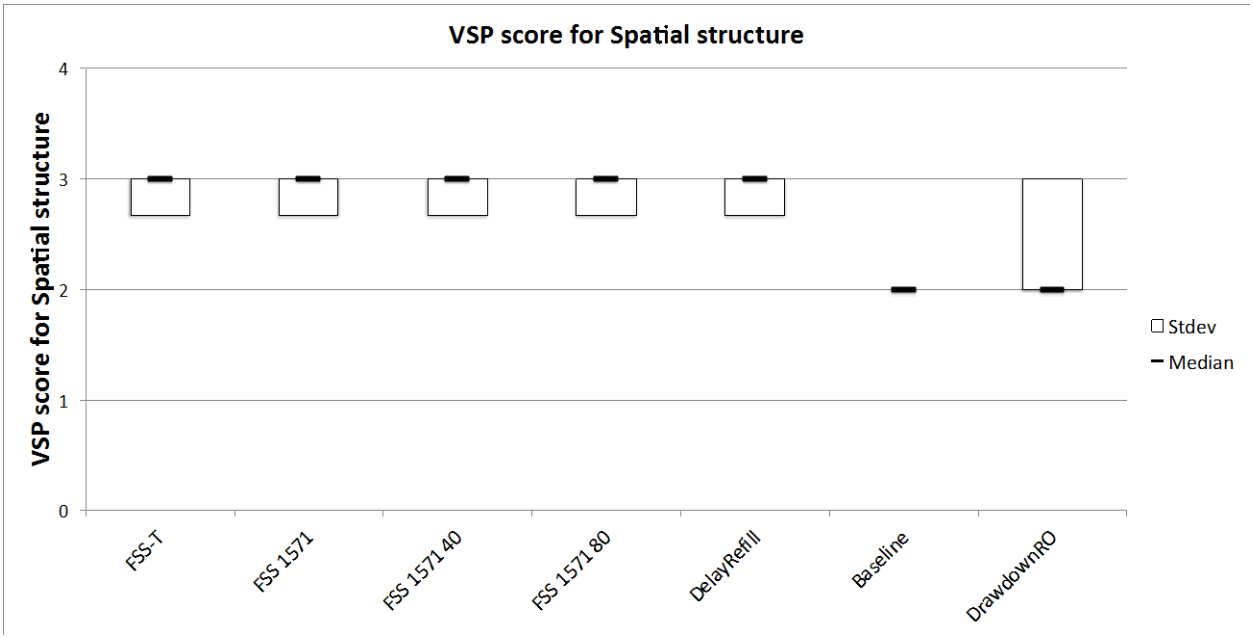


Figure 4.12: Spatial Structure VSP scores among McKenzie River alternatives. Median and standard deviation are shown (line and box, respectively), which were calculated using the median and standard deviation of spawner-to-spawner ratio.

Total VSP Score

To estimate the Total VSP score, we combined all the component VSP scores according to the following equation:

$$Total\ VSP\ score = \frac{2(Abundance) + 2(Productivity) + Diversity + Spatial\ Structure}{6}$$

Of the McKenzie River alternatives, the greatest Total VSP Score came from FSS-T, FSS 1571, and FSS 1571 80, which all yielded the highest Total VSP Score (>3.8), while Baseline conditions yielded a score of 2.6 (Figure 4.13).

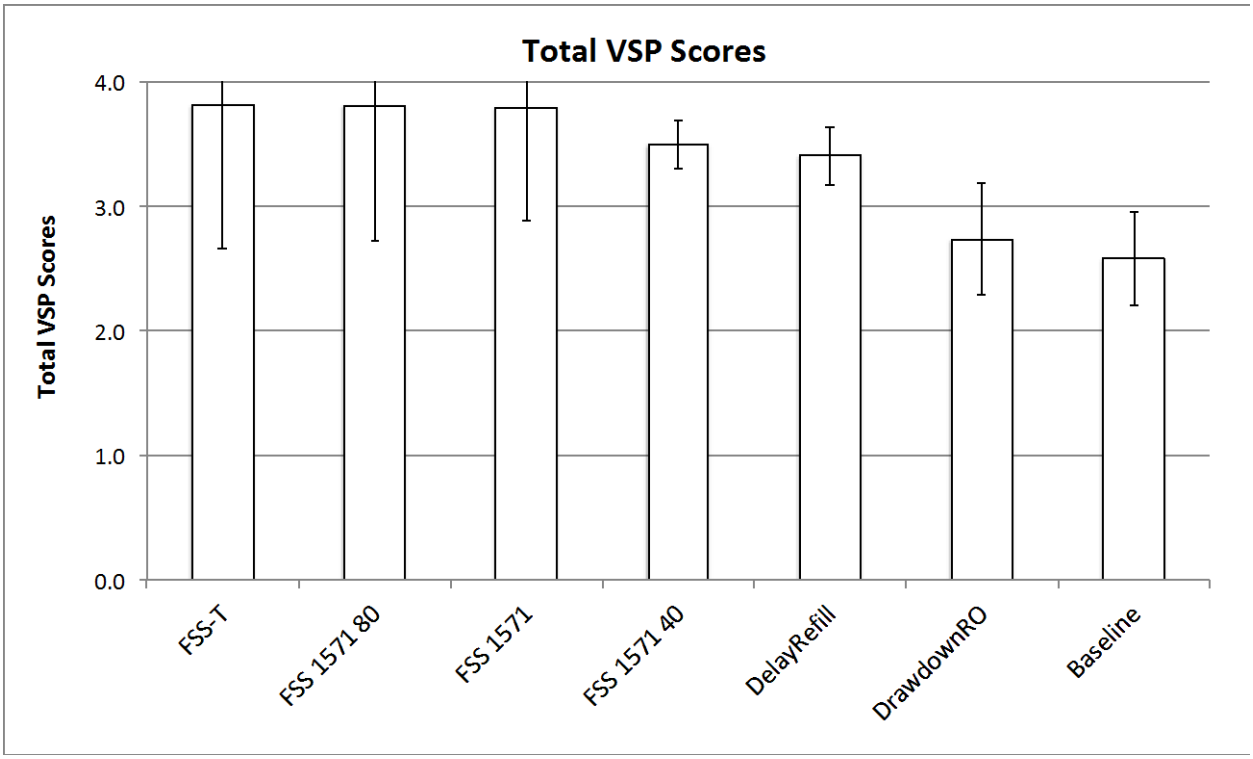


Figure 4.13: Total VSP scores among McKenzie alternatives. Whiskers denote +/- one standard deviation.

4.6. References

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CHAPTER 5. SLAM MODEL OF NORTH SANTIAM RIVER CHINOOK SALMON

This chapter provides a description of the parameter values used in the North Santiam River SLAM model. Below, we provide a short description of the model parameters used in each of five categories (1. Productivity, capacity, & survivals, 2. Splits, 3. Datafiles, 4. Dynamic drivers & influencers, and 5. Initialized). For reference purposes, a map of North Santiam River (Figure 5.1) is provided that highlights each reach used in SLAM. Figure 5.2 shows how the life-cycle model is modeled within SLAM. Lastly, Table 5.1 is a list of definitions corresponding to each box within the life-cycle model, while Table 5.2 is a list of abbreviations used throughout this chapter.

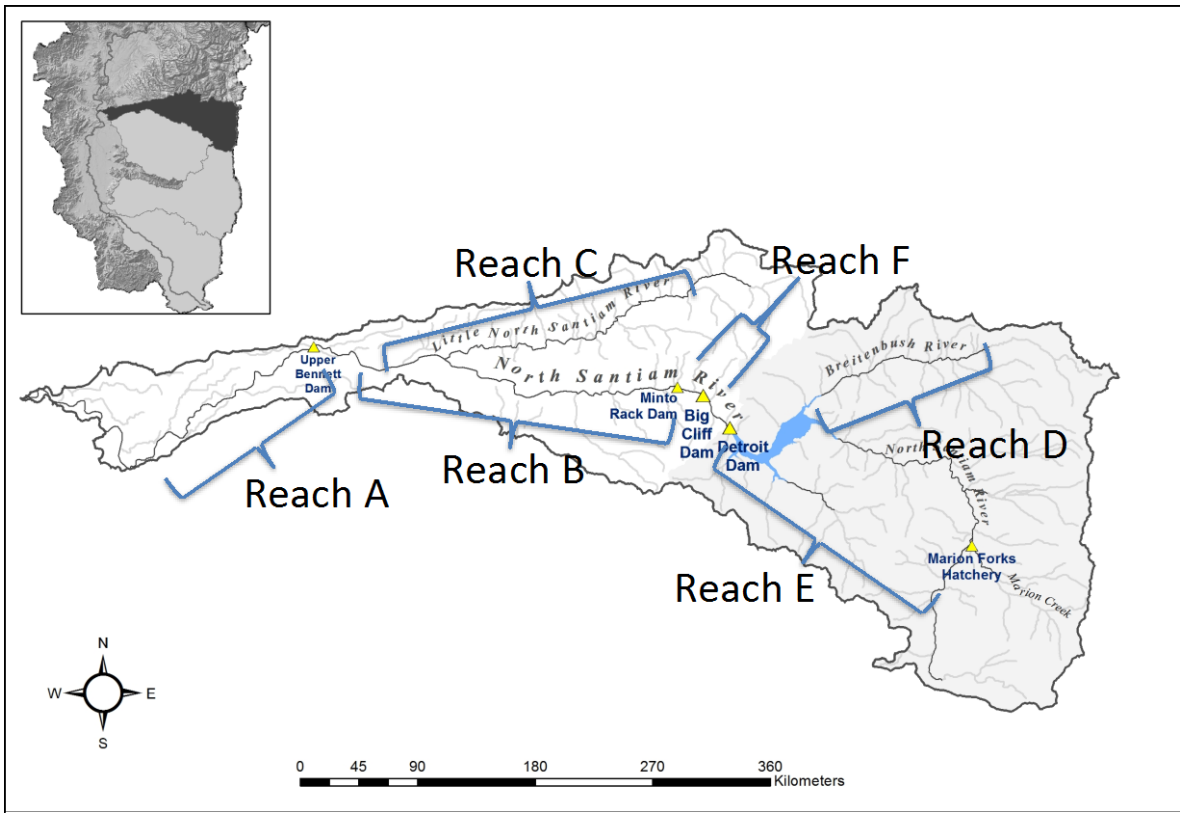


Figure 5.1: Map showing North Santiam River and the six reaches (A-F) that are modeled in SLAM; Reach A corresponds to mainstem North Santiam River downstream of Upper Bennett Dam, Reach B corresponds to mainstem North Santiam River between Upper Bennett Dam and the Minto Collection Facility, Reach C corresponds to Little North Santiam River, Reach D corresponds to Breitenbush River, Reach E corresponds to North Santiam River upstream of Detroit Dam, and Reach F corresponds to maintstem North Santiam River from Minto Collection Facility to Big Cliff Dam.

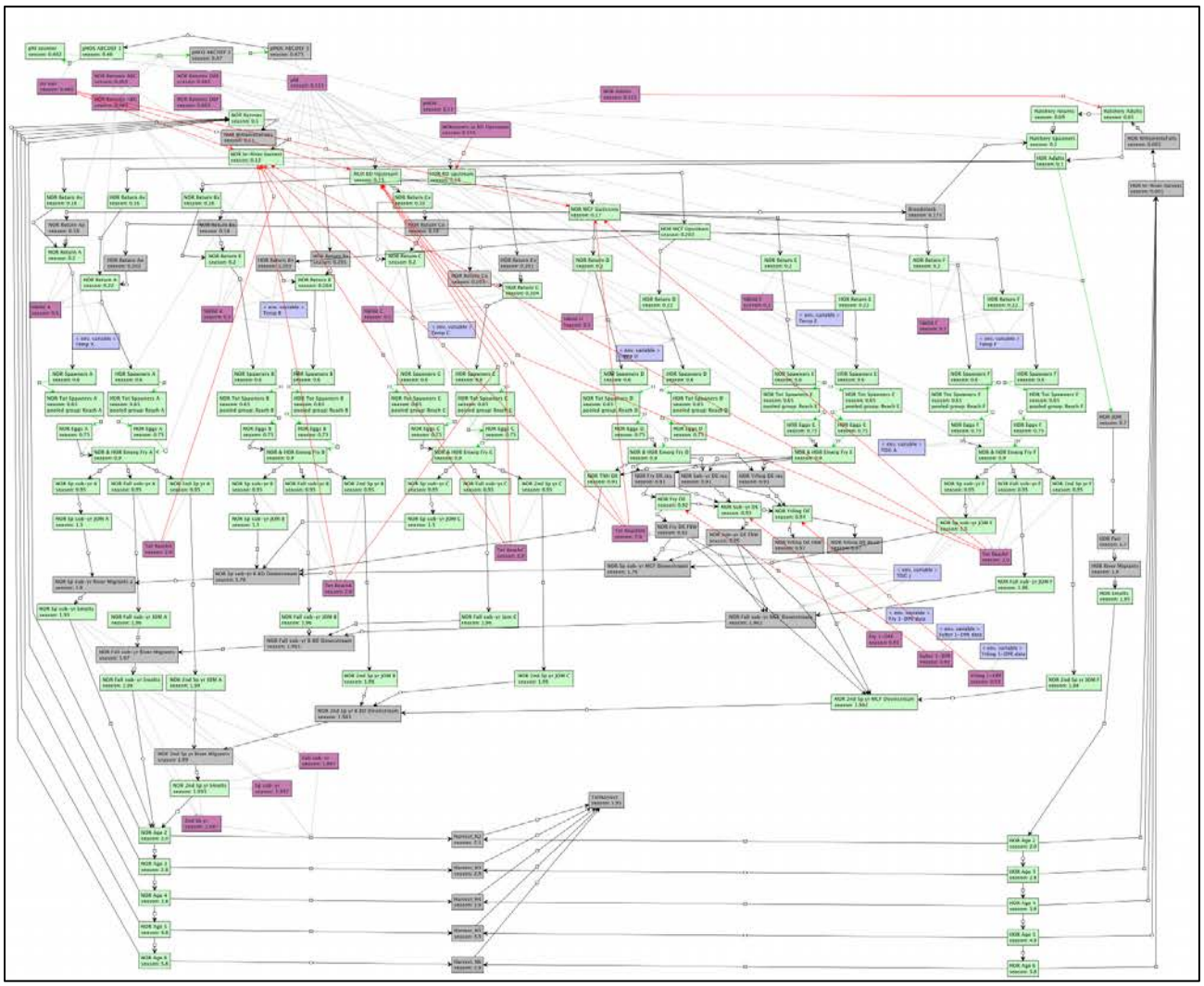


Figure 5.2: SLAM generated flow diagram of North Santiam River Chinook salmon life cycle model. Details of this model are provided in Table 5.1 and subsequent figures in this chapter will emphasize components of this diagram.

Table 5.1: Life history stages and transitions for the North Santiam River Chinook salmon life cycle model (Figure 5.2).

Life Stage	Definition
HOR In-River harvest	Freshwater harvest of hatchery fish
Hatchery Adult	Hatchery origin adults
Hatchery returns	Hatchery fish that return to the hatchery rack
Hatchery Spawners	Adults that spawn in hatchery, including some natural origin adults for brood stock improvement
HOR Adults	Hatchery origin adults that spawn in wild
Returning Adults	Returning adults of natural origin
Brood Sup	Natural origin individuals that are supplied to brood supply at hatchery program
NOR In-River Harvest	Freshwater harvest of natural origin
NOR Returns Av	Volitional natural origin adults that return to Reach A
NOR Returns Ao	Natural origin adults outplanted from Minto Collection Facility to Reach A
NOR Returns A	Natural origin adults that return to Reach A
NOR BD upstream	Natural origin adults that are upstream of Bennett Dam
NOR Returns Bv	Volitional natural origin adults that return to Reach B
NOR Returns Bo	Natural origin adults outplanted from Minto Collection Facility to Reach B
NOR Returns B	Natural origin adults that return to Reach B
NOR Returns Cv	Volitional natural origin adults that return to Reach C
NOR Returns Co	Natural origin adults outplanted from Minto Collection Facility to Reach C
NOR Returns C	Natural origin adults that return to Reach C
NOR MCF Upstream	Natural origin adults that return to Minto Collection Facility
NOR Returns D	Natural origin adults that return to Reach D
NOR Returns E	Natural origin adults that return to Reach E
NOR Returns F	Natural origin adults that return to Reach F
HOR Returns Av	Volitional hatchery origin adults that return to Reach A
HOR Returns A	Hatchery origin adults that return to Reach A
HOR BD upstream	Hatchery origin adults that are upstream of Bennett Dam
HOR Returns Bv	Volitional hatchery origin adults that return to Reach B
HOR Returns Bo	Hatchery origin adults outplanted from Minto Collection Facility to Reach B
HOR Returns B	Hatchery origin adults that return to Reach B
HOR Returns Cv	Volitional hatchery origin adults that return to Reach C
HOR Returns Co	Hatchery origin adults outplanted from Minto Collection Facility to Reach C
HOR Returns C	Hatchery origin adults that return to Reach C
HOR Returns D	Hatchery origin adults that return to Reach D
HOR Returns E	Hatchery origin adults that return to Reach E
HOR Returns F	Hatchery origin adults that return to Reach F
NOR Spawners A	Natural origin spawners that spawn in Reach A
HOR Spawners A	Hatchery origin spawners that spawn in Reach A
NOR Spawners B	Natural origin spawners that spawn in Reach B

HOR Spawners B	Hatchery origin spawners that spawn in Reach B
NOR Spawners C	Natural origin spawners that spawn in Reach C
HOR Spawners C	Hatchery origin spawners that spawn in Reach C
NOR Spawners D	Natural origin spawners that spawn in Reach D
HOR Spawners D	Hatchery origin spawners that spawn in Reach D
NOR Spawners E	Natural origin spawners that spawn in Reach E
HOR Spawners E	Hatchery origin spawners that spawn in Reach E
NOR Spawners F	Natural origin spawners that spawn in Reach F
HOR Spawners F	Hatchery origin spawners that spawn in Reach F
NOR Tot Spawners A	Natural origin and hatchery origin spawners that spawn in Reach A
HOR Tot Spawners A	Natural origin and hatchery origin spawners that spawn in Reach A
NOR Tot Spawners B	Natural origin and hatchery origin spawners that spawn in Reach B
HOR Tot Spawners B	Natural origin and hatchery origin spawners that spawn in Reach B
NOR Tot Spawners C	Natural origin and hatchery origin spawners that spawn in Reach C
HOR Tot Spawners C	Natural origin and hatchery origin spawners that spawn in Reach C
NOR Tot Spawners D	Natural origin and hatchery origin spawners that spawn in Reach D
HOR Tot Spawners D	Natural origin and hatchery origin spawners that spawn in Reach D
NOR Tot Spawners D	Natural origin and hatchery origin spawners that spawn in Reach E
HOR Tot Spawners D	Natural origin and hatchery origin spawners that spawn in Reach E
NOR Tot Spawners F	Natural origin and hatchery origin spawners that spawn in Reach F
HOR Tot Spawners F	Natural origin and hatchery origin spawners that spawn in Reach F
NOR Egg A	Eggs in Reach A produced by natural origin spawners in Reach A
HOR Egg A	Eggs in Reach A produced by hatchery origin spawners in Reach A
NOR Egg B	Eggs in Reach B produced by natural origin spawners in Reach B
HOR Egg B	Eggs in Reach B produced by hatchery origin spawners in Reach B
NOR Egg C	Eggs in Reach C produced by natural origin spawners in Reach C
HOR Egg C	Eggs in Reach C produced by hatchery origin spawners in Reach C
NOR Egg D	Eggs in Reach D produced by natural origin spawners in Reach D
HOR Egg D	Eggs in Reach D produced by hatchery origin spawners in Reach D
NOR Egg E	Eggs in Reach E produced by natural origin spawners in Reach E
HOR Egg E	Eggs in Reach E produced by hatchery origin spawners in Reach E
NOR Egg F	Eggs in Reach F produced by natural origin spawners in Reach F
HOR Egg F	Eggs in Reach F produced by hatchery origin spawners in Reach F
NOR & HOR Emerg Fry A	Natural and hatchery produced emergent fry in Reach A
NOR & HOR Emerg Fry B	Natural and hatchery produced emergent fry in Reach B
NOR & HOR Emerg Fry C	Natural and hatchery produced emergent fry in Reach C
NOR & HOR Emerg Fry D	Natural and hatchery produced emergent fry in Reach D
NOR & HOR Emerg Fry E	Natural and hatchery produced emergent fry in Reach E
NOR & HOR Emerg Fry F	Natural and hatchery produced emergent fry in Reach F
HOR JOM	Hatchery origin juvenile out-migrants
NOR Sp sub-yr A	Natural origin fry in Reach A that express a Spring sub-yearling life history strategy

NOR Fall sub-yr A	Natural origin fry in Reach A that express a Fall sub-yearling life history strategy
NOR 2nd Sp yr A	Natural origin fry in Reach A that express a 2nd Spring yearling life history strategy
NOR Sp sub-yr B	Natural origin fry in Reach B that express a spring sub-yearling life history strategy
NOR Fall sub-yr B	Natural origin fry in Reach B that express a fall sub-yearling life history strategy
NOR 2nd Sp yr B	Natural origin fry in Reach B that express a 2nd spring yearling life history strategy
NOR Sp sub-yr C	Natural origin fry in Reach C that express a spring sub-yearling life history strategy
NOR Fall sub-yr C	Natural origin fry in Reach C that express a fall sub-yearling life history strategy
NOR 2nd Sp yr C	Natural origin fry in Reach C that express a 2nd spring yearling life history strategy
NOR TNH DE	Downstream movement of Natural origin juveniles via trap and haul program
NOR Fry DE res	Natural origin fry from Reach DE within in Detroit reservoir
NOR Sub-yr DE res	Natural origin sub-yearlings from Reach DE within in Detroit reservoir
NOR Yrling DE res	Natural origin yearlings from Reach DE within in Detroit reservoir
NOR Sp sub-yr F	Natural origin fry in Reach F that express a spring sub-yearling life history strategy
NOR Fall sub-yr F	Natural origin fry in Reach F that express a fall sub-yearling life history strategy
NOR 2nd Sp yr F	Natural origin fry in Reach F that express a 2nd spring yearling life history strategy
NOR Fry DE FBW	Natural origin fry from Reach DE that pass through Detroit Dam
NOR Sub-yr DE FBW	Natural origin sub-yearlings from Reach DE that pass through Detroit Dam
NOR Yrling DE FBW	Natural origin yearlings from Reach DE that pass through Detroit Dam
NOR Yrling DE dead	Natural origin yearlings from Reach DE that do not pass through Detroit Dam
NOR Sp sub-yr JOM A	Natural origin spring sub-yearlings in Reach A that are juvenile out migrants
NOR Fall sub-yr JOM A	Natural origin fall sub-yearlings in Reach A that are juvenile out migrants
NOR 2nd Sp yr JOM A	Natural origin 2nd spring sub-yearlings in Reach A that are juvenile out migrants
NOR Sp sub-yr JOM B	Natural origin spring sub-yearlings in Reach B that are juvenile out migrants
NOR Fall sub-yr JOM B	Natural origin fall sub-yearlings in Reach B that are juvenile out migrants
NOR 2nd Sp yr JOM B	Natural origin 2nd spring sub-yearlings in Reach B that are juvenile out migrants
NOR Sp sub-yr JOM C	Natural origin spring sub-yearlings in Reach C that are juvenile out migrants
NOR Fall sub-yr JOM C	Natural origin fall sub-yearlings in Reach C that are juvenile out migrants
NOR 2nd Sp yr JOM C	Natural origin 2nd spring sub-yearlings in Reach C that are juvenile out migrants
NOR Sp sub-yr JOM F	Natural origin spring sub-yearlings in Reach F that are juvenile out migrants
NOR Fall sub-yr JOM F	Natural origin fall sub-yearlings in Reach F that are juvenile out migrants
NOR 2nd Sp yr JOM F	Natural origin 2nd spring sub-yearlings in Reach F that are juvenile out migrants
NOR Sp sub-yr MCF Downstream	Natural origin spring sub-yearlings from Reach DEF that are juvenile out migrants
NOR Fall sub-yr MCF Downstream	Natural origin fall sub-yearlings from Reach DEF that are juvenile out migrants
NOR 2nd Sp yr MCF Downstream	Natural origin 2nd spring yearlings from Reach DEF that are juvenile out migrants
NOR Sp sub-yr River Migrants a	Natural origin spring sub-yearlings leaving North Santiam River
NOR Fall sub-yr River Migrants	Natural origin fall sub-yearlings leaving North Santiam River
NOR 2nd Spy r River Migrants	Natural origin 2nd spring sub-yearlings leaving North Santiam River
NOR Sp sub-yr Smolts	Natural origin smolts that are spring sub-yearlings
NOR Fall sub-yr Smolts	Natural origin smolts that are fall sub-yearlings
NOR 2nd sub-yr Smolts	Natural origin smolts that are 2nd spring sub-yearlings

HOR Parr	Hatchery origin parr downstream of Leaburg Dam
HOR River Migrants	Hatchery origin juvenile out-migrants leaving North Santiam River
HOR Smolt	Hatchery origin smolts
NOR Age 2	Age 2 natural origin adults
NOR Age 3	Age 3 natural origin adults
NOR Age 4	Age 4 natural origin adults
NOR Age 5	Age 5 natural origin adults
NOR Age 6	Age 6 natural origin adults
HOR Age 2	Second generation age 2 hatchery origin adults, indistinguishable from natural origin age 2 adults
HOR Age 3	Second generation age 3 hatchery origin adults, indistinguishable from natural origin age 3 adults
HOR Age 4	Second generation age 4 hatchery origin adults, indistinguishable from natural origin age 4 adults
HOR Age 5	Second generation hatchery origin age 5 adults, indistinguishable from natural origin age 5 adults
HOR Age 6	Second generation hatchery origin age 6 adults, indistinguishable from natural origin age 6 adults
Harvest_N2	Adults (both natural and hatchery origin) harvested at age 2
Harvest_N3	Adults (both natural and hatchery origin) harvested at age 3
Harvest_N4	Adults (both natural and hatchery origin) harvested at age 4
Harvest_N5	Adults (both natural and hatchery origin) harvested at age 5
Harvest_N6	Adults (both natural and hatchery origin) harvested at age 6

Table 5.2: List of Acronyms and Abbreviations.

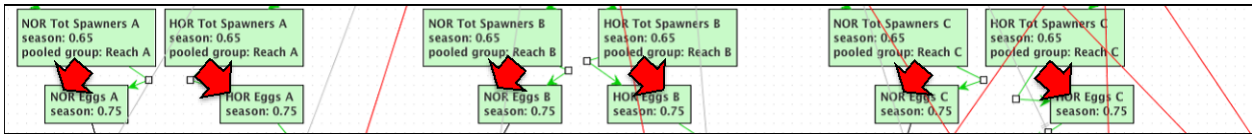
Abbreviation	**Definition**
0+	Juveniles less than one year old
1+	Juveniles older than one year but less than two years old
Beverton-Holt	Beverton-Holt spawner-recruit relationship
BD	Bennett Dam
d/s	Downstream
Harvest_N#	Fishery harvest of age N# fish (# = 2, 3, 4, 5, & 6 for spring Chinook)
FBW	Fish Benefit Workbook
Hockey-Stick	Spawner-recruit relationship in the Hockey-stick shape
HOR	Hatchery origin
HoR	Head of reservoir
JOM	Juvenile out-migrant
MCF	Minto Collection Facilty
NOR	Natural origin
ODFW	Oregon Department of Fish and Wildlife
SE	Standard Error
SLAM	Species Life-Cycle Analysis Modules
u/s	Upstream
TDG	Total Dissolved Gas
DPE	Dam Passage Efficiency
TNH	Trap and Haul
PSS, PSM	Prespawning survival, prespawning mortality

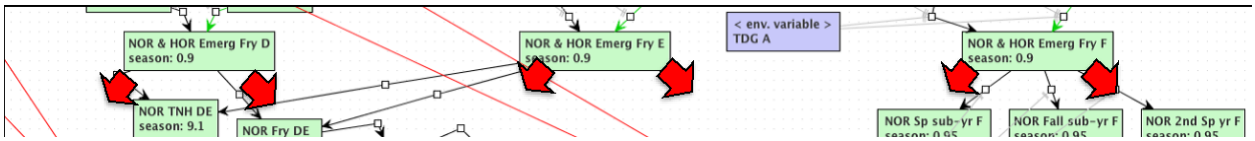
5.1. Productivity, Capacity, & Survivals

This section describes the reproductive capability of spawners within each reach and hatchery, reach-specific capacity, and the proportion of individuals that survive as they move among stages in the life-cycle model (Figure 4.2, Tables 4.1 and 4.2).

Productivity and capacity parameter values of wild spawning natural and hatchery origin individuals. Within each reach natural and hatchery origin spawners are pooled by reach, and a reach-specific Beverton-Holt capacity function is applied to determine the number of eggs. The Beverton-Holt productivity term is fixed at 0.5 times fecundity, with the assumption that the sex ratio of spawning fish is 50:50. The productivity to 2,250 eggs/individual is a slightly more conservative estimate than the 5000 eggs per female noted by Willis et al. (1995) (see Chapter 3, Fecundity). Egg capacity is stochastic, and each year reach-specific egg capacity is drawn from a normal distribution according to the following parameters (see Chapter 3, Spawner Capacity):

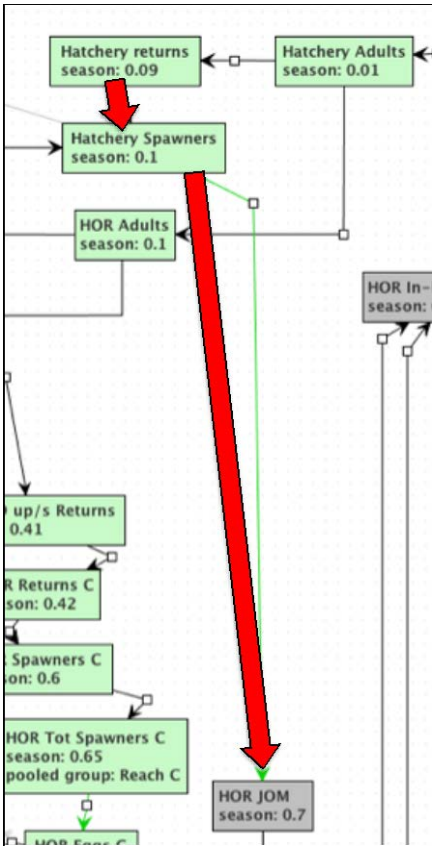
Reach	From	To	Capacity & Productivity	Mean	SD	Min	Max
A	NOR Tot Spawners	Eggs	Capacity	300,000	50,000	150,000	500,000
			Productivity				2,250
B	NOR Tot Spawners	Eggs	Capacity	5,000,000	100,000	1,000,000	6,000,000
			Productivity				2,250
C	NOR Tot Spawners	Eggs	Capacity	1,500,000	100,000	2,000,000	2,500,000
			Productivity				2,250
D	NOR Tot Spawners	Eggs	Capacity	6,000,000	100,000	2,000,000	7,500,000
			Productivity				2,250
E	NOR Tot Spawners	Eggs	Capacity	12,500,000	250,000	4,000,000	14,000,000
			Productivity				2,250
F	NOR Tot Spawners	Eggs	Capacity	500,000	50,000	200,000	600,000
			Productivity				2,250
A	HOR Tot Spawners	Eggs	Capacity	300,000	50,000	150,000	500,000
			Productivity				2,000
B	HOR Tot Spawners	Eggs	Capacity	5,000,000	100,000	1,000,000	6,000,000
			Productivity				2,000
C	HOR Tot Spawners	Eggs	Capacity	1,500,000	100,000	500,000	2,500,000
			Productivity				2,000
D	HOR Tot Spawners	Eggs	Capacity	6,000,000	100,000	2,000,000	7,500,000
			Productivity				2,000
E	HOR Tot Spawners	Eggs	Capacity	12,500,000	250,000	4,000,000	14,000,000
			Productivity				2,000
F	HOR Tot Spawners	Eggs	Capacity	500,000	50,000	200,000	600,000
			Productivity				2,000





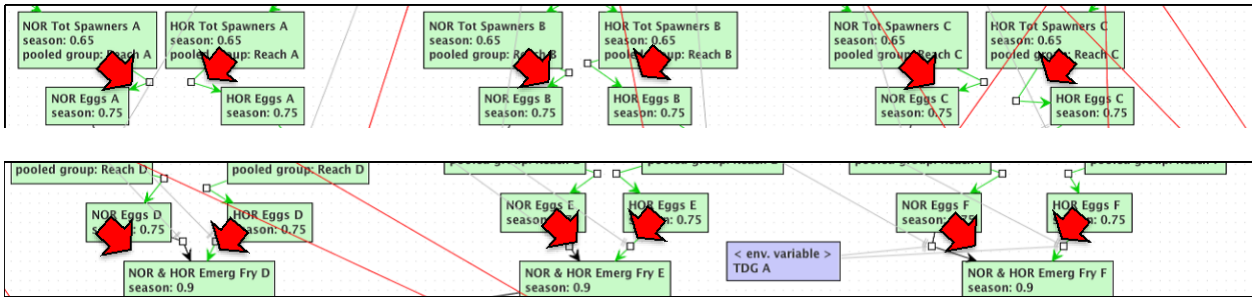
Productivity and capacity parameter values of hatchery spawners. A number of hatchery origin fish (up to 550-750 individuals; see Splits section below) are spawned in the hatchery, based on productivity of 1,600 eggs/individual (Willis et al. (1995), using a Hockey-Stick capacity function to determine the number of hatchery origin juveniles released in the North Santiam River (HOR JOM).

Reach	From	To	Capacity & Productivity	Mean	SD	Min	Max
Hatchery	Hatchery returns	Hatchery Spawners	Capacity	550	50	450	750
			Productivity				1
Hatchery	Hatchery Spawners	HOR JOM	Capacity	660,000	50,000	600,000	700,000
			Productivity				1,600



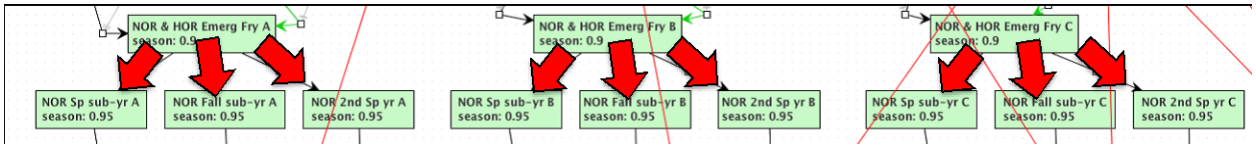
Survival parameter values from Eggs to Emergent Fry stage. The below values correspond to the reach-specific proportion of eggs that survive to become emergent fry (see Chapter 3, Survival). These values are from parameter workshops (see Chapter 3):

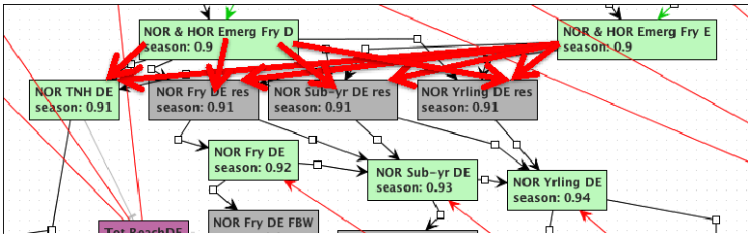
Reach	From	To	Curve type	Capacity & Productivity	Distribution type	Proportion of fish that survive
A	NOR/HOR Eggs	NOR & HOR Emerg Fry	Linear	Productivity	Constant	0.25
B	NOR/HOR Eggs	NOR & HOR Emerg Fry	Linear	Productivity	Triangular	0.425 (mean), 0.405 & 0.5 (min & max)
C	NOR/HOR Eggs	NOR & HOR Emerg Fry	Linear	Productivity	Constant	0.425
D	NOR/HOR Eggs	NOR & HOR Emerg Fry	Linear	Productivity	Constant	0.55
E	NOR/HOR Eggs	NOR & HOR Emerg Fry	Linear	Productivity	Constant	0.55
F	NOR/HOR Eggs	NOR & HOR Emerg Fry	Linear	Productivity	Triangular	0.425 (mean), 0.405 & 0.5 (min & max)



Survival parameter values from Emergent Fry stage to each juvenile life history strategy. The values below correspond to the reach-specific proportion of emergent fry that survive to become spring sub-yearlings, fall sub-yearlings, and 2nd spring yearlings:

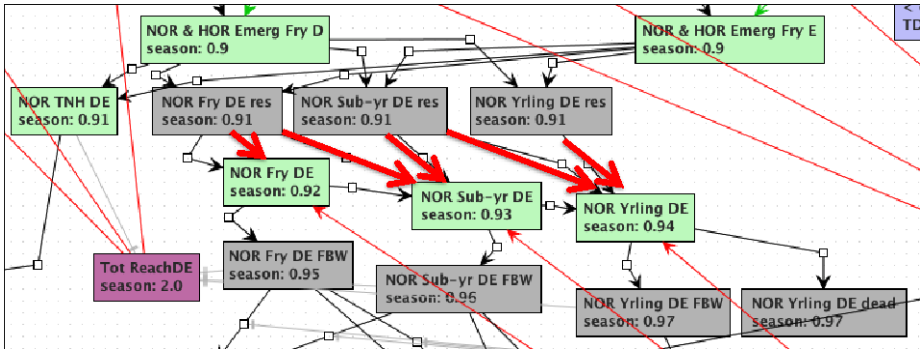
Reach	From	To	Curve type	Capacity & Productivity	Dist. type	Proportion of fish that survive
A	NOR & HOR Emerg Fry	NOR Sp sub-yr A	Linear	Productivity	Constant	0.16
		NOR Fall sub-yr A	Linear	Productivity	Constant	0.14
		NOR 2nd Sp yr A	Linear	Productivity	Constant	0.11
B	NOR & HOR Emerg Fry	NOR Sp sub-yr B	Linear	Productivity	Constant	0.26
		NOR Fall sub-yr B	Linear	Productivity	Constant	0.20
		NOR 2nd Sp yr B	Linear	Productivity	Constant	0.17
C	NOR & HOR Emerg Fry	NOR Sp sub-yr C	Linear	Productivity	Constant	0.225
		NOR Fall sub-yr C	Linear	Productivity	Constant	0.175
		NOR 2nd Sp yr C	Linear	Productivity	Constant	0.15
D & E	NOR & HOR Emerg Fry	NOR TNH DE	Linear	Productivity	Constant	0.8
		NOR Fry DE res	Linear	Productivity	Constant	0.75
		NOR Sub-yr DE res	Linear	Productivity	Constant	0.4
		NOR Yrling DE res	Linear	Productivity	Constant	0.3
F	NOR & HOR Emerg Fry	NOR Sp sub-yr F	Linear	Productivity	Constant	0.2
		NOR Fall sub-yr F	Linear	Productivity	Constant	0.15
		NOR 2nd Sp yr F	Linear	Productivity	Constant	0.125





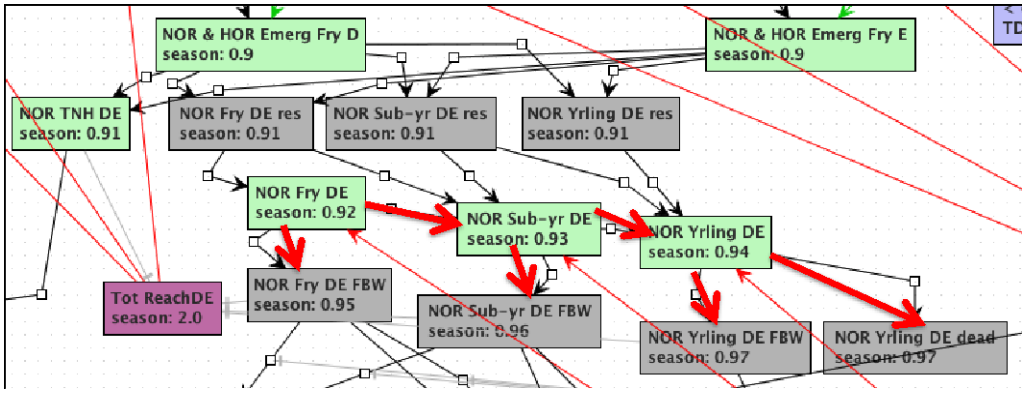
Survival parameter values while in Cougar reservoir for each of three life history strategies. These values are from parameter workshops (see Chapter 3).

Reach	From	To	Curve type	Capacity & Productivity	Dist. type	Proportion of fish that survive
DE	NOR Fry DE res	NOR Fry DE	Linear	Productivity	Constant	1
		NOR Sub-yr DE	Linear	Productivity	Triangular	0.2 (mean), 0.15 & 0.35 (min & max)
	NOR Sub-yr DE res	NOR Sub-yr DE	Linear	Productivity	Constant	1
		NOR Yrling DE	Linear	Productivity	Uniform	0.4-0.9 (min & max)
	NOR Yrling DE res	NOR Yrling DE	Linear	Productivity	Constant	1



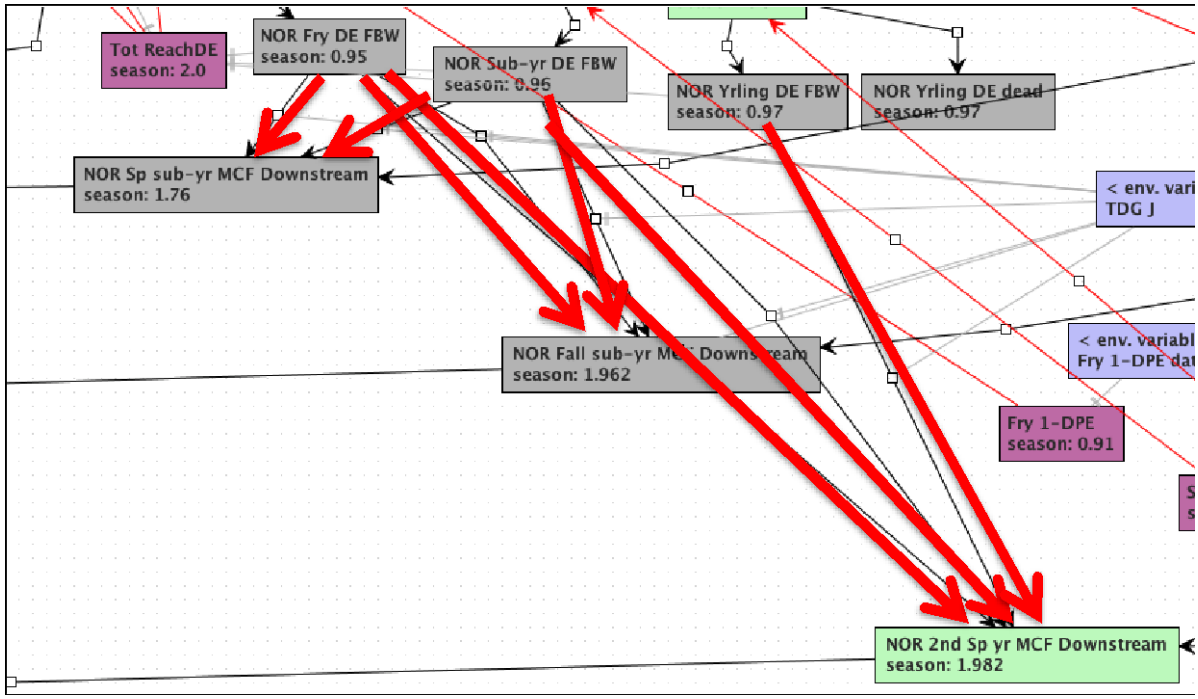
Survival parameter values for each of three life history strategy that rear in the reservoir to the next life history strategy. The survival values listed below that correspond to transitions between life history strategies. These values are from parameter workshops (see Chapter 3). Dam passage survival ('Passage survival' in the below table) is one of two datafiles from the Fish Benefits Workbook, the other being dam passage efficiency (DPE) (Fish Benefits Workbooks User Guide 2014). Dam passage efficiency is the fraction of fish available to pass a dam that actually pass, those that do not pass remain in the reservoir.

Reach	From	To	Curve type	Capacity & Productivity	Dist. type	Proportion of fish that survive Max
DE	NOR Fry DE	NOR Sub-yr DE	Linear	Productivity	Triangular	0.2 (mean), 0.15 & 0.35 (min & max)
		NOR Fry DE FBW	Linear	Productivity	Datafile	Passage survival
	NOR Sub-yr DE	NOR Yrling DE	Linear	Productivity	Uniform	0.4-0.9 (min & max)
		NOR Sub-yr DE FBW	Linear	Productivity	Datafile	Passage survival
		NOR Yrling DE FBW	Linear	Productivity	Datafile	Passage survival
		NOR Yrling DE dead	Linear	Productivity	Constant	0



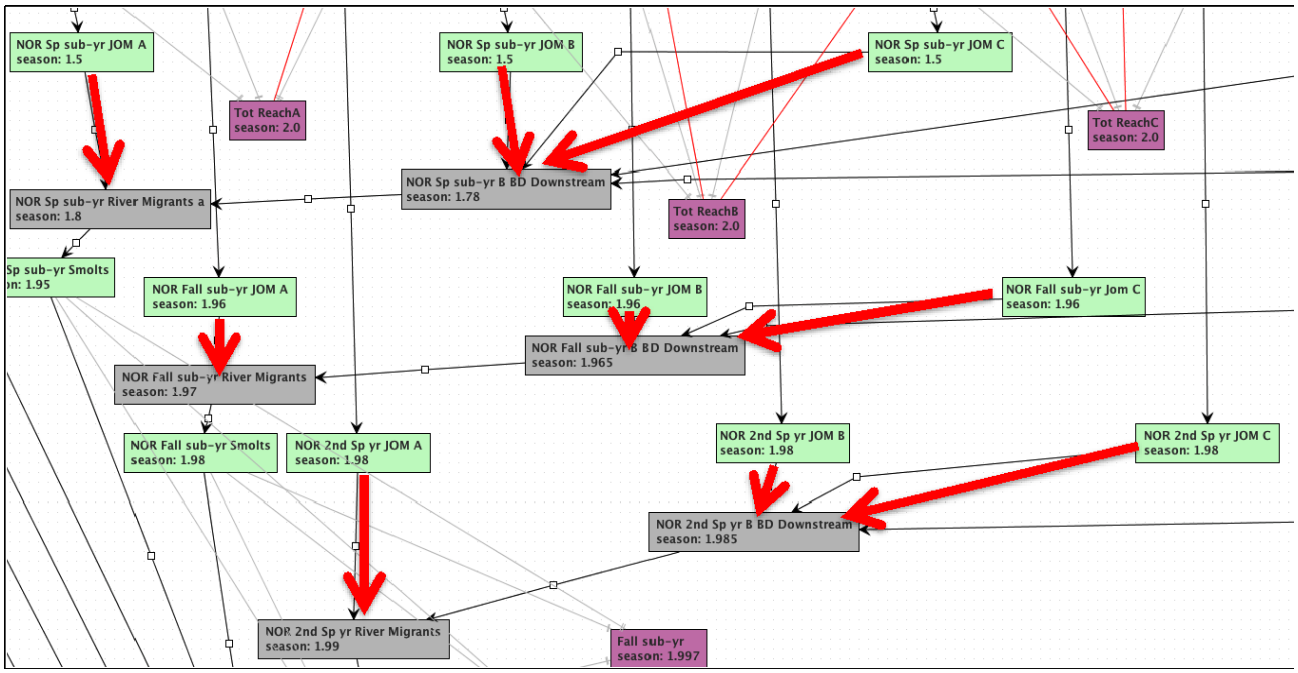
Survival parameter values for juveniles as that passed Detroit Dam and are downstream of Minto Collection Facility (MCF). Each of three life history strategies is represented in the table below.

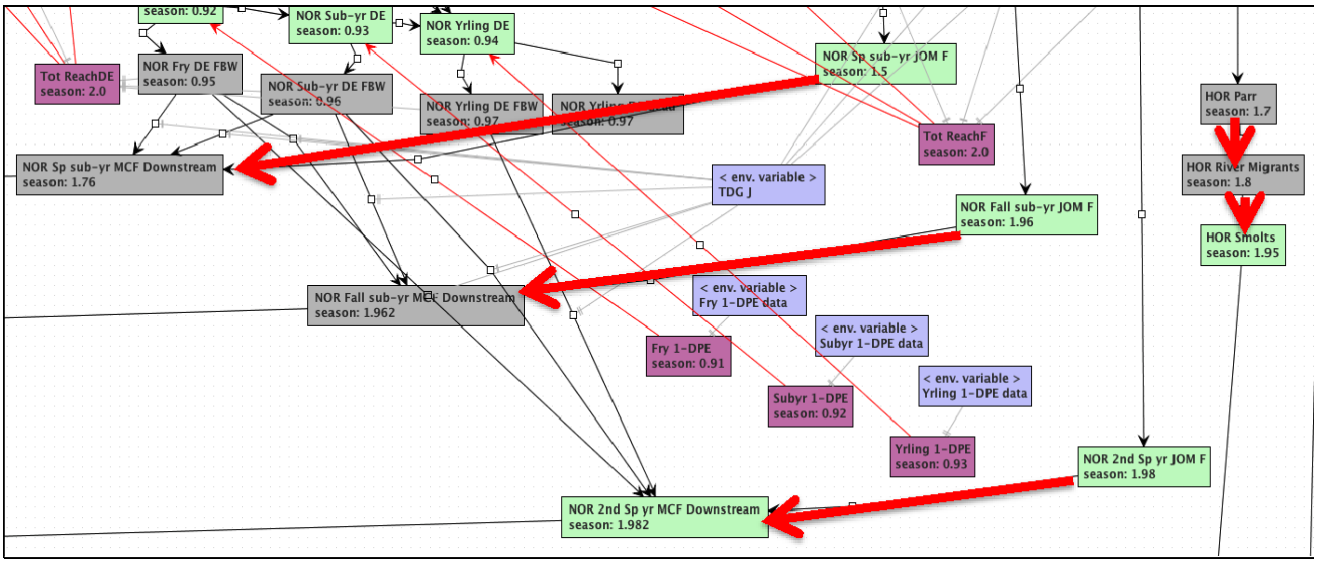
Reach	From	To	Curve type	Capacity & Productivity	Distr. type	Proportion of fish that survive Max
DE	NOR Fry DE FBW	NOR Sp sub-yr MCF Downstream	Linear	Productivity	Constant	0.15
		NOR Fall sub-yr MCF Downstream	Linear	Productivity	Constant	0.375
		NOR 2nd Sp yr MCF Downstream	Linear	Productivity	Constant	0.575
	NOR Sub-yr DE FBW	NOR Sp sub-yr MCF Downstream	Linear	Productivity	Constant	0.15
		NOR Fall sub-yr MCF Downstream	Linear	Productivity	Constant	0.425
		NOR 2nd Sp yr MCF Downstream	Linear	Productivity	Constant	0.575
	NOR Yrling DE FBW	NOR 2nd Sp yr MCF Downstream	Linear	Productivity	Constant	0.6



Survival parameter values from juvenile out migrants (JOM) to River Migrant stage (downstream of North Santiam).

Reach	From	To	Curve type	Capacity & Productivity	Distr. type	Proportion of fish that survive
A	NOR Sp sub-yr JOM A	NOR Sp sub-yr River Migrants a	Linear	Productivity	Constant	0.125
	NOR Fall sub-yr JOM A	NOR Fall sub-yr River Migrants	Linear	Productivity	Constant	0.25
	NOR 2nd Sp yr JOM A	NOR 2nd Sp yr River Migrants	Linear	Productivity	Constant	0.4
B	NOR Sp sub-yr JOM B	NOR Sp sub-yr B BD Downstream	Linear	Productivity	Constant	0.18
	NOR Fall sub-yr JOM B	NOR Fall sub-yr B BD Downstream	Linear	Productivity	Constant	0.4
	NOR 2nd Sp yr JOM B	NOR 2nd Sp yr B BD Downstream	Linear	Productivity	Constant	0.5
C	NOR Sp sub-yr JOM C	NOR Sp sub-yr MCF Downstream	Linear	Productivity	Constant	0.18
	NOR Fall sub-yr JOM C	NOR Fall sub-yr MCF Downstream	Linear	Productivity	Constant	0.35
	NOR 2nd Sp yr JOM C	NOR 2nd Sp yr MCF Downstream	Linear	Productivity	Constant	0.475
F	NOR Sp sub-yr JOM F	NOR Sp sub-yr MCF Downstream	Linear	Productivity	Constant	0.15
	NOR Fall sub-yr JOM F	NOR Fall sub-yr MCF Downstream	Linear	Productivity	Constant	0.375
	NOR 2nd Sp yr JOM F	NOR 2nd Sp yr MCF Downstream	Linear	Productivity	Constant	0.475
Hatchery	HOR JOM	HOR Parr	Linear	Productivity	Constant	0.95
	HOR Parr	HOR River Migrants	Linear	Productivity	Constant	0.85

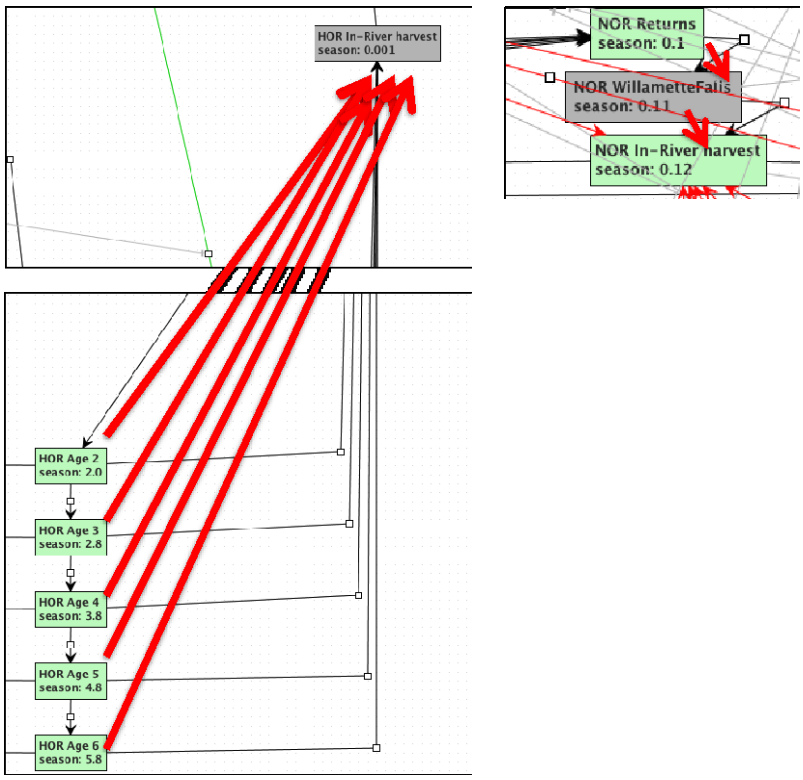




Estuary and ocean survival. Juveniles below Willamette Falls have an estuary survival time series applied, and in subsequent ocean years from, from 1, up to 4 ocean years, an ocean survival time series is applied (see Table 5.6 in Parameter variability section).

Survival parameter values associated with ocean and freshwater adult harvest and mainstem "loss". Natural origin fish from the North Santiam River experience an average fishing mortality of 8.7% (range of 5% - 14.2%; 2013, Fisheries Management & Evaluation) (i.e. 0.913 survival). There is also a loss of fish observed from Willamette Falls to counts within the North Santiam River, which we calculated as an average of 28.4% using data from 1995-2011) (i.e., 0.716 survival) (based on Willis et al. 1996; Foster et al. 1997; Bennett 1998; Lindsay et al. 1998; Ford 2011; Foster & Boatner 2002). Hatchery origin individuals are targeted in mainstem and McKenzie River fisheries. There is 45.6% mortality (average of 2006-2011) applied to account for harvest below Willamette Falls (Fisheries Management and Evaluation for 2012 Willamette River spring Chinook 2013). This 45.6% mortality is the sum of mortality by recreational fishery at the mouth of the Columbia River to Willamette River (5.2%), lower Willamette recreational fishery (20.8%), mainstem net fishery (9%), and the recreational fishery in the North Santiam River (10.6%). This 45.6% mortality (i.e., 0.544 survival) is comparable to 30.7% and 55% mortality reported by Lindsay et al. (1998) and Ford 2011, respectively. There is also a loss of fish observed from Willamette Falls to counts within the North Santiam River, which we calculated as an average of 28.4% using data from 1995-2011 (i.e., 0.716 survival).

Reach	From	To	Curve type	Capacity & Productivity	Dist. type	Proportion of fish that survive
Hatchery	HOR Age 2	HOR In-River harvest	Linear	Productivity	Constant	0.544
	HOR Age 3	HOR In-River harvest	Linear	Productivity	Constant	0.544
	HOR Age 4	HOR In-River harvest	Linear	Productivity	Constant	0.544
	HOR Age 5	HOR In-River harvest	Linear	Productivity	Constant	0.544
	HOR Age 6	HOR In-River harvest	Linear	Productivity	Constant	0.544
	HOR In-River harvest	HOR WillametteFalls	Linear	Productivity	Constant	0.716
NORs	NOR Returns	NOR WillametteFalls	Linear	Productivity	Constant	0.716
	NOR WillametteFalls	NOR In-River harvest	Linear	Productivity	Constant	0.913



5.2. Splits

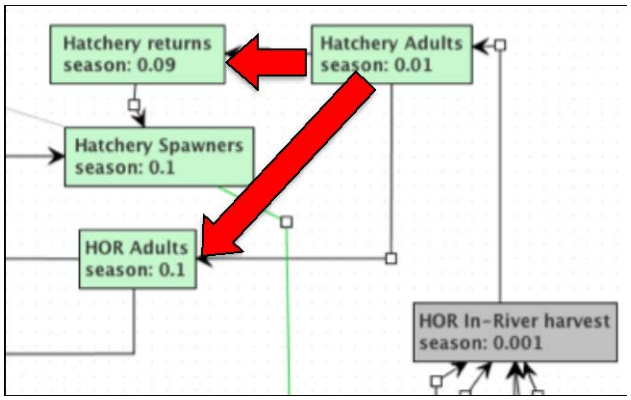
This section describes the proportion of fish directed from an individual life-stage to two or more subsequent life-stages via different pathways (splits).

Proportion of hatchery origin adults (Hatchery Adults) that return to hatchery (Hatchery Returns) or reach (HOR Adults). These proportions are based on abundance of natural origin fish at Willamette Falls. When fewer than 2501 North Santiam River natural origin adults are counted passing above Willamette Falls then 22.9% of hatchery fish that are returning to the North Santiam River are returned to the hatchery rack (Hatchery returns) while the remaining 77.1% will attempt to spawn in the wild (HOR Adults). When greater than 9487 natural origin fish are counted at Willamette Falls then 95% of hatchery fish that are returning to the North Santiam River will return to the hatchery rack (Hatchery Returns) while the remaining 5% will attempt to spawn in the wild (HOR Adults). When the number of North Santiam River natural origin fish counted at Willamette Falls is between 2501 and 9487 individuals, then a linear relationship (below) sets the proportion of hatchery fish that return to the rack between 22-95%:

$$Proportion\ of\ hatchery\ fish\ that\ return\ to\ rack = 0.229\ + (0.771 \times (\frac{NORs\ at\ Willamette\ Falls - 2500}{7500})$$

From	To	Proportion
Hatchery Adults	Hatchery returns	0.229
	HOR Adults	0.771

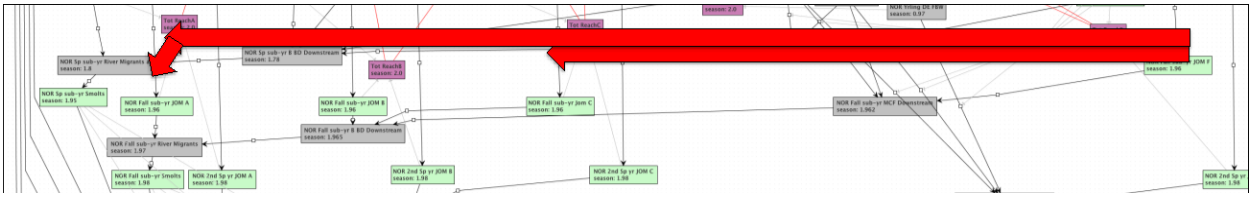
Values taken from Hendrix and Shi (2012) (page 8) and are based on Schroeder et al. (2007), Kenaston et al. (2009), and Cannon et al. (2010 and 2011), and Johnson and Friesen (2010).



Proportion of hatchery origin adults (HOR Adults) that return to Reach A (HOR Returns Av) or continue upstream of Bennett Dam (HOR BD upstream). Of the hatchery-origin adults that do not return to the hatchery, some spawn in Reach A.

From	To	Proportion
HOR Adults	HOR BD upstream	0.85
	HOR Returns Av	0.15

Values taken from Hendrix and Shi (2012) (page 8) and are based on Schroeder et al. (2007), Kenaston et al. (2009), and Cannon et al. (2010 and 2011), and Johnson and Friesen (2010).



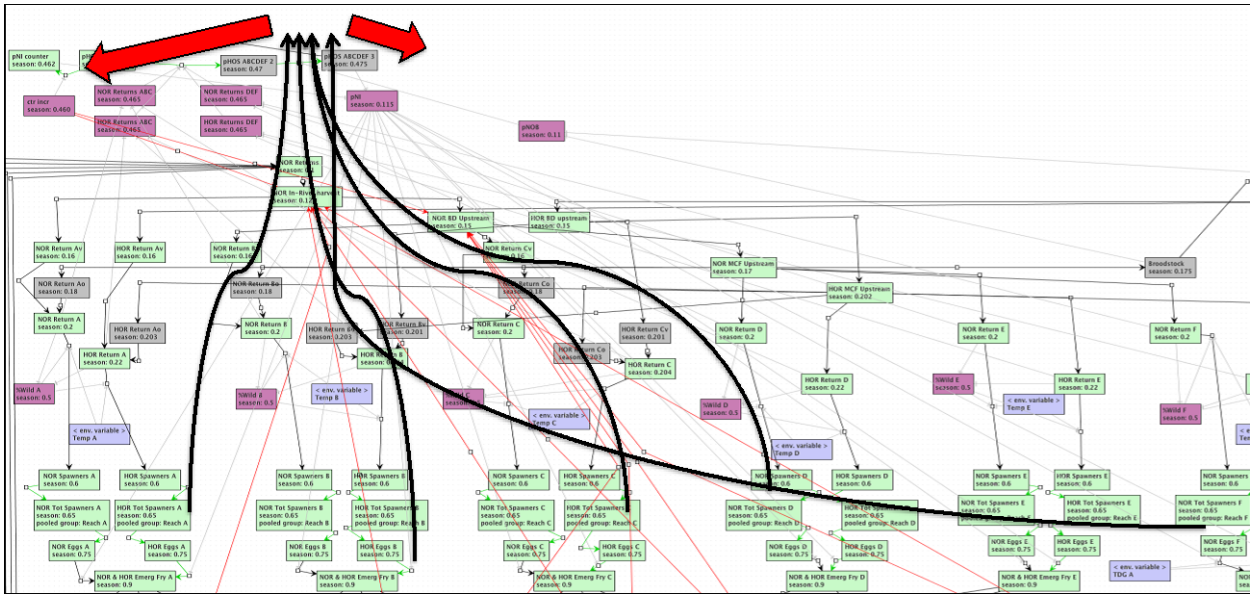
Proportion of Returning Adults that survived freshwater harvest (In-River harvest) to return to Reach A (NOR Returns Av) or move upstream of Bennett Dam (NOR BD upstream). In the process of simplifying the SLAM model structure we pooled together juveniles from all reaches starting at the estuary since estuary/ocean survivals and ocean and mainstem harvest were applied equally to fish from all reaches. Because of homing of adult Chinook salmon to their natal reaches we reapportioned returning adults in year *t* back to their natal reaches according to the numbers of juveniles produced in year *t*-4. Specifically, for each simulated year we quantified the proportion of juveniles that exited each reach. These proportions were then used to split Returning Adults (four simulated years later) that survived freshwater harvest (NOR In-River harvest) to those that return to Reach A (NOR Returns Av) and those that continue upstream of Bennett Dam (NOR BD Upstream). To achieve this in SLAM we used a tool called a Split Influence, which influences the ratios of a split (McElhany et al. 2012). After the model was initialized with a fixed set of ratios for a split, the Split Influence determined the from the juvenile counts four years previously:

$$Proportion\ of\ fish\ returning\ to\ NOR\ Returns\ Av = \left(\frac{Tot\ ReachA}{Tot\ ReachA+Tot\ ReachB+Tot\ ReachC+Tot\ ReachDE+Tot\ ReachF}\right)$$

Tot ReachA, B, C, DE, and F correspond to the abundance of juvenile outmigrants. This equation was applied for model years 4 and onward. For the first 3 years of model runs we apportioned fish to reaches according to a fixed proportion.

From	To	Proportion
NOR In-River harvest	NOR Return Av	Split influence (otherwise 0.037)
	NOR BD Upstream	Split influence (otherwise 0.963)

Values taken from Hendrix and Shi (2012) (page 11) and are based on Schroeder et al. (2007), Kenaston et al. (2009), and Cannon et al. (2010 and 2011), and Johnson and Friesen (2010).



Black lines show that five boxes (Tot ReachA, Tot ReachB, Tot ReachC, Tot ReachDE, and Tot ReachF) are used to influence the split of fish from In-River harvest to either NOR Returns Av or NOR BD upstream. Tot ReachA, Tot ReachB, Tot ReachC, Tot ReachDE, and Tot ReachF sum all the juveniles that exit Reach A, B, C, DE, and F respectively.

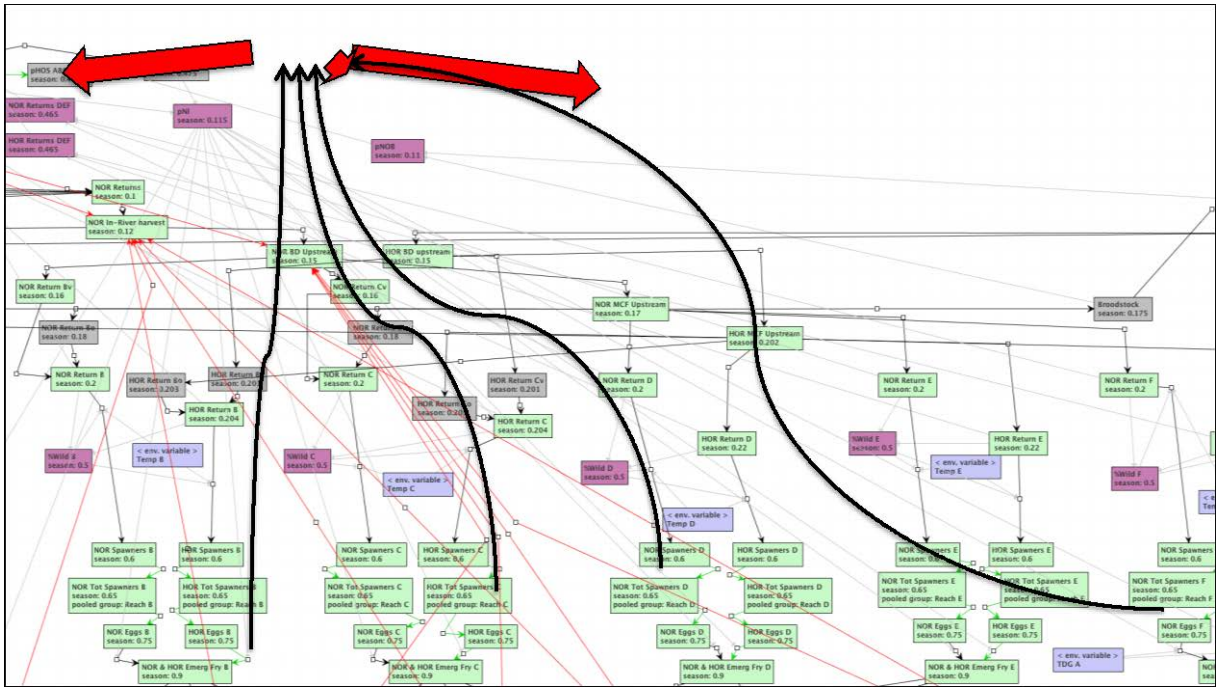
Proportion of NORs above Bennett Dam (NOR BD upstream) that will return to Reach B (NOR Returns Bv), Reach C (NOR Returns Cv), or upstream of Minto Collection Facility (NOR MCF Upstream). We followed the same procedure, noted above, to calculate the proportion of adults that return to Reach B, C, or above Minto Collection Facility during the simulation run.

$$Proportion\ of\ fish\ returning\ to\ NOR\ Returns\ Bv = \left(\frac{Tot\ ReachB}{Tot\ ReachB + Tot\ ReachC + Tot\ ReachDE + Tot\ ReachF}\right)$$

Tot ReachB, C, DE, and F correspond to the abundance of juvenile outmigrants, when pooling life history strategies, for each reach.

From	To	Proportion
NOR BD upstream	NOR Return Bv	Split influence (otherwise 0.542)
	NOR Return Cv	Split influence (otherwise 0.078)
	NOR MCF Upstream	Split influence (otherwise 0.38)

Values taken from Hendrix and Shi (2012) (page 11) and are based on Schroeder et al. (2007), Kenaston et al. (2009), and Cannon et al. (2010 and 2011), and Johnson and Friesen (2010).

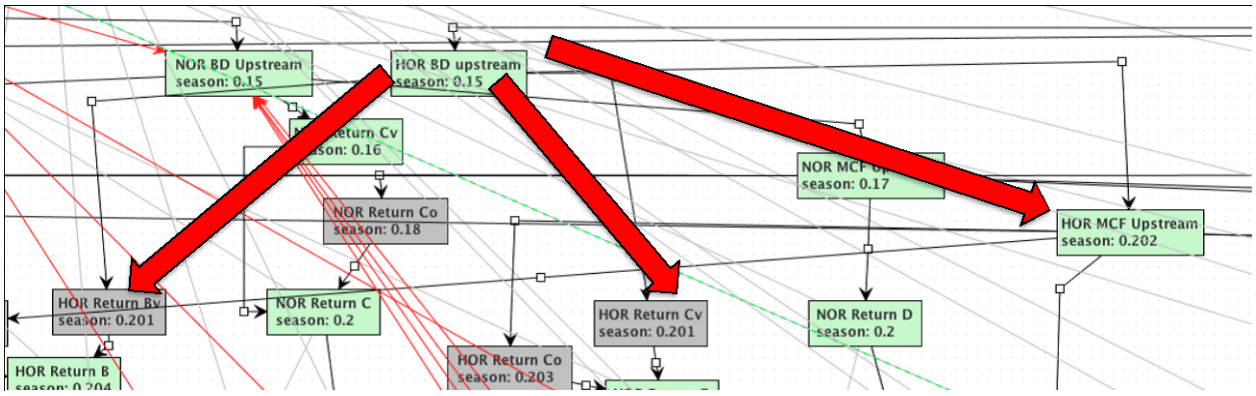


Black lines show four boxes (Tot ReachB, Tot ReachC, Tot ReachDE, and Tot ReachF) used to influence the split of fish from NOR BD Upstream to NOR Returns Bv, NOR Returns Cv, or NOR MCF upstream. Tot ReachB, Tot ReachC, Tot ReachDE, and Tot ReachF sum all the juveniles that exit Reach B, C, DE, and F respectively.

Proportion of hatchery origin adults upstream of Bennett Dam (HOR BD upstream) that return to Reach B (HOR Returns Bv), Reach C (HOR Return Cv), or upstream of Minto Collection Facility (HOR MCF Upstream).

From	To	Proportion
HOR BD upstream	HOR Returns Bv	0.352
	HOR Returns Cv	0.038
	HOR MCF Upstream	0.61

Values taken from Hendrix and Shi (2012) (page 10) and are based on Schroeder et al. (2007), Kenaston et al. (2009), and Cannon et al. (2010 and 2011), and Johnson and Friesen (2010).



Proportion of natural origin adults at Minto Collection Facility (NOR MCF upstream) that are outplanted to Reach A (NOR Return Ao), Reach B (NOR Return Bo), Reach C (NOR Return Co), Reach D (NOR Return D), Reach E (NOR Return E), Reach F (NOR Return F), or broodstock.

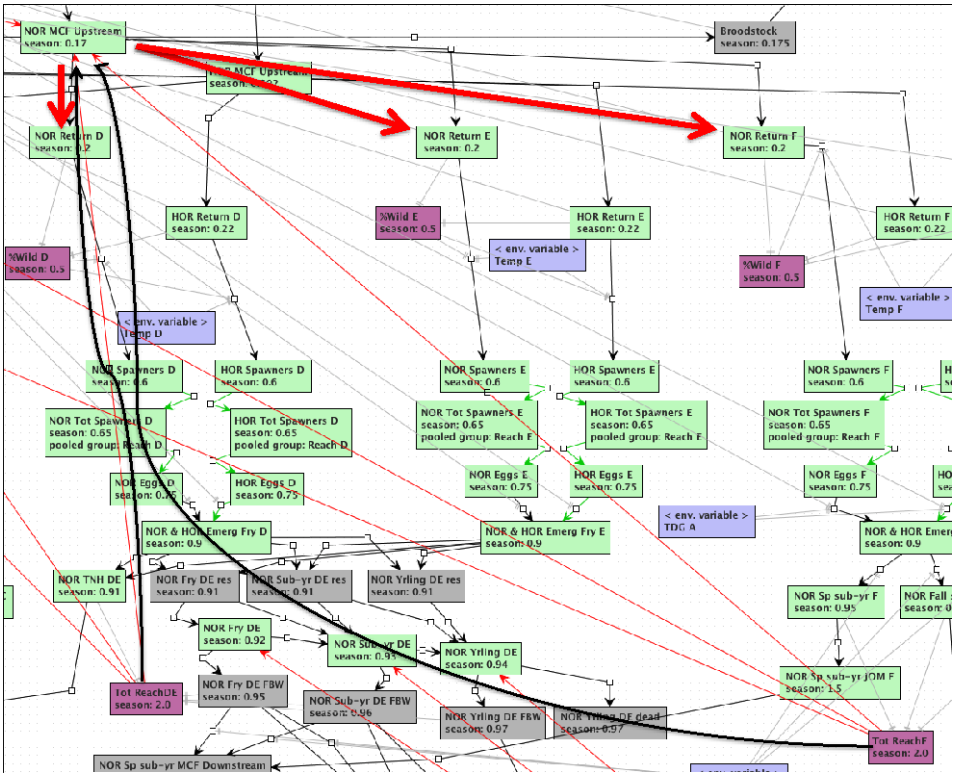
We followed the same procedure, noted above, to calculate the proportion of adults that return to Reach D, Reach E or Reach F) during the simulation run:

$$Proportion\ of\ fish\ returning\ to\ NOR\ Return\ F = \left(\frac{Tot\ ReachF}{Tot\ ReachDE + Tot\ ReachF}\right)$$

Tot Reach DE and F correspond to the abundance of juvenile outmigrants, when pooling life history strategies, for each reach.

From	To	Proportion
NOR MCF upstream	NOR Return Ao	0
	NOR Return Bo	0
	NOR Return Co	0
	NOR Return D	Split influence (otherwise 0.33)
	NOR Return E	Split influence (otherwise 0.67)
	NOR Return F	Split influence (otherwise 0.03)
	Broodstock	Split influence of 0.05

Values taken from Hendrix and Shi (2012) (page 13).

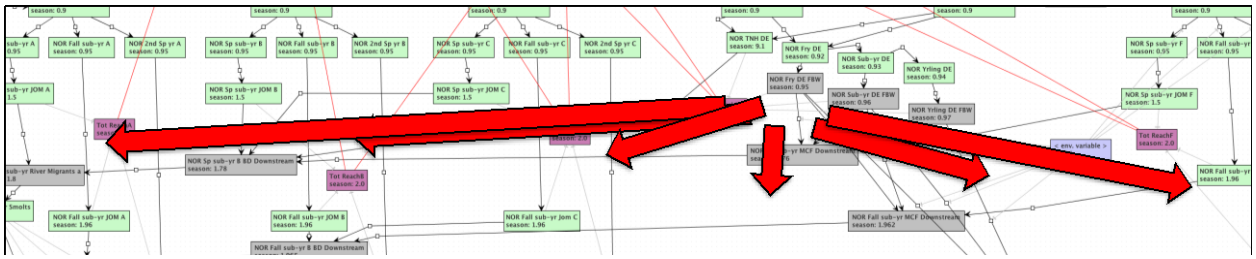


Black lines show that two boxes (Tot ReachDE and Tot ReachF) are used to influence the split of fish from NOR MCF Upstream to NOR Return D, NOR Return E, or NOR Return F. Tot ReachDE and Tot ReachF sum all the juveniles that exit Reach DE and F respectively.

Proportion of hatchery origin adults at Minto Collection Facility (HOR MCF upstream) that are outplanted to Reach A (HOR Return Ao), Reach B (HOR Return Bo), Reach C (HOR Return Co), Reach D (HOR Return D), Reach E (HOR Return E), and Reach F (HOR Return F).

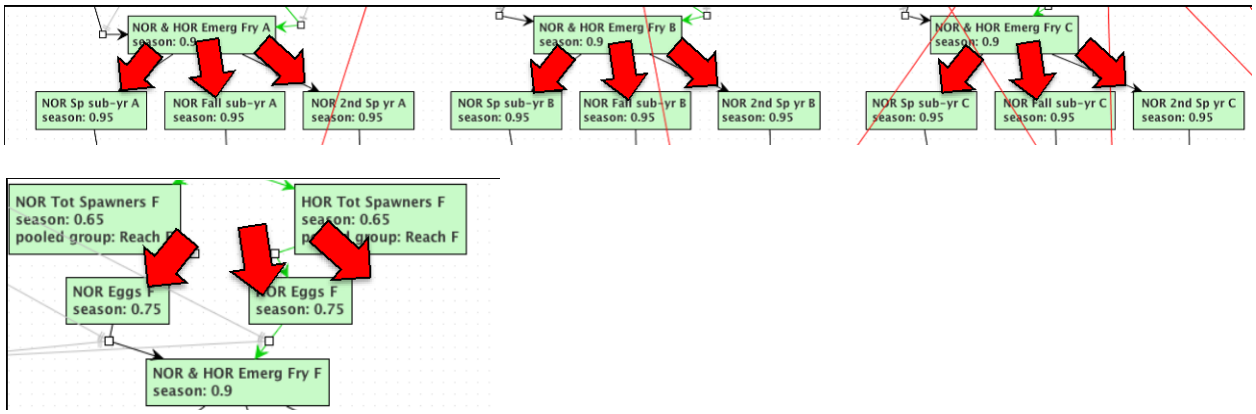
From	To	Proportion
HOR MCF upstream	HOR Return Ao	0.053
	HOR Return Bo	0
	HOR Return Co	0.037
	HOR Return D	0.302
	HOR Return E	0.52
	HOR Return F	0.088

Values taken from Hendrix and Shi (2012) (page 10) and are based on Schroeder et al. (2007), Kenaston et al. (2009), and Cannon et al. (2010 and 2011), and Johnson and Friesen (2010).



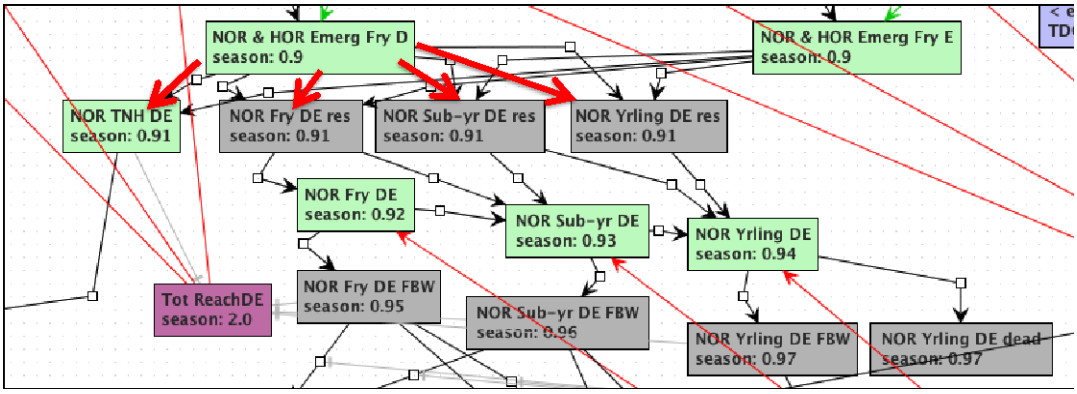
Proportion of emergent fry (NOR & HOR Emerg Fry) within Reach A and B that become spring sub-yearling (NOR Sp sub-yr), fall sub-yearling (NOR Fall sub-yr), and second spring yearling (NOR 2nd Sp yr). The proportions of emergent fry in reaches A and B that followed particular life history trajectories were determined based on Mattson (1962).

From	To	Proportion
NOR & HOR Emerg Fry A, B, C, & F	NOR Sp sub-yr	0.41
	NOR Fall sub-yr	0.304
	NOR 2nd Sp yr	0.286



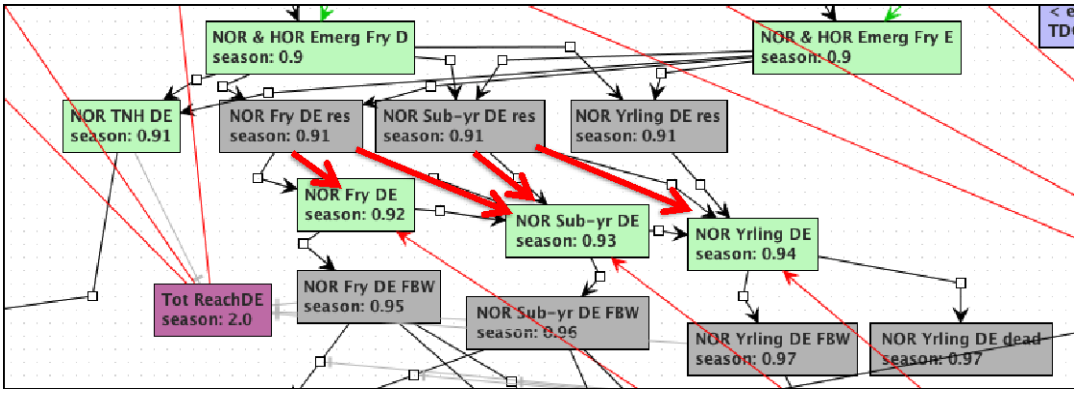
Proportion of emergent fry (NOR & HOR Emerg Fry) within Reach D and E that become reservoir fry (NOR Fry DE res), sub-yearlings (NOR Sub-yr DE res), yearlings (NOR Yrling DE res) or are transported downstream (NOR TNH DE). In Reach D and E, above Detroit Dam, the proportions of juveniles entering the reservoir of the three life history strategies were based on data from rotary screw-traps located upstream of Detroit reservoir (ODFW, unpublished data).

From	To	Proportion
NOR & HOR Emerg Fry D & E	NOR TNH DE	0
	NOR Fry DE res	0.89
	NOR Sub-yr DE res	0.1
	NOR Yrling DE res	0.01



Proportion of reservoir fry and sub-yearlings that remain or change life history strategies. Proportion of fry and sub-yearlings in Detroit reservoir (NOR Fry DE res and NOR Sub-yr DE res, respectively) that remain as fry (NOR Fry DE) or rear in the reservoir and become sub-yearlings (NOR Sub-yr DE), and remain as sub-yearlings (NOR Sub-yr DE) or rear in the reservoir and become yearlings (NOR Yrling DE). These values are from parameter workshops (see Chapter 3, appendix 3.6).

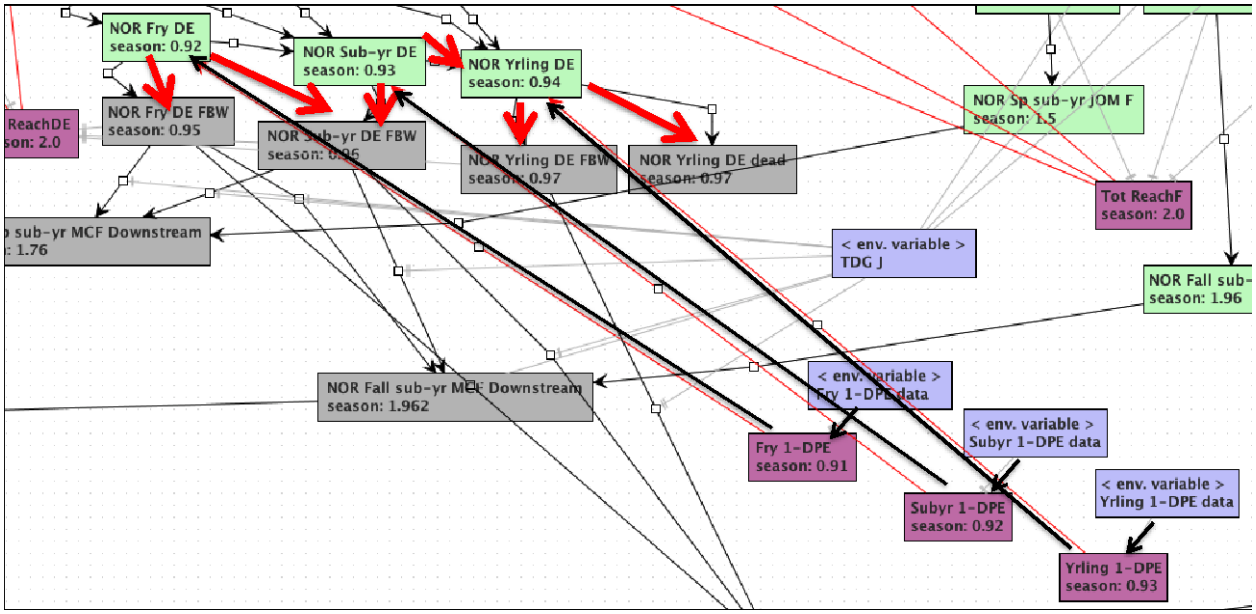
From	To	Proportion
NOR Fry DE res	NOR Fry DE	0.01-0.05
	NOR Sub-yr DE	0.95-0.99
NOR Sub-yr DE res	NOR Sub-yr DE	0.75-0.9
	NOR Yrling DE	0.1-0.25



Proportion of individuals in Detroit reservoir that are available to pass Detroit Dam or unavailable to pass and thus remain and rear in the reservoir. Fry in Detroit reservoir (NOR Fry DE) that are available to pass Detroit Dam (NOR Fry DE FBW) or unavailable to pass and thus remain in the reservoir and become sub-yearlings (NOR Sub-yr DE). Proportion of sub-yearling in Detroit reservoir (NOR Sub-yr DE) that are available to pass Detroit Dam (NOR Sub-yr DE FBW) or unavailable to pass and thus remain in the reservoir and become yearlings (NOR Yrling DE).

Proportion of yearling in Detroit reservoir (NOR Yrling DE) that are available to pass Detroit Dam (NOR Yrling DE FBW) or unavailable to pass, and are removed from the simulation (NOR Yrling DE). These proportions use dam passage efficiency (DPE) estimates that were specific to particular dam project alternatives and were provided by USACE (Fish Benefits Workbooks User Guide 2014).

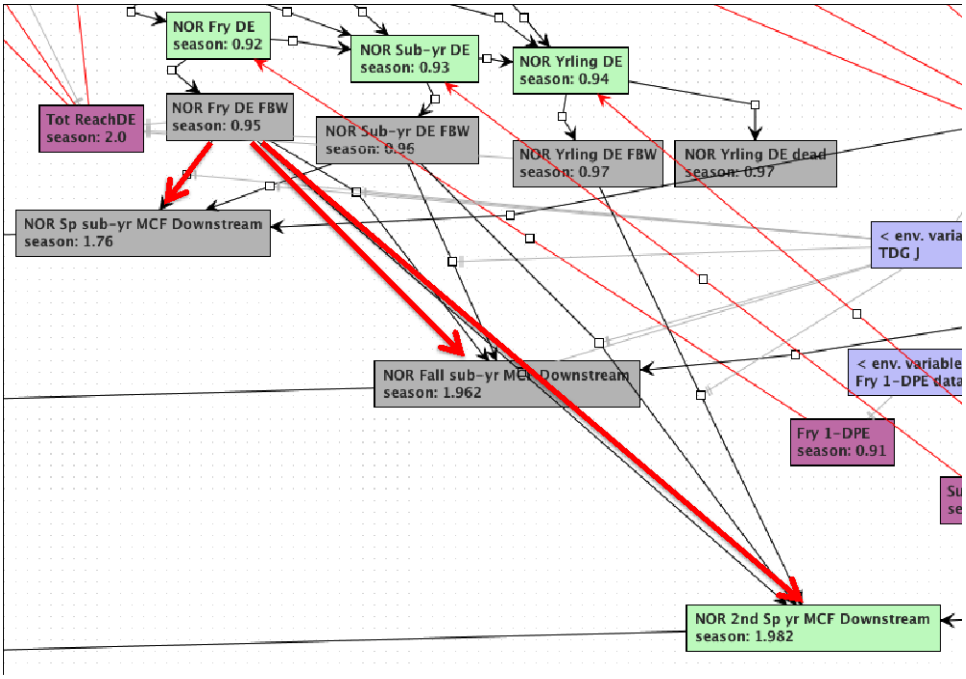
From	To	Proportion
NOR Fry DE	NOR Fry DE FBW	Split influencer determined by DPE file
	NOR Sub-yr DE	Split influencer determined by DPE file
NOR Sub-yr DE	NOR Sub-yr DE FBW	Split influencer determined by DPE file
	NOR Yrling DE	Split influencer determined by DPE file
NOR Yrling DE	NOR Yrling DE FBW	Split influencer determined by DPE file
	NOR Yrling DE dead	Split influencer determined by DPE file



Black arrows represent the split influence from dam passage efficiency data.

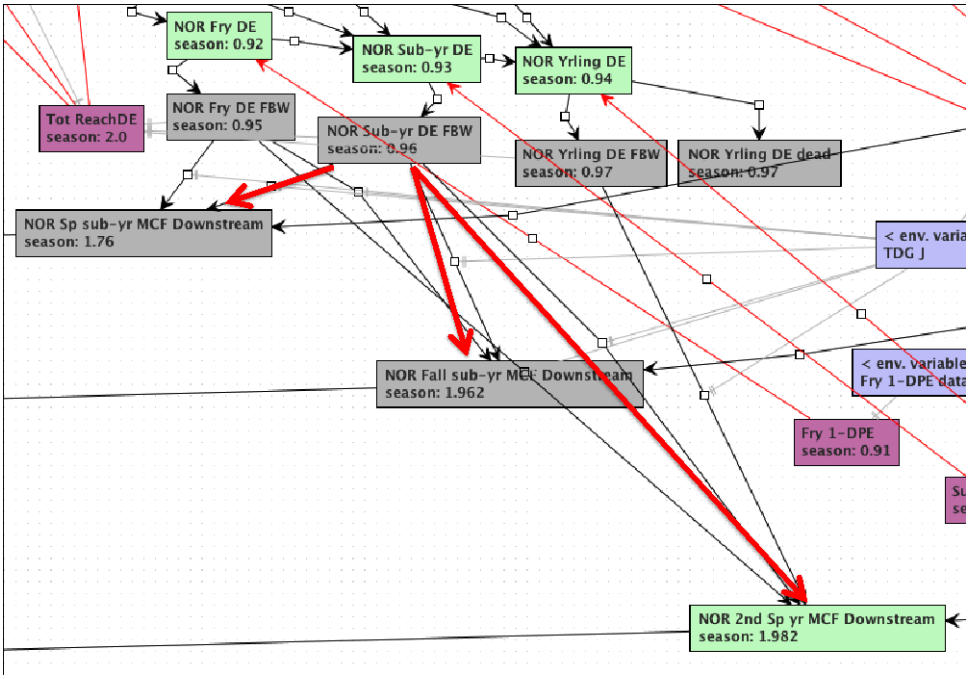
Proportion of fry downstream of Detroit Dam (NOR Fry DE FBW) that pass Minto Collection Facility and are spring sub-yearling (NOR Sp sub-yr MCF Downstream), fall sub-yearlings (NOR Fall sub-yr MCF Downstream), or second spring yearlings (NOR 2nd Sp yr MCF Downstream). These values are from parameter workshops (see Chapter 3, appendix 3.6).

From	To	Proportion
NOR Fry DE FBW	NOR Sp sub-yr MCF Downstream	0.2-0.5
	NOR Fall sub-yr MCF Downstream	0.4-0.6
	NOR 2nd Sp yr MCF Downstream	0.1-0.2



Proportion of sub-yearlings downstream of Detroit Dam (NOR Sub-yr DE FBW) that pass Minto Collection Facility and are spring sub-yearling (NOR Sp sub-yr MCF Downstream), fall sub-yearlings (NOR Fall sub-yr MCF Downstream), or second spring yearlings (NOR 2nd Sp yr MCF Downstream). These values are from parameter workshops (see Chapter 3, appendix 3.6).

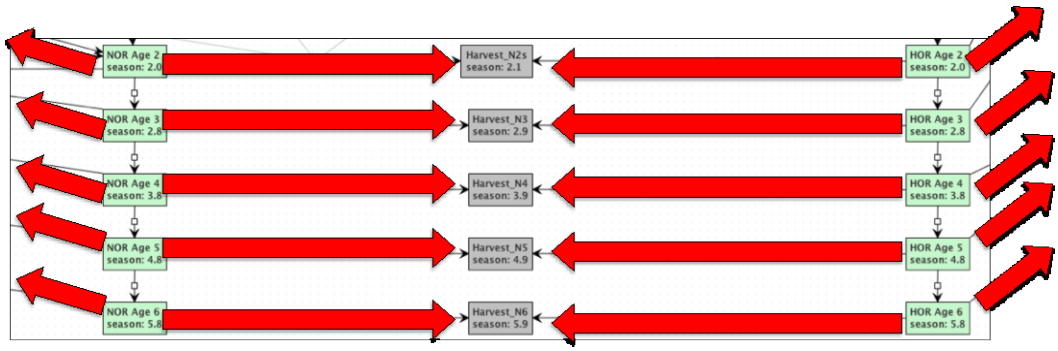
From	To	Proportion
NOR Sub-yr DE FBW	NOR Sp sub-yr MCF Downstream	0
	NOR Fall sub-yr MCF Downstream	0.7-0.8
	NOR 2nd Sp yr MCF Downstream	0.2-0.3



Proportional splits of ocean adults (NOR/HOR Age 2, 3, 4, 5, & 6) that stay in the ocean for another year, are harvested in the ocean, or return to freshwater.

From	To	Proportion
NOR Age 2	NOR Age 3	0.999
	Harvest N2	0
	NOR Returns	0.001
HOR Age 2	HOR Age 3	0.999
	Harvest N2	0
	HOR In-River harvest	0.001
NOR Age 3	NOR Age 4	0.996
	Harvest N3	0.002
	NOR Returns	0.002
HOR Age 3	HOR Age 4	0.996
	Harvest N3	0.002
	HOR In-River harvest	0.002
NOR Age 4	NOR Age 5	0.6
	Harvest N4	0.09
	NOR Returns	0.31
HOR Age 4	HOR Age 5	0.6
	Harvest N4	0.09
	HOR In-River harvest	0.31
NOR Age 5	NOR Age 6	0.03
	Harvest N5	0.09
	NOR Returns	0.88
HOR Age 5	HOR Age 6	0.03
	Harvest N5	0.09
	HOR In-River harvest	0.88
NOR Age 6	Harvest N5	0
	NOR Returns	1
HOR Age 6	Harvest N5	0
	HOR In-River harvest	1

Values taken from Hendrix and Shi (2012) (page 21-23), which are based on ODFW SLAM parameter values and adjusted to fit age composition from ODFW.



5.3. Datafiles

Most parameter values are scalars or are drawn from distributions according to parameters within SLAM, however there are stage transitions within the life-cycle model where survivals or life history splits come from datafiles. For example, dam passage survival and efficiency, and environmental variables like temperature, enter into SLAM as a datafile. The following are the stages or stage transitions that call a datafile with survivals or splits.

5.3.1. Survivals

Stage at which datafile is located	Name of datafile	Name of series
NOR Fry DE FBW	Detroit_FBW_Alternatives_toSLAM.csv	Baseline-April 15 2014 FBW-Fry-146yr
NOR Sub-yr DE FBW	Detroit_FBW_Alternatives_toSLAM.csv	Baseline-April 15 2014 FBW-Subyr-146yr
NOR Yrling DE FBW	Detroit_FBW_Alternatives_toSLAM.csv	Baseline-April 15 2014 FBW-Yrling-146yr
NOR Sp sub-yr Smolts	EstuaryCurrent_modified_1_2013.csv	EstuaryCurrent x 2 (200yrs)
NOR Fall sub-yr Smolts	EstuaryCurrent_modified_1_2013.csv	EstuaryCurrent x 2 (200yrs)
NOR 2nd Sp yr Smolts	EstuaryCurrent_modified_1_2013.csv	EstuaryCurrent x 2 (200yrs)
HOR Smolts	EstuaryCurrent_modified_1_2013.csv	EstuaryHatOr x 2 (200yrs)
NOR HOR Age 2	ChSOcean4thRt_modified_1_2013.csv	ChSAge2 10% down x 2 (200yrs)
NOR HOR Age 3	ChSOcean4thRt_modified_1_2013.csv	ChSAge3 10% down x 2 (200yrs)
NOR HOR Age 4	ChSOcean4thRt_modified_1_2013.csv	ChSAge4 10% down x 2 (200yrs)
NOR HOR Age 5	ChSOcean4thRt_modified_1_2013.csv	ChSAge 5 x 2 (200yrs)
NOR HOR Age 6	ChSOcean4thRt_modified_1_2013.csv	ChSAge 6 x 2 (200yrs)
TDGJ	TDG_NS_modified_1_2013.csv	BC_WorstScenario_JuvenileF (146yrs) 15%reduction
TDGA	TDG_NS_modified_1_2013.csv	BC_WorstScenario_AlevinF (146yrs) 15%reduction
Temp A	Nsantiam_Temp_Max7-DADM.csv	Reach A 200yr max7DADM (based on 5yrs of USGS data)
Temp B	Nsantiam_Temp_Max7-DADM.csv	Reach B 200yr max7DADM (based on 12yrs of USGS data)
Temp C	Nsantiam_Temp_Max7-DADM.csv	Reach B 200yr max7DADM (based on 12yrs of USGS data)
Temp D	Nsantiam_Temp_Max7-DADM.csv	Reach D 200yr max7DADM (based on 14yrs of USGS data)
Temp E	Nsantiam_Temp_Max7-DADM.csv	Reach E 200yr max7DADM (based on 14yrs of USGS data)
Temp F	Nsantiam_Temp_Max7-DADM.csv	Reach F 200yr max7DADM (based on 14yrs of USGS data)
Temp F	Nsantiam_Temp_Max7-DADM.csv	Reach F 200yr max7DADM (based on 14yrs of USGS data)

5.3.2. Splits

Stage at which datafile is used	Name of datafile	Recruit stage datafile is applied	Name of series
NOR Fry DE res	NOR Fry DE res.csv	NOR Fry DE	Baseline NOR Fry DE
		NOR Sub-yr DE	Baseline NOR Sub-yr DE
NOR Sub-yr DE res	NOR Sub-yr DE res.csv	NOR Sub-yr DE	Baseline NOR Sub-yr DE
		NOR Yrling DE	Baseline NOR Yrling DE
NOR Fry DE FBW	NOR Fry DE FBW.csv	NOR Sp sub-yr MCF Downstream	NOR Sp sub-yr MCF Downstream
		NOR Fall sub-yr MCF Downstream	NOR Fall sub-yr MCF Downstream
		NOR 2nd Sp yr MCF Downstream	NOR 2nd Sp yr MCF Downstream
NOR Sub-yr DE FBW	NOR Sub-yr DE FBW.csv	NOR Sp sub-yr MCF Downstream	NOR Sp sub-yr MCF Downstream
		NOR Fall sub-yr MCF Downstream	NOR Fall sub-yr MCF Downstream
		NOR 2nd Sp yr MCF Downstream	NOR 2nd Sp yr MCF Downstream

USACE provided R2 Consultants, who in turn provided NWFSC, with the following SLAM datafiles; EstuaryCurrent, ChSOcean4thRt, TDGCougar, and McKenzie_Temp_Max7-DADM. Each of the aforementioned files was expanded by NWFSC by repeating from the beginning, such that the files that were 74 years became 146 years, and those that were 100 years became 200 years. USACE provided Fish Benefits Workbooks datafiles that correspond to dam passage survival (e.g. Detroit_FBW_Alternatives_toSLAM.csv) and dam passage efficiency (e.g., Detroit_1-DPE_Alternatives_toSLAM.csv) (Fish Benefits Workbooks User Guide 2014).

5.4. Dynamic Drivers and Influence Scripts

In some cases we used scripts to influence life stage transitions and splits. These were written in a Java-compatible syntax and are called groovy script. These gave us the ability to dynamically influence splits such as apportioning adults to natal reaches based on juvenile outmigrants four years earlier, or for applying the dam passage efficiency (DPE) to juveniles attempting to pass the dam. Below is a list of boxes where dynamic drivers are applied.

Box where dynamic driver is located	Dynamic driver file name	What does dynamic driver do?
pNOB	pNOB.groovy	Calculates proportion of natural origin broodstock.
pNI	pNI.groovy	Calculates proportion of natural influence.
NOR Adults	NORs.groovy	Counts the number of NORs at Willamette Falls.
NORcounts at BD Upstream	NORs.groovy	Counts the number of NORs at Bennett Dam.
ctr incr	ctr_incr.groovy	A counter to keep track of the year number being simulated.
NOR & HOR Returns DEF	NOR HOR Returns DEF.groovy	Calculates total number of natural or hatchery origin adults that returned to Reach D, E, & F.
NOR & HOR Returns ABC	NOR HOR Returns ABC.groovy	Calculates total number of natural or hatchery origin adults that returned to Reach A, B, & C.
%Wild ABCDEF	%Wild.groovy	Calculates percent of natural origin fish with each Reach.
Fry 1-DPE	1-DPE.groovy	Takes proportion from DPE datafile and calculates the proportion of fry that pass dam.
Subyr 1-DPE	1-DPE.groovy	Takes proportion from DPE datafile and calculates the proportion of sub-yearlings that pass dam.
Yrling 1-DPE	1-DPE.groovy	Takes proportion from DPE datafile and calculates the proportion of yearlings that pass dam.
Fall sub-yr	Prop per Strategy-at Smolt.groovy	Calculates proportion of smolts that are fall sub-yearlings.
Sp sub-yr	Prop per Strategy-at Smolt.groovy	Calculates proportion of smolts that are spring sub-yearlings.
2nd Sp yr	Prop per Strategy-at Smolt.groovy	Calculates proportion of smolts that are second spring yearlings.
Tot Reach A, B, C, & F	Tot ReachABCF.groovy	Calculates total number of juveniles that exit Reach A, B, C & F that is then used to calculate proportion of juveniles that exit each reach (see Split Influencer below).
Tot Reach DE	Tot ReachDE.groovy	Calculates total number of juveniles that exit Reach D & E that is then used to calculate proportion of juveniles that exit each reach (see Split Influencer below).

Stage where influence script is located	Groovy script file name	What does script do?
HOR JOM	HOR JOM.groovy	
NOR or HOR Spawners ABCDEF	PSM.groovy	Calculates prespawn survival by using reach specific temperature and % wild as inputs PSM=((-9.5789)+(%wild * -2.39)+(Temp * 0.5492)); modified from Roumasset (2012) equation.
pHOS ABCDEF 2	pHOS ABCDEF 2.groovy	Calculates proportion of hatchery origin spawners.
pNI counter	PNI counter.groovy	A counter to keep track of the year number being simulated.
pHOS ABCDEF 3	pHOS ABCDEF 3.groovy	Calculates proportion of hatchery origin spawners.
NOR Emerg Fry A, B, C, D, & E	pNI_NORs Eggs to Emerg Fry.groovy	Calculates proportion of eggs that survive.
HOR Emerg Fry A, B, C, D, & E	pNI_HORs Eggs to Emerg Fry.groovy	Calculates proportion of eggs that survive.
NOR Emerg Fry F	pNI_NORs Eggs To Emerg Fry W TDG.groovy	Calculates proportion of eggs that survive w TDG influence.
HOR Emerg Fry F	pNI_HORs Eggs To Emerg Fry W TDG.groovy	Calculates proportion of eggs that survive w TDG influence.
NOR Sp sub-yr F	TDG.groovy	Calculates proportion of juveniles that survive the total dissolved gas.
NOR Fall sub-yr F	TDG.groovy	Calculates proportion of juveniles that survive the total dissolved gas.
NOR 2nd Sp yr F	TDG.groovy	Calculates proportion of juveniles that survive the total dissolved gas.
NOR Sp sub-yr MCF Downstream	TDG.groovy	TDG influence hits fish as they pass Detroit/Big Cliff dam & enter Reach F (ie. above Minto)
NOR Fall sub-yr MCF Downstream	TDG.groovy	TDG influence hits fish as they pass Detroit/Big Cliff dam & enter Reach F (ie. above Minto)
NOR 2nd Sp yr MCF Downstream	TDG.groovy	TDG influence hits fish as they pass Detroit/Big Cliff dam & enter Reach F (ie. above Minto)
Harvest_N2	Harvest_N2s.groovy	

Stage where split influencer is located	Stage where groovy script is located	Groovy script file name	What does split influencer do?
Hatchery Adults	Hatchery returns	Hatchery returns.groovy	Calculates the proportion of Hatchery Adults that return to hatchery.
	HOR Adults	HOR Adults.groovy	Calculates the proportion of Hatchery Adults that stay in river.
NOR In-River harvest	NOR Return Av	NOR Return Av.groovy	Calculates the proportion of natural origin adults that go to Reach A.
	NOR BD Upstream	NOR BD Upstream.groovy	Calculates the proportion of natural origin adults that go above Bennett Dam.
NOR BD Upstream	NOR Return Bv	NOR Return Bv.groovy	Calculates the proportion of natural origin adults that go to Reach B.
	NOR Return Cv	NOR Return Cv.groovy	Calculates the proportion of natural origin adults that go to Little North Santiam (Reach C).
	NOR MCF Upstream	NOR MCF Upstream.groovy	Calculates the proportion of natural origin adults that go above Minto Collection Facility.
NOR MCF Upstream	NOR Return D	NOR Return D.groovy	Calculates the proportion of natural origin adults that go to Reach D.
	NOR Return E	NOR Return E.groovy	Calculates the proportion of natural origin adults that go to Reach E.
	NOR Return F	NOR Return F.groovy	Calculates the proportion of natural origin adults that go to Reach F.
	Broodstock	Broodstock.groovy	Calculates the proportion of natural origin adults that go hatchery as broodstock.
NOR Fry DE	NOR Sub-yr DE	NOR Sub-yr DE.groovy	Calculates the proportion of fry in Detroit reservoir that stay in Detroit reservoir to become sub-yearlings.
	NOR Fry DE FBW	NOR Fry DE FBW.groovy	Calculates the proportion of fry in Detroit reservoir that attempt to pass Detroit Dam.
NOR Sub-yr DE	NOR Yrling DE	NOR Yrling DE.groovy	Calculates the proportion of sub-yearlings in Detroit reservoir that stay in Detroit reservoir to become yearlings.
	NOR Sub-yr DE FBW	NOR Sub-yr DE FBW.groovy	Calculates the proportion of sub-yearlings in Detroit reservoir that attempt to pass Detroit Dam.
NOR Yrling DE	NOR Yrling DE FBW	NOR Yrling DE FBW.groovy	Calculates the proportion of yearlings in Detroit reservoir that attempt to pass Detroit Dam.
	NOR Yrling DE dead	NOR Yrling DE dead.groovy	Calculates the proportion of yearlings in Detroit reservoir that do not pass Detroit Dam.

5.5. Initialization Values

When SLAM begins a simulation not all of the boxes are populated with fish. As a result, the first several simulated years can show large fluctuations in abundance and frequent extinctions. To reduce these fluctuations many of the boxes are initialized with some number of fish at the start of the model. The values used to initialize these boxes were taken from the 100th year in a previous baseline simulation.

Stage	Initialized
Hatchery Adults	4,000
Hatchery returns	500
NOR Returns	500
Hatchery Spawners	400
HOR Adults	1
pNOB	100
pNI	125
NOR In-River harvest	1
NOR BD Upstream	500
HOR BD upstream	1
NORcounts at BD Upstream	1000
NOR Return Av	1
HOR Return Av	1
NOR Return Cv	1
NOR Return Bv	1
NOR MCF Upstream	1
NOR Return A	1
NOR Return B	1
NOR Return C	1
NOR Return D	1
NOR Return E	1
NOR Return F	1
HOR MCF Upstream	1
HOR Return B	1
HOR Return C	1
HOR Return A	1
HOR Return D	1
HOR Return E	1
HOR Return F	1
pHOS ABCDEF 1	150
ctr incr	20
pNI counter	20
HOR Returns DEF	800
NOR Returns DEF	30
HOR Returns ABC	900
NOR Returns ABC	400
%Wild B	40
%Wild C	500
%Wild A	12
%Wild D	-
%Wild E	-
%Wild F	30
NOR Spawners A	1
HOR Spawners A	1
NOR Spawners B	1
HOR Spawners B	1
NOR Spawners C	1
HOR Spawners C	1
NOR Spawners D	1
HOR Spawners D	1
NOR Spawners E	1
HOR Spawners E	1
NOR Spawners F	1
HOR Spawners F	1
NOR Tot Spawners A	1
HOR Tot Spawners A	1
NOR Tot Spawners B	1
HOR Tot Spawners B	1
NOR Tot Spawners C	1
HOR Tot Spawners C	1
NOR Tot Spawners D	1
HOR Tot Spawners D	1
NOR Tot Spawners E	1
HOR Tot Spawners E	1
NOR Tot Spawners F	1
HOR Tot Spawners F	1
HOR Eggs D	1
NOR Eggs D	1
HOR Eggs C	1
NOR Eggs C	1
HOR Eggs B	1
NOR Eggs B	1
HOR Eggs A	1
NOR Eggs A	1
NOR Eggs E	1
HOR Eggs E	1
NOR Eggs F	1
HOR Eggs F	1
NOR & HOR Emerg Fry A	1
NOR & HOR Emerg Fry B	1
NOR & HOR Emerg Fry C	1

NOR & HOR Emerg Fry D	1
NOR & HOR Emerg Fry E	1
NOR & HOR Emerg Fry F	1
NOR TNH DE	0
NOR Fry DE	1000
NOR Sub-yr DE	1000
NOR Yrling DE	1000
NOR Sp sub-yr A	1
NOR Fall sub-yr A	1
NOR 2nd Sp yr A	1
NOR Sp sub-yr B	1
NOR Fall sub-yr B	1
NOR 2nd Sp yr B	1
NOR Sp sub-yr C	1
NOR Fall sub-yr C	1
NOR 2nd Sp yr C	1
NOR Sp sub-yr D	1
NOR Sp sub-yr E	1
NOR Sp sub-yr F	1
NOR Fall sub-yr F	1
NOR 2nd Sp yr F	1
NOR Sp sub-yr JOM C	2,500
NOR Sp sub-yr JOM B	7,500
NOR Sp sub-yr JOM A	1,000
NOR Sp sub-yr JOM F	2,500
NOR Sp sub-yr Smolts	1
HOR Smolts	140,000
NOR Fall sub-yr Jom C	2,500
NOR Fall sub-yr JOM A	5,000
NOR Fall sub-yr Jom B	5,000
NOR Fall sub-yr JOM F	500
NOR 2nd Sp yr JOM C	1,000
NOR 2nd Sp yr JOM B	2,500
NOR Fall sub-yr Smolts	1
NOR 2nd Sp yr JOM A	500
NOR 2nd Sp yr JOM F	500
NOR 2nd Sp yr MCF Downstream	500
NOR 2nd Sp yr Smolts	1
Sp sub-yr	200
Fall sub-yr	350
2nd yr	300
Tot Reach A	1,000
Tot Reach B	3,000
Tot Reach C	1,500
Tot Reach DE	1,000
Tot Reach F	900
NOR Age 2	6000
HOR Age 2	26,000
NOR Age 3	1,500
HOR Age 3	22,500
NOR Age 4	1,000
HOR Age 4	17,500
NOR Age 5	750
HOR Age 5	9,000
NOR Age 6	5
HOR Age 6	80

5.5.1. Model Demonstration & Alternative Scenarios

Here we report results from SLAM model runs that evaluated potential population responses to a set of the most recent dam project alternatives (received May 27, 2014) identified by the USACE. Below (Table 5.3) is a list of alternatives that represent various operational and structural modifications to Detroit Dam whose goal is to improve access to Reach D and E (above Detroit Dam). Each alternative was run in SLAM and estimates were produced of several variables including abundance of natural origin spawners and each life history strategy, and percent wild. Each alternative was run 500 times, and each run is 100 years long. We used 500 runs because output stabilized at this level. USACE provided datafiles of dam passage survival and efficiency (Fish Benefit Workbook), which were time series of 73 years in length, and we duplicated them to produce time series that were 146 years in length. All alternatives were provided by USACE.

Table 5.3: List of alternatives run in the SLAM model of North Santiam River Chinook salmon. Description of each alternative can be found in Appendix D.

	Alternative Description	SLAM output name	Reach B & F: Egg to Fry survival (based on temp workshop March 19, 2014)	Passage survival (average %)			1-DPE (average %)			Detroit Trap & Haul releases fish below TDG influence?
				Fry	Sub-yr	Yrling	Fry	Sub-yr	Yrling	
1	Baseline	Baseline	0.4525(0.405-0.5)	65	45	45	41	51	44	NA
2	Selective Withdrawal Str with Weir Box	SWS-Weir	0.498(0.471-0.525)	56	49	48	31	31	31	Y
3	Selective Withdrawal Str	SWS	0.498(0.471-0.525)	52	44	44	31	31	31	NA
4	Selective Withdrawal Str, Floating Screen Str	SWS-FSS	0.498(0.471-0.525)	96	96	95	31	31	31	Y
5	Selective Withdrawal Str, Floating Screen Str, 40% DPE	SWS-FSS-40	0.498(0.471-0.525)	96	96	95	60	60	60	Y
6	Selective Withdrawal Str, Floating Screen Str, 80% DPE	SWS-FSS-80	0.498(0.471-0.525)	96	96	95	20	20	20	Y
7	FSS (SWS) Temp Alts Alden Timing	FSS Temp Alts	0.498(0.471-0.525)	97	96	94	31	31	31	Y
8	Floating Surface Collector @ 220 cfs. No temp	FSC 220	0.4525(0.405-0.5)	70	68	66	31	31	31	Y
9	Floating Surface Collector @ 750 cfs. No temp	FSC 750	0.4525(0.405-0.5)	88	89	84	31	31	31	Y
10	Floating Surface Collector @ 1000 cfs. No temp	FSC 1000	0.4525(0.405-0.5)	92	89	84	31	31	31	Y
11	Floating Surface Outlet	FSO	0.467(0.448-0.486)	65	63	75	31	31	31	NA
12	Operate as Run of River (1276') from 1 Sep - 1 Jun (eval	RoR	0.4525(0.405-0.5)	80	69	74	70	63	69	NA

5.5.2. Parameter Variability

The following tables identify parameters that vary among years in each model run. In all the parameters listed below (except passage survival and estuary and ocean survival) values are randomly selected each model year from the specified distribution and these distributions and the parameters defining them do not vary among alternatives (Table 5.4). For any given alternative, passage survival values vary among years of a model run, but do not vary among the 500 model runs (passage survival values are taken from a datafile). Values of passage survival vary among alternatives (Table 5.5). For any given alternative, estuary and ocean survival values vary among years of a model run, but do not vary among the 500 model runs (estuary and ocean survival values are taken from a datafile). Values of estuary and ocean survival do not vary among alternatives (Table 5.6).

Table 5.4: Capacity and survival parameters whose values vary among years in each model run and vary among model runs.

Location in Life Cycle	From	To	Curve type	Capacity &/or Productivity	Distribution type	Mean	SD	Min	Max
Reach A Downstream of Bennett Dam (18.8miles)	NOR Tot Spawners	Eggs	Beverton-Holt	Capacity	Normal	300,000	50,000	150,000	500,000
Reach B Bennett to Minto Collection Facility (26.5miles)	NOR Tot Spawners	Eggs	Beverton-Holt	Capacity	Normal	5,000,000	100,000	1,000,000	6,000,000
Reach C Little North Santiam River (17.5miles)	NOR Tot Spawners	Eggs	Beverton-Holt	Capacity	Normal	1,500,000	100,000	500,000	2,500,000
Reach D Breitenbush River (14.2miles)	NOR Tot Spawners	Eggs	Beverton-Holt	Capacity	Normal	6,000,000	100,000	2,000,000	7,500,000
Reach E Upper North Santiam (27.4miles)	NOR Tot Spawners	Eggs	Beverton-Holt	Capacity	Normal	12,500,000	250,000	4,000,000	14,000,000
Reach F Minto to Big Cliff (2.9miles)	NOR Tot Spawners	Eggs	Beverton-Holt	Capacity	Normal	500,000	50,000	200,000	600,000
Reach A Downstream of Bennett Dam (18.8miles)	HOR Tot Spawners	Eggs	Beverton-Holt	Capacity	Normal	300,000	50,000	150,000	500,000
Reach B Bennett to Minto Collection Facility (26.5miles)	HOR Tot Spawners	Eggs	Beverton-Holt	Capacity	Normal	5,000,000	100,000	1,000,000	6,000,000
Reach C Little North Santiam River (17.5miles)	HOR Tot Spawners	Eggs	Beverton-Holt	Capacity	Normal	1,500,000	100,000	500,000	2,500,000
Reach D Breitenbush River (14.2miles)	HOR Tot Spawners	Eggs	Beverton-Holt	Capacity	Normal	6,000,000	100,000	2,000,000	7,500,000
Reach E Upper North Santiam (27.4miles)	HOR Tot Spawners	Eggs	Beverton-Holt	Capacity	Normal	12,500,000	250,000	4,000,000	14,000,000
Reach F Minto to Big Cliff (2.9miles)	HOR Tot Spawners	Eggs	Beverton-Holt	Capacity	Normal	500,000	50,000	200,000	600,000
Hatchery	Hatchery returns	Hatchery Spawners	Hockey-Stick	Capacity	Normal	550	50	450	750
Hatchery	Hatchery Spawners	HOR JOM	Hockey-Stick	Capacity	Normal	660,000	50,000	600,000	700,000
Reach B	Eggs	Emergent Fry	Linear	Productivity	Triangular	0.4525		0.4050	0.5000
Reach F	Eggs	Emergent Fry	Linear	Productivity	Triangular	0.4525		0.4050	0.5000
Reach DE	NOR Fry DE res	NOR Sub-yr DE	Linear	Productivity	Triangular	0.2000		0.1500	0.3500
Reach DE	NOR Sub-yr DE res	NOR Yrling DE	Linear	Productivity	Uniform			0.4000	0.9000
Reach DE	NOR Fry DE	NOR Sub-yr DE	Linear	Productivity	Triangular	0.2000		0.1500	0.3500
Reach DE	NOR Sub-yr DE	NOR Yrling DE	Linear	Productivity	Uniform			0.4000	0.9000

Table 5.5: Average, minimum, and maximum passage survival for each alternative and life history strategy. These values vary among years of a model run but do not vary among model runs.

FBW		Average Passage Survival			Min Passage Survival			Max Passage Survival		
Output File name	Alternative	Fry	Sub-yr	Yrling	Fry	Sub-yr	Yrling	Fry	Sub-yr	Yrling
Ch_NS_1_052714	Baseline-May 27 2014	0.65	0.45	0.45	0.51	0.44	0.44	0.69	0.45	0.45
Ch_NS_2_052714	SWS-Weir-May 27 2014	0.56	0.49	0.48	0.55	0.46	0.47	0.59	0.50	0.55
Ch_NS_2b_052714	SWS-May 27 2014	0.52	0.44	0.44	0.51	0.44	0.44	0.55	0.45	0.47
Ch_NS_3_052714	SWS-FSS-May 27 2014	0.96	0.96	0.95	0.94	0.75	0.79	0.98	0.98	0.97
Ch_NS_3a_052714	SWS-FSS-40-May 27 2014	0.96	0.96	0.95	0.94	0.75	0.79	0.98	0.98	0.97
Ch_NS_3b_052714	SWS-FSS-80-May 27 2014	0.96	0.96	0.95	0.94	0.75	0.79	0.98	0.98	0.97
Ch_NS_3t_052714	FSS Temp Alts-May 27 2014	0.97	0.96	0.94	0.93	0.80	0.70	0.98	0.97	0.97
Ch_NS_6_052714	FSC 220-May 27 2014	0.70	0.68	0.66	0.67	0.60	0.61	0.73	0.71	0.71
Ch_NS_6a_052714	FSC 750-May 27 2014	0.88	0.89	0.84	0.81	0.72	0.74	0.92	0.93	0.93
Ch_NS_6b_052714	FSC 1000-May 27 2014	0.92	0.89	0.84	0.85	0.72	0.74	0.96	0.93	0.93
Ch_NS_7_052714	FSO-May 27 2014	0.65	0.63	0.75	0.56	0.54	0.62	0.83	0.84	0.84
Ch_NS_9_052714	RoR-May 27 2014	0.80	0.69	0.74	0.57	0.65	0.53	0.83	0.75	0.80

Table 5.6: Average, minimum, and maximum survival values during estuary and ocean stages. Age-specific time series of estuary and ocean survival were generated by ODFW, and incorporated into SLAM as datafiles.

Stage	Min	Average	Max
Estuary	0.61	0.66	0.70
Ocean 2yr olds	0.21	0.36	0.51
Ocean 3yr olds	0.28	0.46	0.67
Ocean 4yr olds	0.33	0.54	0.78
Ocean 5yr olds	0.42	0.68	0.99
Ocean 6yr olds	0.47	0.76	1

5.5.3. SLAM Output and VSP Scores

For each alternative run in SLAM, four categories of model output are produced; abundance and productivity, proportion of hatchery origin spawners, life history diversity, and spatial structure (see Chapter 3, Parameterization of VSP Criteria). For each of these categories we generate VSP scores, and then use the following equation to produce a Total VSP score:

$$Total\ VSP\ score = \frac{2(Abundance) + 2(Productivity) + Diversity + Spatial\ Structure}{6}$$

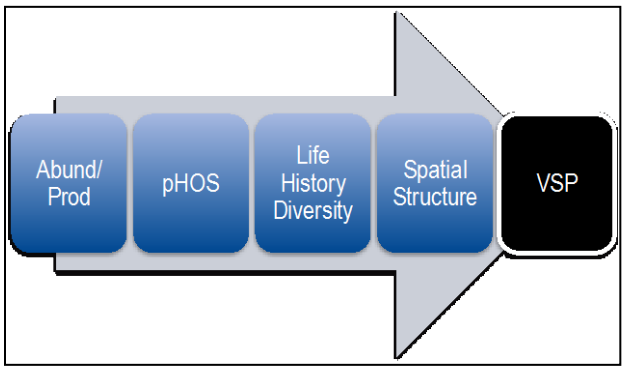


Figure 5.3: Representation of the four components (abundance and productivity, proportion of hatchery origin spawners, life history diversity, and spatial structure) that comprise VSP score.

Abundance and Productivity

Under Baseline (i.e., current) conditions, a median of 1,425 natural origin spawners was estimated for North Santiam River, while Selective Withdrawal Structure with Floating Screen Structure of 80% dam passage efficiency (DPE) (SWS-FSS-80) had the largest median of 12,175 (Table 5.3 and Figure 5.4).

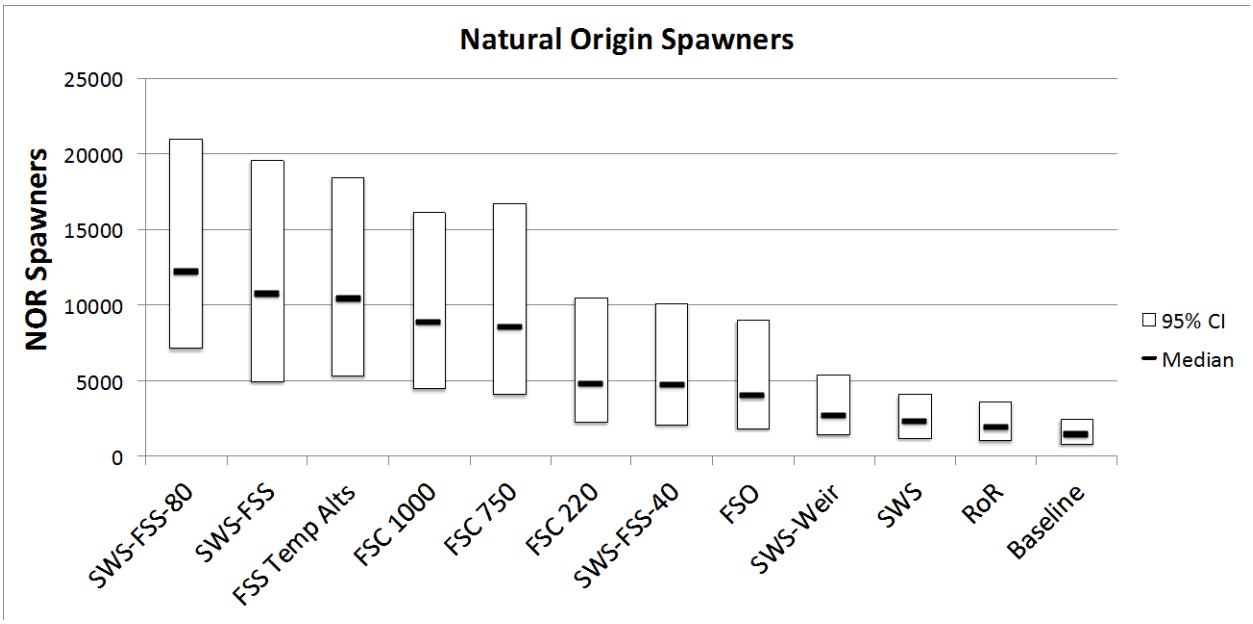


Figure 5.4: Abundance of natural origin spawners among North Santiam River alternatives (see Table 5.3). Median and 95% confidence limits (line and box, respectively) were calculated from the 500 geomeans (1 geomean per run) of abundance, each of which was for a 100-year period.

We estimated the probability quasi-exinction threshold (QET) for each alternative under the following conditions; critical abundance was set as 150 individuals (set by the Lower Columbia/Willamette TRT), a four-year moving average was used over a 100-year period (from year 6 to year 105). We started QET calculation at year 6 because the model was fully initialized beyond this point and reflected system dynamics rather than the influences of starting values. Under Baseline (i.e., current) conditions, pr(QET) was estimated as 12% for North Santiam River, while pr(QET) was <2% for all other alternatives except Run of River (RoR)(Figure 5.5).

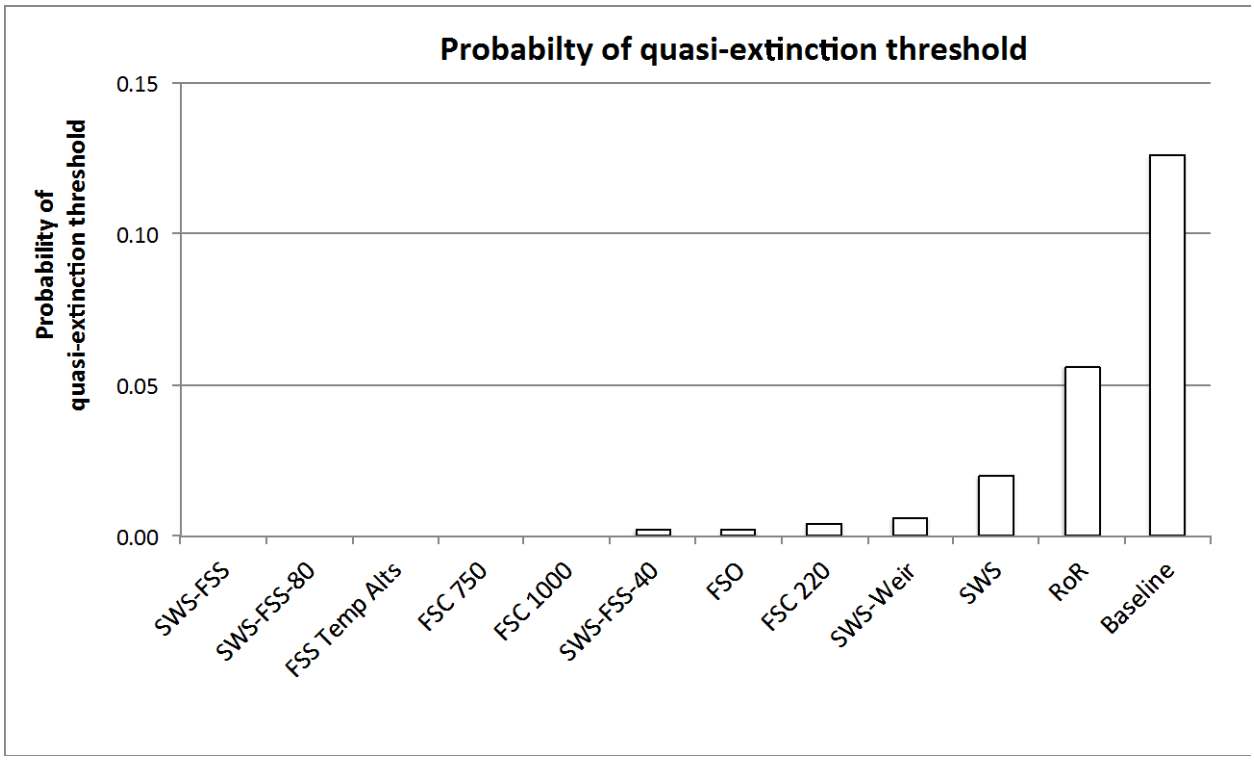


Figure 5.5: Probability of quasi-extinction among North Santiam River alternatives. The maximum value on the y-axis is 0.15 (instead of 1.0) to improve visibility of QET for several alternatives.

Based on a relationship between VSP score and abundance and productivity (see Chapter 3, Parameterization of VSP Criteria), the Baseline (i.e., current) conditions was given a median VSP score of 2.8, while all other alternatives yielded VSP scores greater than 3.2 (Figure 5.6).

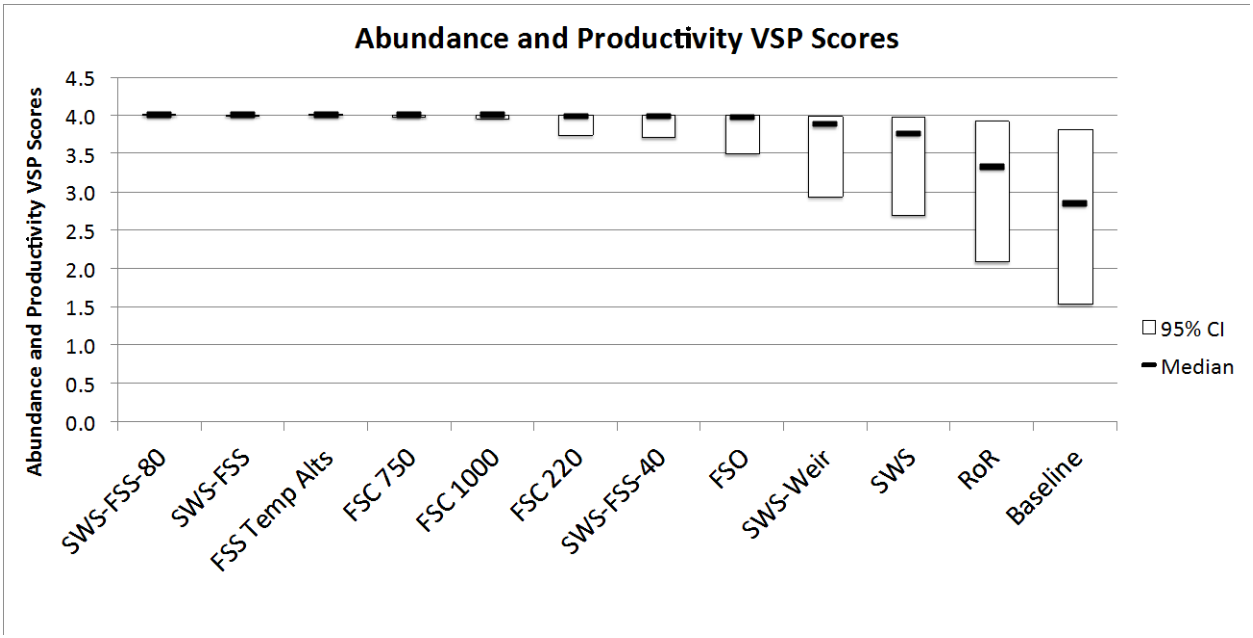


Figure 5.6: Abundance and Productivity VSP scores among North Santiam River alternatives.

Proportion of Hatchery Origin Spawners

Under Baseline (i.e., current) conditions, the median proportion of hatchery origin spawners was estimated as 0.45, while the Selective Withdrawal Structure with Floating Screen Structure and a 80% DPE (SWS-FSS-80) alternative was estimated to have a median of 0.03. This decline in the proportion of hatchery origin spawners for the SWS-FSS-80 alternative is due to an increase in natural origin spawners that resulted from improved dam passage efficiency and survival relative to the Baseline (Figure 5.7).

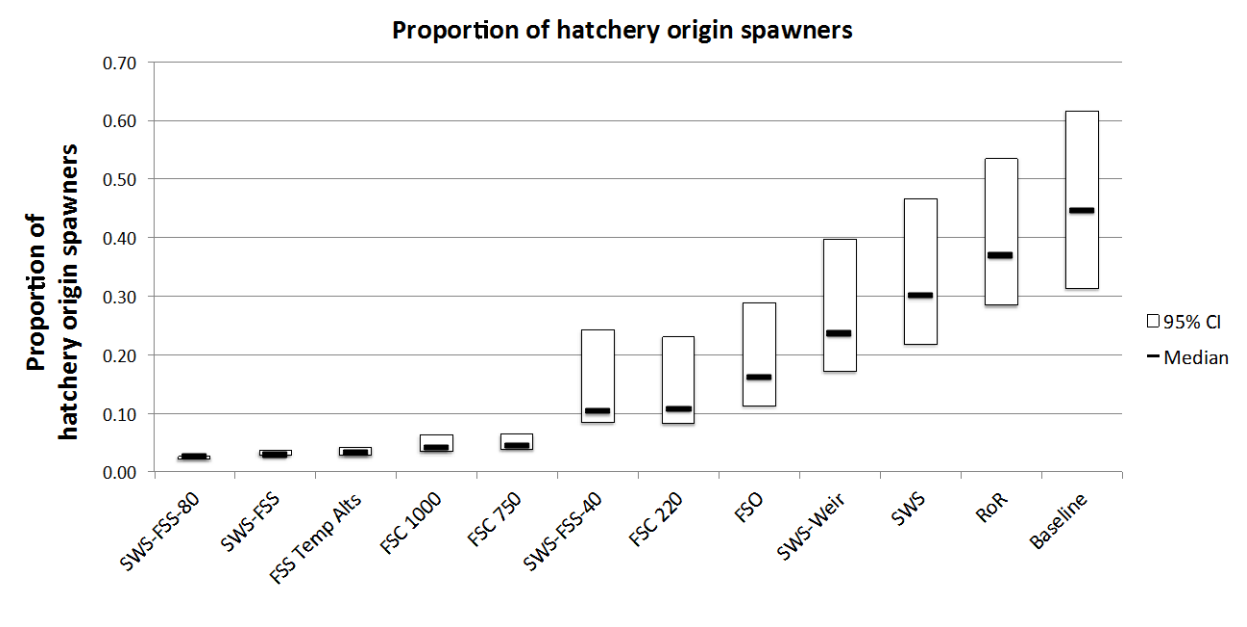


Figure 5.7: Proportion of hatchery origin spawners among North Santiam River alternatives (see Table 5.3). Median and standard deviation are shown (line and box, respectively), which were calculated at the final simulated year using all 500 SLAM trajectories.

The VSP score for proportion of hatchery origin spawners is calculated based on a combination of proportion of natural influence and proportion of hatchery origin spawners (see Chapter 3, Parameterization of VSP Criteria). Under Baseline (i.e., current) conditions, a median VSP score of 1.7 was estimated, while the SWS-FSS-80 alternative was estimated to have a median of 3.9 (see figure below) (Figure 5.8).

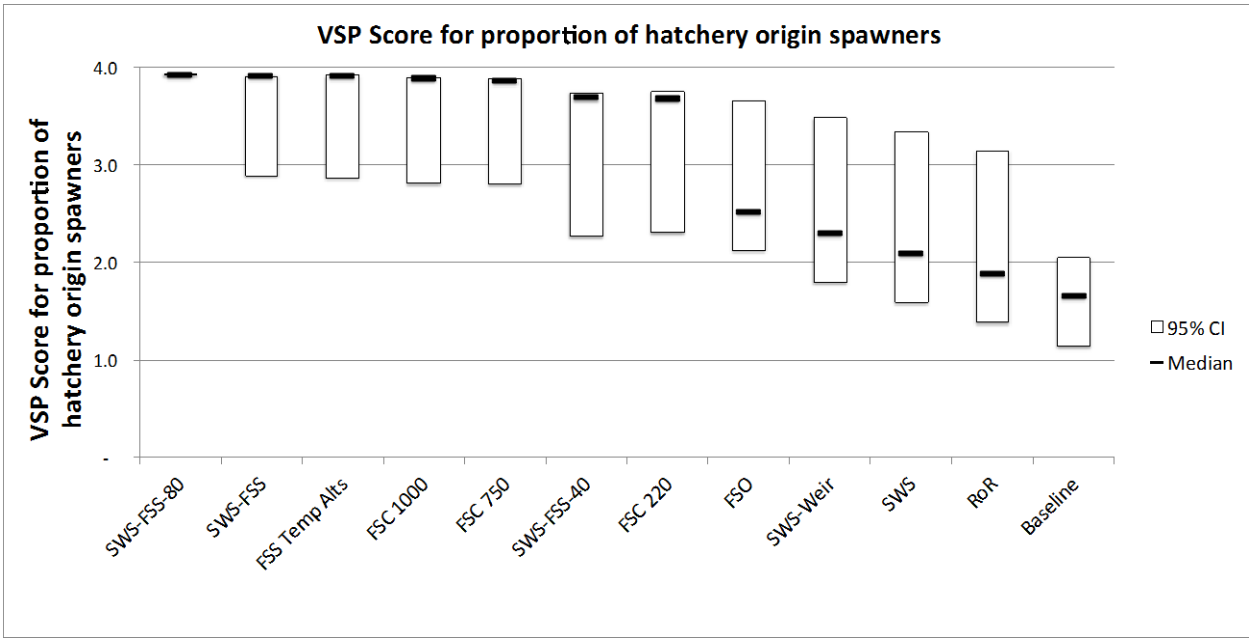


Figure 5.8: Proportion of Hatchery Origin Spawners VSP scores among North Santiam River alternatives. Median and standard deviation are shown (line and box, respectively), which were calculated using the median and standard deviation of PNI and pHOS.

Life History Diversity

Moving from baseline conditions to most of the alternatives, the number of spring subyearlings increased but not as much as the numbers of fall subyearlings and spring yearlings (Fig. 5.9). The composition of each life history was the most similar to baseline conditions in the RoR alternative.

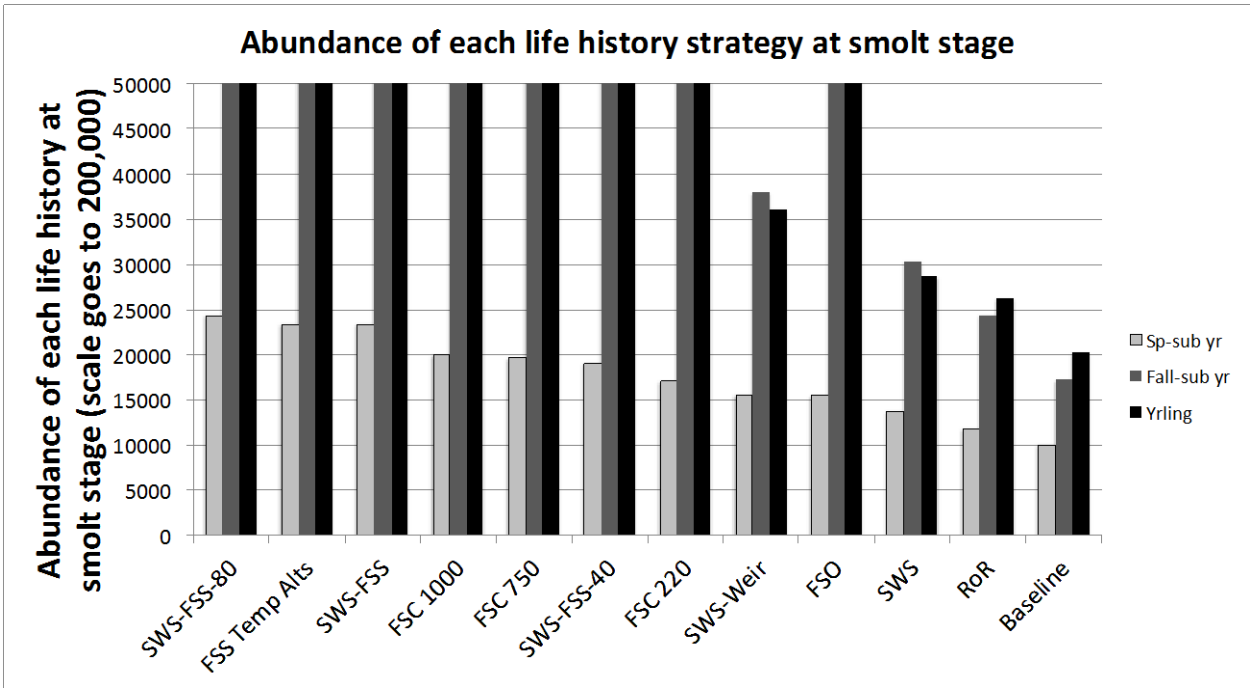


Figure 5.9: Median smolt abundance for each life history strategy among alternatives (see Table 5.3). Median was calculated at the final simulated year using all 500 SLAM trajectories. Standard deviation are excluded to improve clarity.

All alternatives were given a VSP score of 4.0 because each juvenile life history strategy was estimated to represent greater than 20% of the smolts (Figure 5.10).

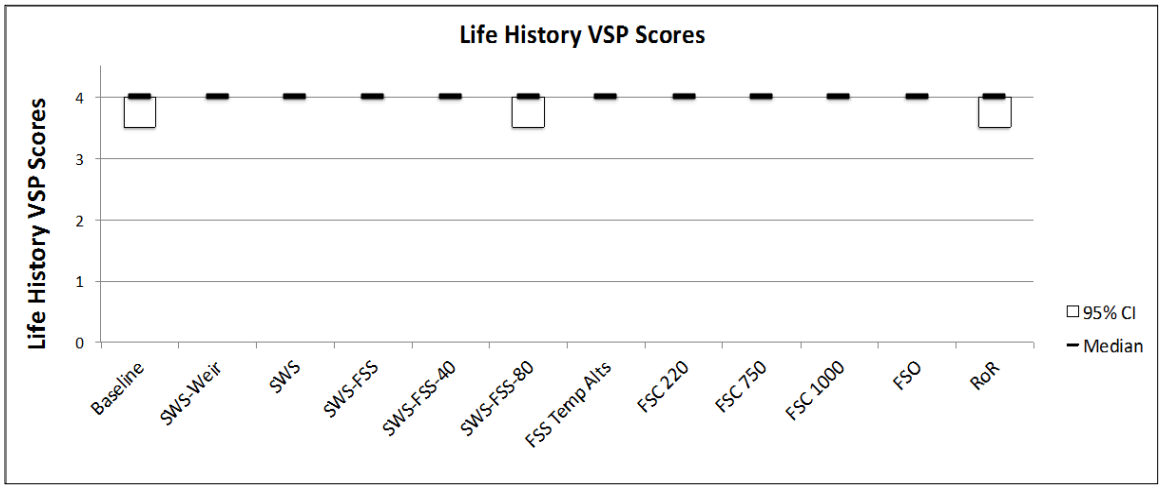


Figure 5.10: Life History Diversity VSP scores among North Santiam River alternatives. Median and standard deviation are shown (line and box, respectively), which were calculated using the median and standard deviation of abundance of smolts among life history strategies.

Spatial Structure

Spatial structure is a measure of population replacement above Detroit Dam. To assess replacement above Detroit Dam (i.e., Reach D & E) we used recruits per spawner, measured as median returning

spawners referenced to the median spawning brood that produced them (i.e., the spawner-to-spawner).

$$Spawner{:}\,Spawner = \frac{Natural\ origin\ spawners\ in\ Reach\ DE\ at\ time\ y + 4yrs}{Hatchery\ origin\ spawners\ in\ Reach\ DE\ at\ time\ y + Natural\ origin\ spawners\ in\ Reach\ DE\ at\ time\ y}$$

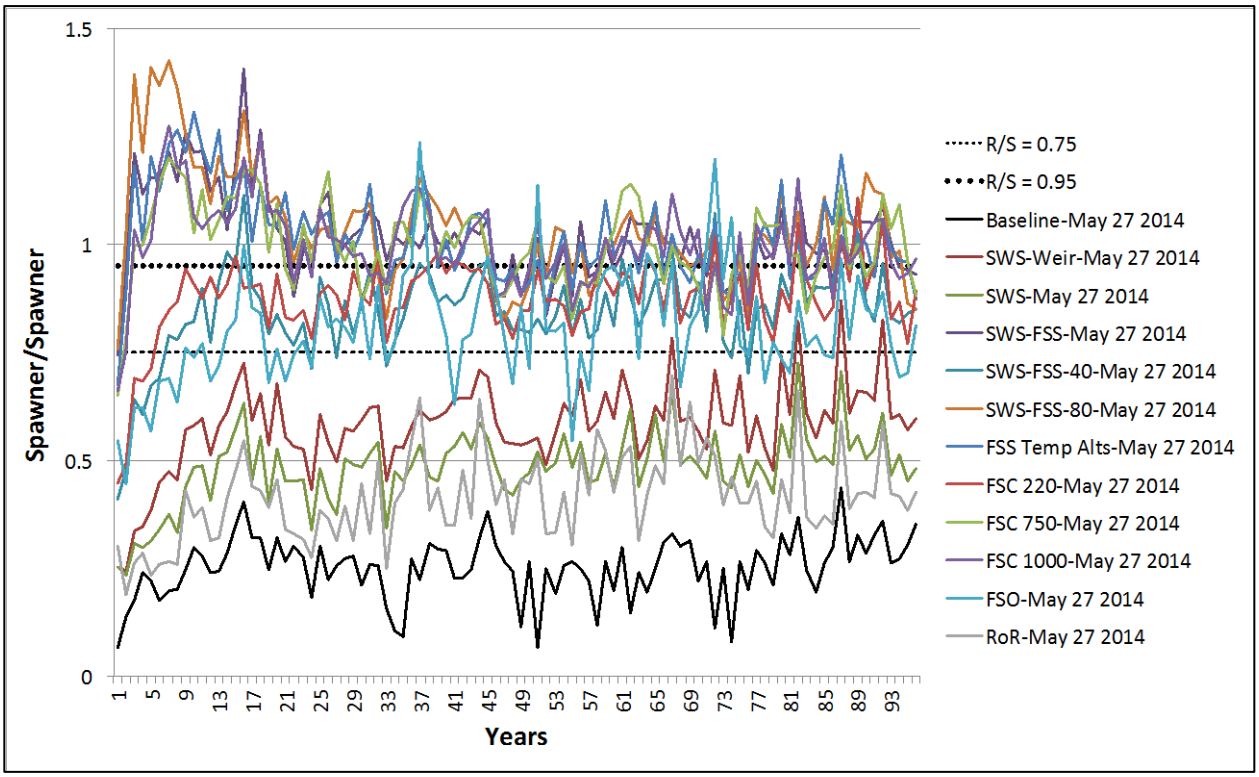


Figure 5.11: Times series of spawner-to-spawner ratio for each North Santiam River alternative. See text above for the equation used to calculate spawner-to-spawner ratio.

For each alternative, we calculated a median spawner-to-spawner ratio less than 0.75 (dotted line in Figure 5.11) yielded a VSP score of 1.5 for Spatial Structure, while a ratio between 0.75 and 0.95 (between dotted and dashed lines) yielded a VSP score of 2.83, and a ratio above 0.95 (dashed line) gets a VSP score of 3.5. Under Baseline conditions, the VSP score for spatial structure is 1.5, while the median score for SWS-FSS-80 alternative is 3.5 (see Figure 5.12).

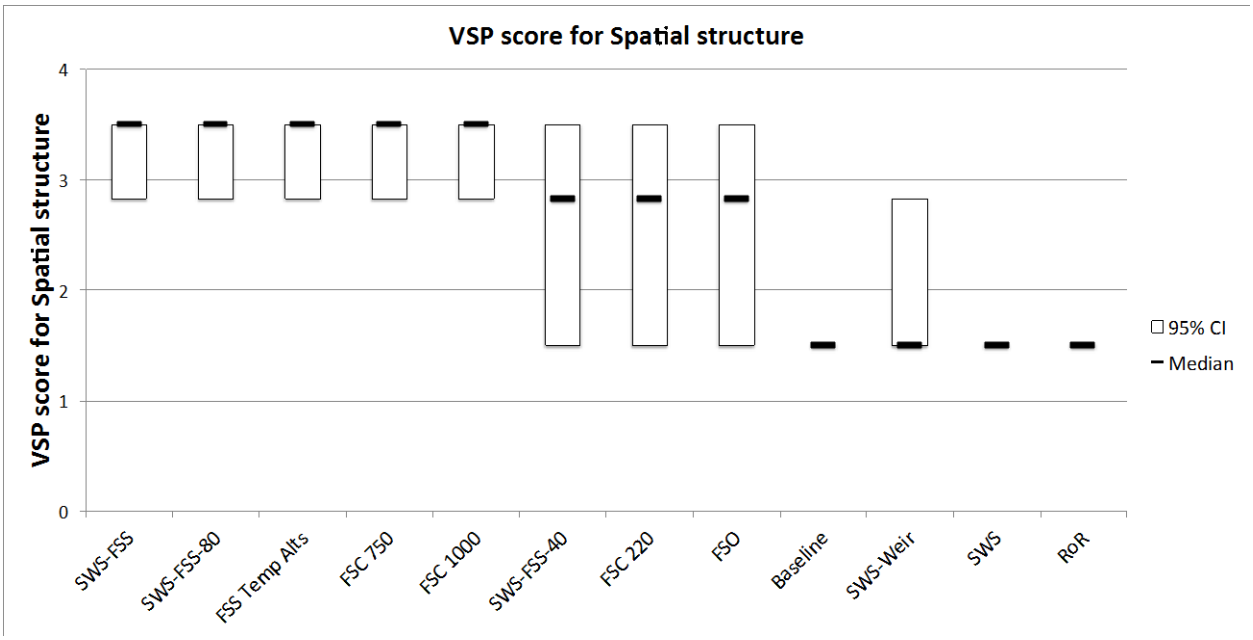


Figure 5.12: Spatial Structure VSP scores among North Santiam River alternatives. Median and standard deviation are shown (line and box, respectively), which were calculated using the median and standard deviation of spawner-to-spawner ratio.

Total VSP Score

To estimate the Total VSP score, we combined all the component VSP scores according to the following equation:

$$Total\ VSP\ score = \frac{2(Abundance) + 2(Productivity) + Diversity + Spatial\ Structure}{6}$$

Of the North Santiam River alternatives, SWS-FSS-80 and FSC-750-Weir produced the highest Total VSP Score of 3.9, while Baseline conditions yielded a score of 2.6 (Figure 5.13).

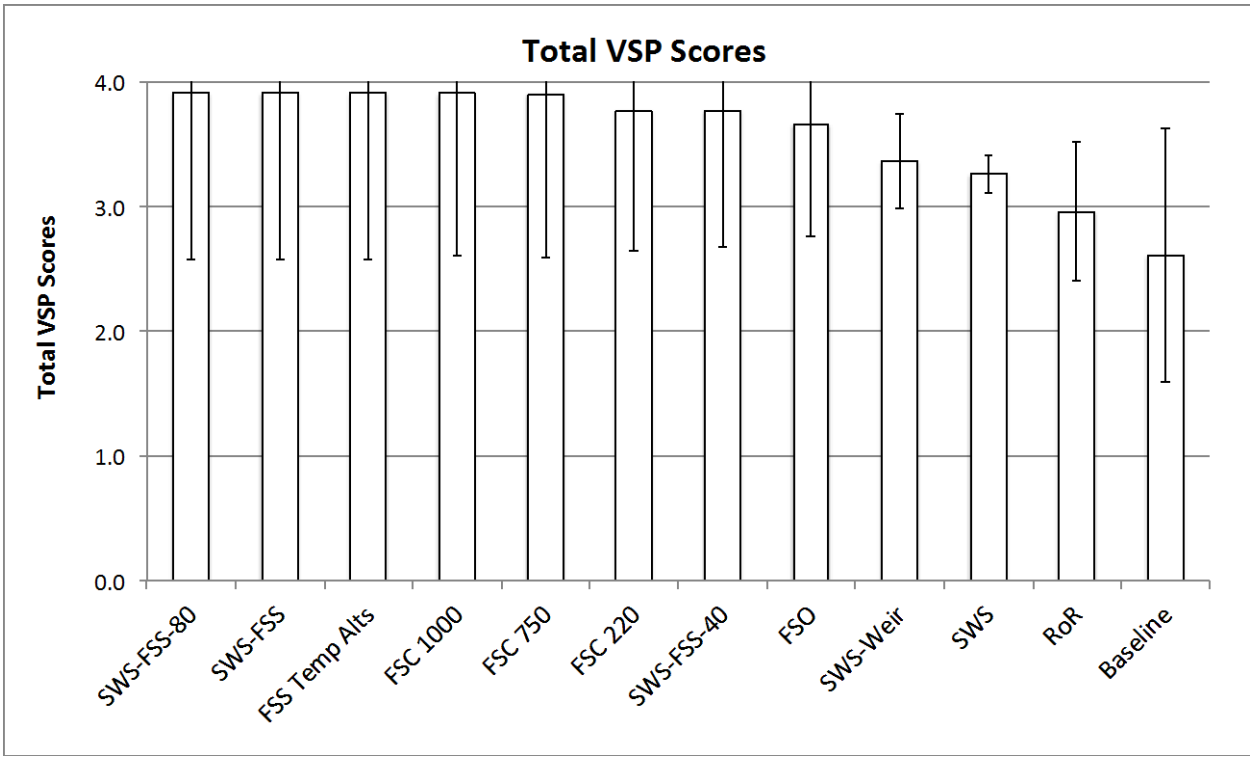


Figure 5.13: Total VSP scores among North Santiam alternatives. Whiskers denote +/- one standard deviation.

5.6. References

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CHAPTER 6. SLAM MODEL OF MIDDLE FORK RIVER CHINOOK SALMON

This chapter provides a description of the parameter values being considered in the Middle Fork River SLAM model. Below, we provide a short description of the model parameters used in each of five categories (1. Productivity, capacity, & survivals, 2. Splits, 3. Datafiles, 4. Dynamic drivers & influencers, and 5. Initialized). For reference purposes, a map of Middle Fork River (Figure 6.1) is provided that highlights each reach used in SLAM. Figure 6.2 shows how the life-cycle model is modeled within SLAM. Lastly, Table 6.1 is a list of definitions corresponding to each box within the life-cycle model, while Table 6.2 is a list of abbreviations used throughout this chapter.

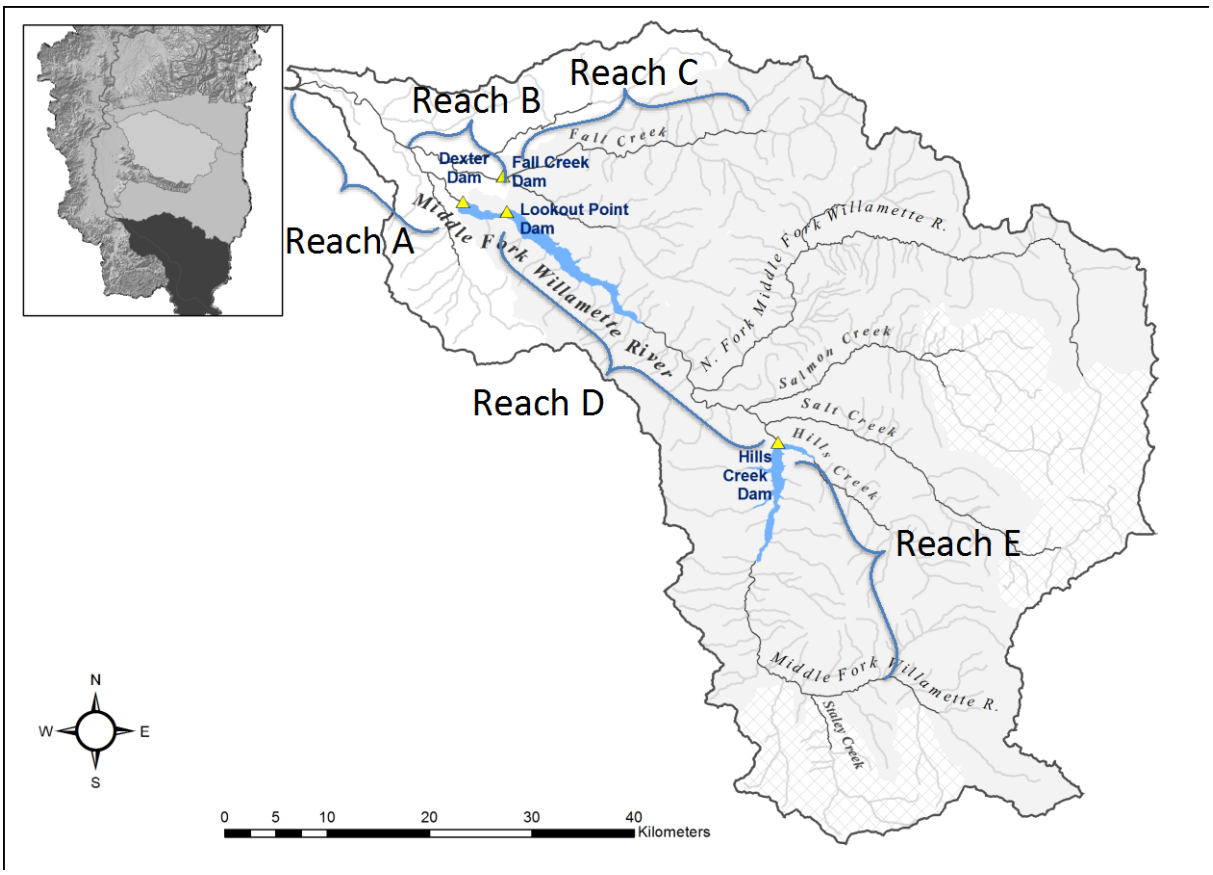


Figure 6.1: Map showing Middle Fork River and the six reaches (A-E) that are modeled in SLAM; Reach A corresponds to mainstem Middle Fork River downstream of Dexter Dam, Reach B corresponds to Fall Creek River downstream of Fall Creek Dam, Reach C corresponds to Fall Creek River upstream of Fall Creek Dam, Reach D corresponds to Middle Fork River between Lookout Dam and Hills Creek Dam, and Reach E corresponds to Middle Fork River upstream of Hills Creek Dam.

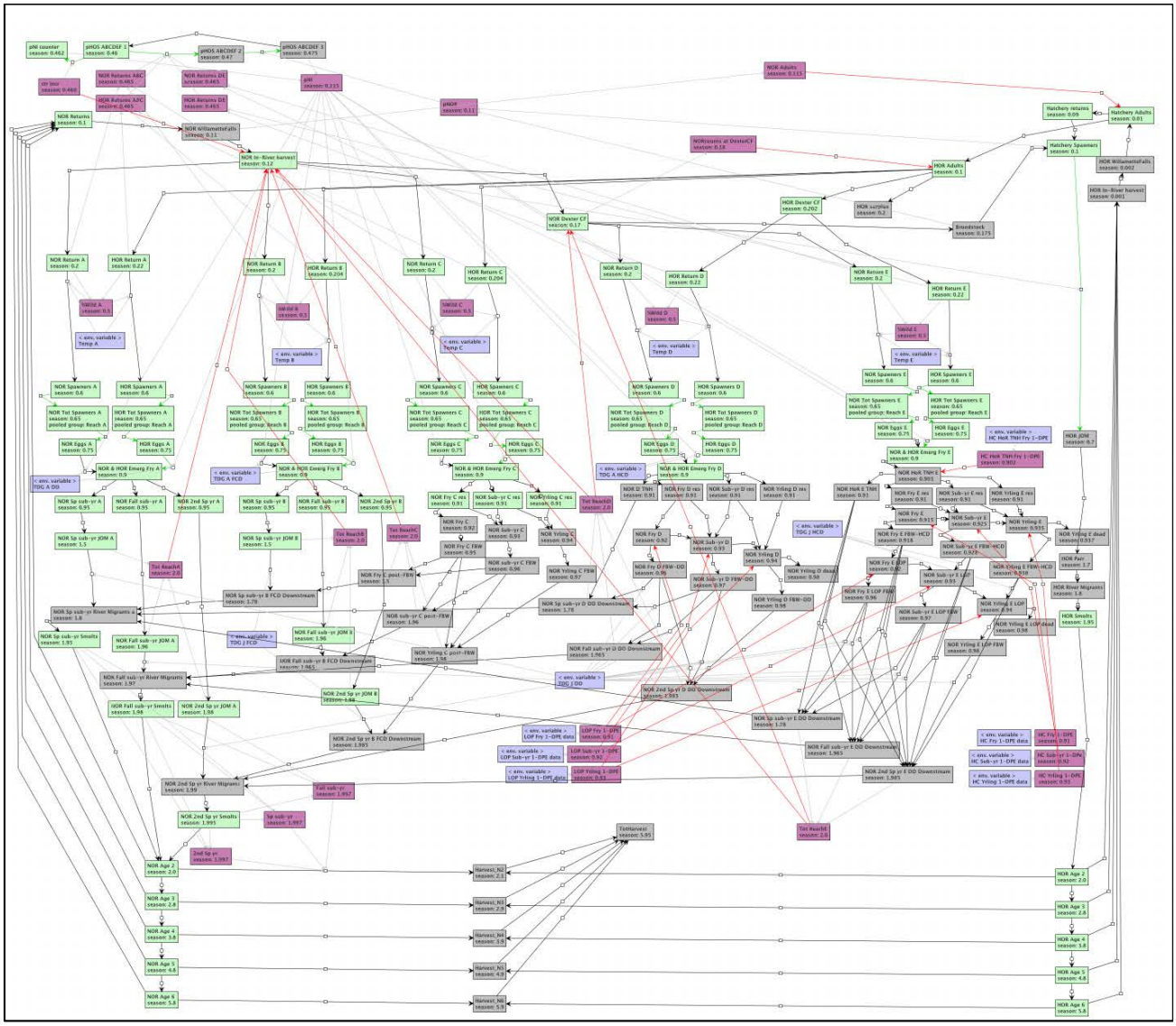


Figure 6.2: Life cycle model (used in SLAM) of spring Chinook salmon from Middle Fork River. See Table 6.1 for a description of each box.

Table 6.1: Life history stages and transitions for the Middle Fork River Chinook salmon life cycle model (Figure 6.2). Reaches correspond to those in Figure 6.1.

Life Stage	Definition
HOR In-River harvest	Freshwater harvest of hatchery fish
Hatchery Adult	Hatchery origin adults
Hatchery returns	Hatchery fish that return to the hatchery rack
NOR Returns	Returning adults of natural origin
Hatchery Spawners	Adults that spawn in hatchery, including some natural origin adults for brood stock improvement
HOR Adults	Hatchery origin adults that spawn in wild
NOR In-River Harvest	Freshwater harvest of natural origin
NOR Dexter CF	Natural origin individuals at Dexter collection facility
Brood Sup	Natural origin individuals that are supplied to brood supply at hatchery program
NOR Returns A	Natural origin adults that return to Reach A
NOR Returns B	Natural origin adults that return to Reach B
NOR Returns C	Natural origin adults that return to Reach C
NOR Returns D	Natural origin adults that return to Reach D
NOR Returns E	Natural origin adults that return to Reach E
HOR Dexter CF	Hatchery origin individuals at Dexter collection facility
HOR Returns A	Hatchery origin adults that return to Reach A
HOR Returns B	Hatchery origin adults that return to Reach B
HOR Returns C	Hatchery origin adults that return to Reach C
HOR Returns D	Hatchery origin adults that return to Reach D
HOR Returns E	Hatchery origin adults that return to Reach E
NOR Spawners A	Natural origin spawners that spawn in Reach A
HOR Spawners A	Hatchery origin spawners that spawn in Reach A
NOR Spawners B	Natural origin spawners that spawn in Reach B
HOR Spawners B	Hatchery origin spawners that spawn in Reach B
NOR Spawners C	Natural origin spawners that spawn in Reach C
HOR Spawners C	Hatchery origin spawners that spawn in Reach C
NOR Spawners D	Natural origin spawners that spawn in Reach D
HOR Spawners D	Hatchery origin spawners that spawn in Reach D
NOR Spawners E	Natural origin spawners that spawn in Reach E
HOR Spawners E	Hatchery origin spawners that spawn in Reach E
NOR Tot Spawners A	Natural origin and hatchery origin spawners that spawn in Reach A
HOR Tot Spawners A	Natural origin and hatchery origin spawners that spawn in Reach A
NOR Tot Spawners B	Natural origin and hatchery origin spawners that spawn in Reach B
HOR Tot Spawners B	Natural origin and hatchery origin spawners that spawn in Reach B
NOR Tot Spawners C	Natural origin and hatchery origin spawners that spawn in Reach C
HOR Tot Spawners C	Natural origin and hatchery origin spawners that spawn in Reach C
NOR Tot Spawners D	Natural origin and hatchery origin spawners that spawn in Reach D

HOR Tot Spawners D	Natural origin and hatchery origin spawners that spawn in Reach D
NOR Tot Spawners E	Natural origin and hatchery origin spawners that spawn in Reach E
HOR Tot Spawners E	Natural origin and hatchery origin spawners that spawn in Reach E
NOR Egg A	Eggs in Reach A produced by natural origin spawners in Reach A
HOR Egg A	Eggs in Reach A produced by hatchery origin spawners in Reach A
NOR Egg B	Eggs in Reach B produced by natural origin spawners in Reach B
HOR Egg B	Eggs in Reach B produced by hatchery origin spawners in Reach B
NOR Egg C	Eggs in Reach C produced by natural origin spawners in Reach C
HOR Egg C	Eggs in Reach C produced by hatchery origin spawners in Reach C
NOR Egg D	Eggs in Reach D produced by natural origin spawners in Reach D
HOR Egg D	Eggs in Reach D produced by hatchery origin spawners in Reach D
NOR Egg E	Eggs in Reach E produced by natural origin spawners in Reach E
HOR Egg E	Eggs in Reach E produced by hatchery origin spawners in Reach E
NOR & HOR Emerg Fry A	Natural and hatchery produced emergent fry in Reach A
NOR & HOR Emerg Fry B	Natural and hatchery produced emergent fry in Reach B
NOR & HOR Emerg Fry C	Natural and hatchery produced emergent fry in Reach C
NOR & HOR Emerg Fry D	Natural and hatchery produced emergent fry in Reach D
NOR & HOR Emerg Fry E	Natural and hatchery produced emergent fry in Reach E
NOR D TNH	Downstream movement of Natural origin juveniles above Lookout Point Dam (Reach D) via trap and haul program
NOR E TNH	Downstream movement of Natural origin juveniles above Hills Creek Dam (Reach E) via trap and haul program
NOR Fry C	Natural origin Fry above Fall Creek Dam
NOR Fry D	Natural origin Fry above Lookout Point Dam
NOR Fry E	Natural origin Fry above Hills Creek Dam
NOR Sub-yr C	Natural origin fry in Reach C that express a sub-yearling life history strategy
NOR Sub-yr D	Natural origin fry in Reach D that express a sub-yearling life history strategy
NOR Sub-yr E	Natural origin fry in Reach E that express a sub-yearling life history strategy
NOR Yrling C	Natural origin fry in Reach C that express a yearling life history strategy
NOR Yrling D	Natural origin fry in Reach D that express a yearling life history strategy
NOR Yrling E	Natural origin fry in Reach E that express a yearling life history strategy
NOR Sp sub-yr A	Natural origin fry in Reach A that express a Spring sub-yearling life history strategy
NOR Fall sub-yr A	Natural origin fry in Reach A that express a Fall sub-yearling life history strategy
NOR 2nd Sp yr A	Natural origin fry in Reach A that express a 2nd Spring yearling life history strategy
NOR Sp sub-yr B	Natural origin fry in Reach B that express a spring sub-yearling life history strategy
NOR Fall sub-yr B	Natural origin fry in Reach B that express a fall sub-yearling life history strategy
NOR 2nd Sp yr B	Natural origin fry in Reach B that express a 2nd spring yearling life history strategy
NOR Fry C FBW	Natural origin fry in Reach C that pass Fall Creek Dam
NOR Fry E FBW-HCD	Natural origin fry in Reach E that pass Hills Creek Dam

NOR Fry D FBW-DD	Natural origin fry in Reach D that pass Dexter Dam
NOR sub-yr C FBW	Natural origin sub-yearlings in Reach C that pass Fall Creek Dam
NOR Sub-yr E FBW-HCD	Natural origin sub-yearlings in Reach E that pass Hills Creek Dam
NOR Sub-yr D FBW-DD	Natural origin sub-yearlings in Reach D that pass Dexter Dam
NOR Yrling C FBW	Natural origin yearlings in Reach C that pass Fall Creek Dam
NOR Yrling E FBW-HCD	Natural origin yearlings in Reach E that pass Hills Creek Dam
NOR Yrling D FBW-DD	Natural origin yearlings in Reach D that pass Dexter Dam
NOR Sp sub-yr JOM B	Natural origin spring sub-yearlings in Reach B that are juvenile out migrants
NOR Sp sub-yr JOM A	Natural origin spring sub-yearlings in Reach A that are juvenile out migrants
NOR Fry C post-FBW	Natural origin fry in Reach C downstream of Fall Creek Dam
HOR Parr	Hatchery origin parr downstream of Dexter Dam
NOR Sp sub-yr B FCD Downstream	Natural origin spring sub-yearlings juvenile out migrants in Reach B (downstream of Fall Creek Dam)
NOR Sp sub-yr DE DD Downstream	Natural origin spring sub-yearlings juvenile out migrants from Reach DE (downstream of Dexter)
NOR Sp sub-yr River Migrants a	Natural origin spring sub-yearlings leaving Middle Fork River
HOR River Migrants	Hatchery origin juvenile out-migrants leaving Middle Fork River
NOR Sp sub-yr Smolts	Natural origin smolts that are spring sub-yearlings
HOR Smolt	Hatchery origin smolts
NOR Fall sub-yr JOM A	Natural origin fall sub-yearlings that are juvenile out migrants in Reach A
NOR Fall sub-yr JOM B	Natural origin fall sub-yearlings that are juvenile out migrants in Reach B
NOR sub-yr C post FBW	Natural origin sub-yearlings that passed Falls Creek Dam
NOR Fall sub-yr B FCD Downstream	Natural origin fall sub-yearlings that are downstream of Falls Creek dam and in Reach B
NOR Fall sub-yr DE DD Downstream	Natural origin fall sub-yearlings from Reach D and E that are downstream of Dexter Dam
NOR Fall sub-yr River Migrants	Natural origin fall sub-yearlings leaving Middle Fork River
NOR 2nd Sp yr JOM B	Natural origin 2nd spring yearlings that are juvenile out migrants in Reach B
NOR Fall sub-yr Smolts	Natural origin smolts that are fall sub-yearlings
NOR 2nd Sp yr JOM A	Natural origin 2nd spring yearlings that are juvenile out migrants in Reach A
NOR Yrling C post-FBW	Natural origin yearlings that passed Falls Creek Dam
NOR 2nd Sp yr B FCD Downstream	Natural origin 2nd spring yearlings that are downstream of Falls Creek dam and in Reach B
NOR 2nd Sp yr DE DD Downstream	Natural origin 2nd spring yearlings from Reach D and E that are downstream of Dexter Dam
NOR 2nd Sp yr River Migrants	Natural origin 2nd spring yearlings leaving Middle Fork River
NOR 2nd sub-yr Smolts	Natural origin smolts that are 2nd spring sub-yearlings
NOR Age 2	Age 2 natural origin adults
HOR Age 2	Second generation age 2 hatchery origin adults, indistinguishable from natural origin age 2 adults
NOR Age 3	Age 3 natural origin adults
HOR Age 3	Second generation age 3 hatchery origin adults, indistinguishable from natural origin age 3 adults
NOR Age 4	Age 4 natural origin adults

HOR Age 4	Second generation age 4 hatchery origin adults, indistinguishable from natural origin age 4 adults
NOR Age 5	Age 5 natural origin adults
HOR Age 5	Second generation hatchery origin age 5 adults, indistinguishable from natural origin age 5 adults
NOR Age 6	Age 6 natural origin adults
HOR Age 6	Second generation hatchery origin age 6 adults, indistinguishable from natural origin age 6 adults
Harvest_N2	Adults (both natural and hatchery origin) harvested at age 2
Harvest_N3	Adults (both natural and hatchery origin) harvested at age 3
Harvest_N4	Adults (both natural and hatchery origin) harvested at age 4
Harvest_N5	Adults (both natural and hatchery origin) harvested at age 5
Harvest_N6	Adults (both natural and hatchery origin) harvested at age 6

Table 6.2: List of Acronyms and Abbreviations.

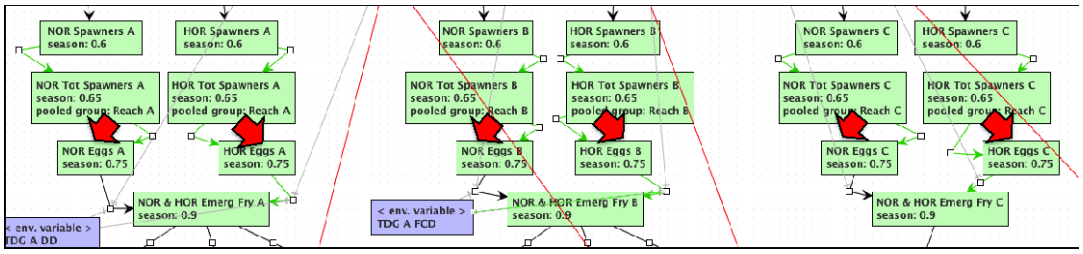
Abbreviation	**Definition**
0+	Juveniles less than one year old
1+	Juveniles older than one year but less than two years old
Beverton-Holt	Beverton-Holt spawner-recruit relationship
FCD	Falls Creek Dam
DD	Dexter Dam
HCD	Hills Creek Dam
d/s	Downstream
Harvest_N#	Fishery harvest of age N# fish (# = 2, 3, 4, 5, & 6 for spring Chinook)
FBW	Fish Benefit Workbook
Hockey-Stick	Spawner-recruit relationship in the Hockey-stick shape
HOR	Hatchery origin
HoR	Head of reservoir
JOM	Juvenile out-migrant
NOR	Natural origin
ODFW	Oregon Department of Fish and Wildlife
SE	Standard Error
PSS, PSM	Prespawning survival, prespawning mortality
SLAM	Species Life-Cycle Analysis Modules
u/s	Upstream
TDG	Total Dissolved Gas
TNH	Trap and Haul
DPE	Dam Passage Efficiency

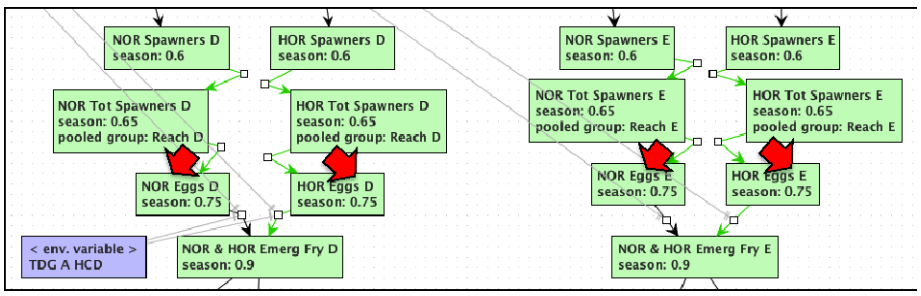
6.1. Productivity, Capacity, & Survivals

This section describes the reproductive capability of spawners within each reach and hatchery, reach-specific capacity, and the proportion of individuals that survive as they move among stages in the life-cycle model.

Productivity and capacity parameter values of wild spawning natural and hatchery origin individuals. Within each reach natural and hatchery origin spawners are pooled by reach, and a reach-specific Beverton-Holt capacity function is applied to determine the number of eggs. The Beverton-Holt productivity term is fixed at 0.5 times fecundity, with the assumption that the sex ratio of spawning fish is 50:50. The productivity to 2,250 eggs/individual is a slightly more conservative estimate than the 5000 eggs per female noted by Willis et al. (1995) (see Chapter 3, Fecundity). Egg capacity is stochastic, and each year reach-specific egg capacity is drawn from a normal distribution according to the following parameters.

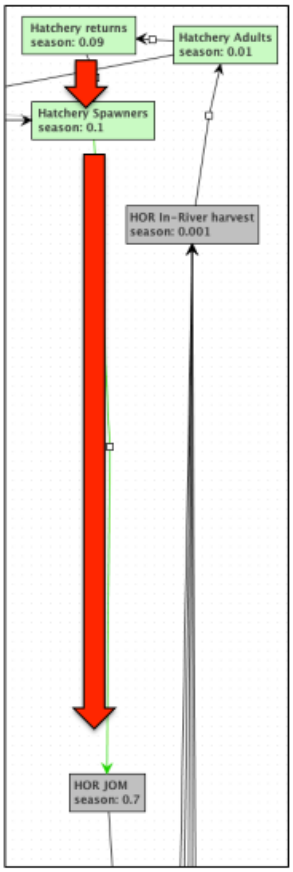
Reach	From	To	Curve type	Capacity & Productivity	Mean	SD	Min	Max
A	NOR Tot Spawners	Eggs	Beverton-Holt	Capacity	150,000	33,000	75,000	200,000
				Productivity				2,250
B	NOR Tot Spawners	Eggs	Beverton-Holt	Capacity	500,000	50,000	300,000	1,000,000
				Productivity				2,250
C	NOR Tot Spawners	Eggs	Beverton-Holt	Capacity	2,000,000	50,000	1,000,000	3,000,000
				Productivity				2,250
D	NOR Tot Spawners	Eggs	Beverton-Holt	Capacity	20,000,000	200,000	10,000,000	22,500,000
				Productivity				2,250
E	NOR Tot Spawners	Eggs	Beverton-Holt	Capacity	10,000,000	200,000	6,000,000	13,000,000
				Productivity				2,250
A	HOR Tot Spawners	Eggs	Beverton-Holt	Capacity	150,000	33,000	75,000	200,000
				Productivity				2,000
B	HOR Tot Spawners	Eggs	Beverton-Holt	Capacity	500,000	50,000	300,000	1,000,000
				Productivity				2,000
C	HOR Tot Spawners	Eggs	Beverton-Holt	Capacity	2,000,000	50,000	1,000,000	3,000,000
				Productivity				2,000
D	HOR Tot Spawners	Eggs	Beverton-Holt	Capacity	20,000,000	200,000	10,000,000	22,500,000
				Productivity				2,000
E	HOR Tot Spawners	Eggs	Beverton-Holt	Capacity	10,000,000	200,000	6,000,000	13,000,000
				Productivity				2,000

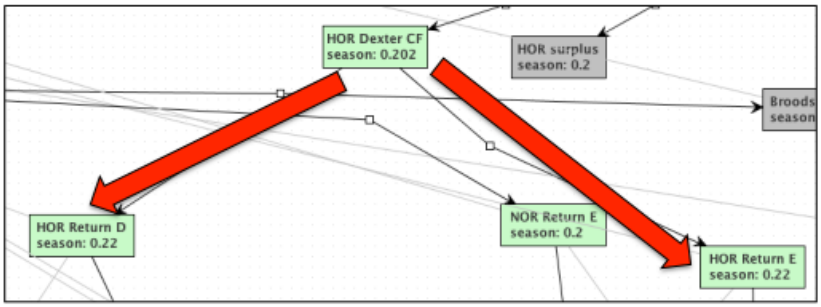




Productivity and capacity parameter values of hatchery spawners. A finite number of hatchery origin fish (up to 1400-2,000 individuals; see Splits section below) are spawned in the hatchery using a Hockey-Stick capacity function, based on productivity of 1,600 eggs/individual (Willis et la. 1995), to determine the number of eggs (HOR JOM).

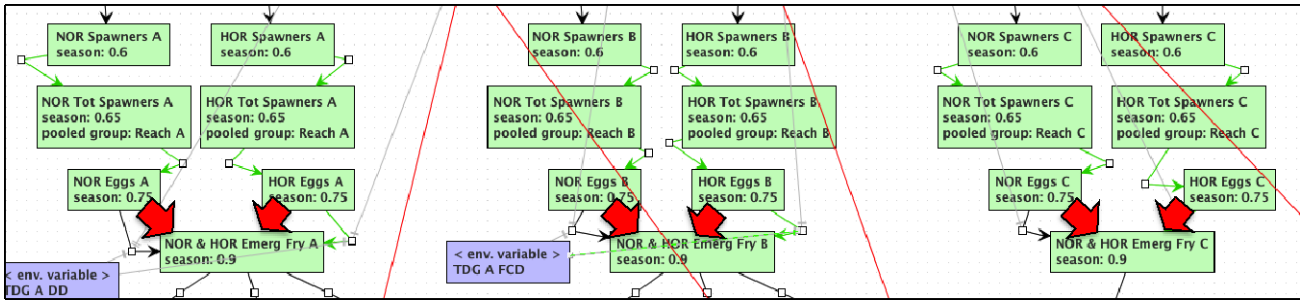
Reach	From	To	Curve type	Capacity & Productivity	Mean	SD	Min	Max
Hatchery	Hatchery returns	Hatchery Spawners	Hockey-Stick	Capacity	1,500	100	1,400	2,000
				Productivity				1
Hatchery	Hatchery Spawners	HOR JOM	Hockey-Stick	Capacity	1,800,000	25,000	1,600,000	2,000,000
				Productivity				1,600
Hatchery	HOR Dexter CF	HOR Return D	Hockey-Stick	Capacity				2,000
				Productivity				1
		HOR Return E	Hockey-Stick	Capacity				1,000
				Productivity				1

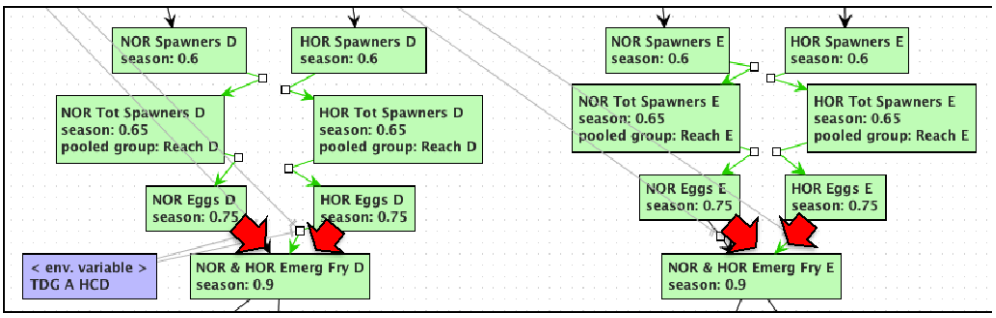




Survival parameter values from Egg to Emergent Fry stage. The below values correspond to the reach-specific proportion of eggs that survive to become emergent fry (see Chapter 3, Survival):

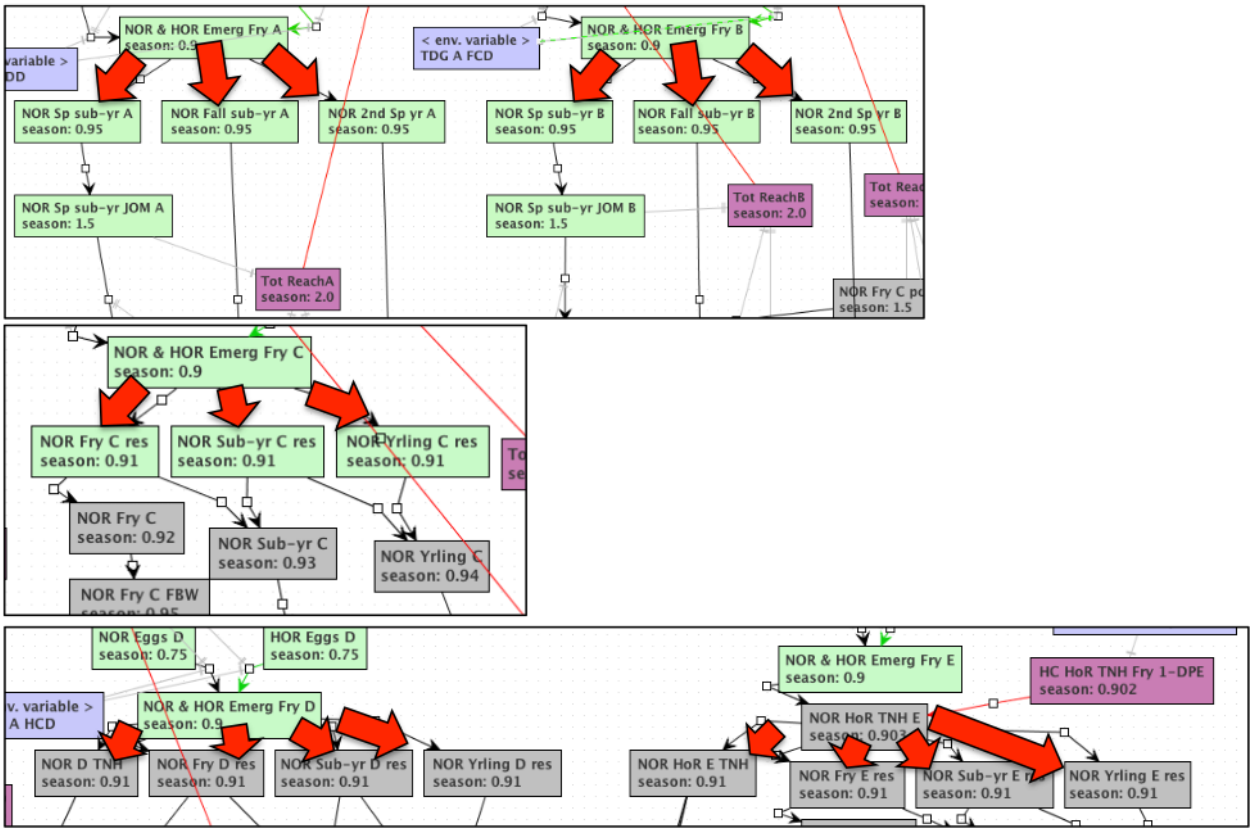
Reach	From	To	Curve type	Capacity & Productivity	Dist. type	Proportion of fish that survive
A	NOR/HOR Eggs	NOR & HOR Emerg Fry	Linear	Productivity	Constant	0.15
B	NOR/HOR Eggs	NOR & HOR Emerg Fry	Linear	Productivity	Constant	0.2
C	NOR/HOR Eggs	NOR & HOR Emerg Fry	Linear	Productivity	Constant	0.35
D	NOR/HOR Eggs	NOR & HOR Emerg Fry	Linear	Productivity	Constant	0.5
E	NOR/HOR Eggs	NOR & HOR Emerg Fry	Linear	Productivity	Constant	0.5





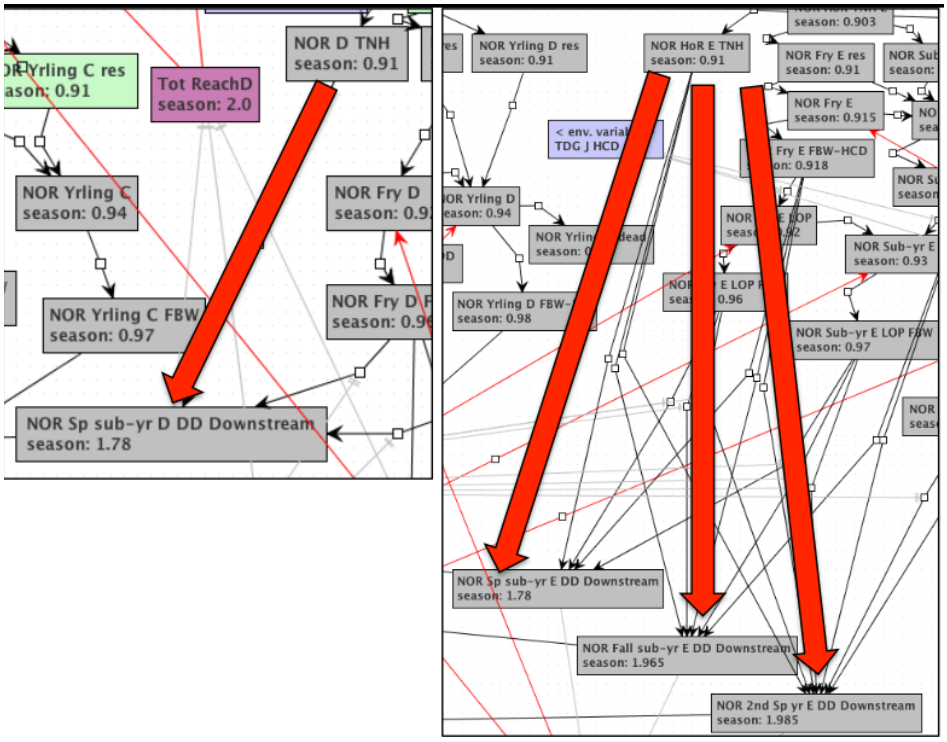
Survival parameter values from Emergent Fry stage to each juvenile life history strategy. The below values correspond to the reach-specific proportion of emergent fry that survive to become spring sub-yearlings, fall sub-yearlings, and 2nd spring yearlings. Survival parameter value associated with head of reservoir (HoR) passage is one of the alternatives and was provided by USACE.

Reach	From	To	Curve type	Capacity & Productivity	Dist. type	Proportion of fish that survive
A	NOR & HOR Emerg Fry	NOR Sp sub-yr A	Linear	Productivity	Constant	0.1
		NOR Fall sub-yr A	Linear	Productivity	Constant	0.1
		NOR 2nd Sp yr A	Linear	Productivity	Constant	0.1
B	NOR & HOR Emerg Fry	NOR Sp sub-yr B	Linear	Productivity	Constant	0.13
		NOR Fall sub-yr B	Linear	Productivity	Constant	0.125
		NOR 2nd Sp yr B	Linear	Productivity	Constant	0.1
C	NOR & HOR Emerg Fry	NOR Fry C res	Linear	Productivity	Constant	0.6
		NOR Sub-yr C res	Linear	Productivity	Constant	0.25
		NOR Yrling C res	Linear	Productivity	Constant	0.2
D	NOR & HOR Emerg Fry	NOR D TNH	Linear	Productivity	Constant	0.75
		NOR Fry D res	Linear	Productivity	Constant	0.6
		NOR Sub-yr D res	Linear	Productivity	Constant	0.25
		NOR Yrling D res	Linear	Productivity	Constant	0.2
E	NOR & HOR Emerg Fry	NOR HoR E TNH	Linear	Productivity	Constant	HoR Passage Survival
		NOR Fry E res	Linear	Productivity	Constant	0.6
		NOR Sub-yr E res	Linear	Productivity	Constant	0.25
		NOR Yrling E res	Linear	Productivity	Constant	0.2



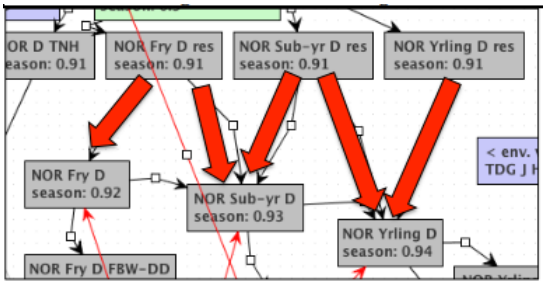
Survival parameter values of juveniles in Reach D (between Dexter and Hills Creek dams) moving downstream of Dexter Dam via a trap and haul at Lookout Point Dam and survival parameter values of juveniles in Reach E (above Hills Creek Dam) moving downstream of Dexter Dam via a head of reservoir (HoR) trap and haul. These values are from parameter workshops (see Chapter 3, appendix 3.6).

Reach	From	To	Curve type	Capacity & Productivity	Distribution type	Proportion of fish that survive
D	NOR D TNH	NOR Sp sub-yr D DD Downstream	Linear	Productivity	Constant	0.05
E	NOR HoR E TNH	NOR Sp sub-yr E DD Downstream	Linear	Productivity	Triangular	0.004
		NOR Fall sub-yr E DD Downstream	Linear	Productivity	Constant	0.055
		NOR 2nd Sp yr E DD Downstream	Linear	Productivity	Uniform	0.075



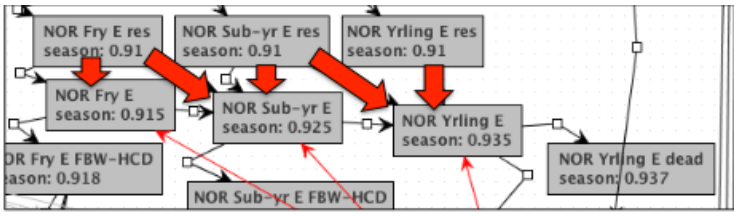
Survival parameter values for each of three life history strategy that rear in Lookout reservoir (Reach D) to next life history strategy. These values are from parameter workshops (see Chapter 3, appendix 3.6).

Reach	From	To	Curve type	Capacity & Productivity	Distr. type	Proportion of fish that survive
D	NOR Fry D res	NOR Fry D	Linear	Productivity	Constant	1
		NOR Sub-yr D	Linear	Productivity	Triangular	0.175 (mean), 0.1 & 0.4 (min & max)
	NOR Sub-yr D res	NOR Sub-yr D	Linear	Productivity	Constant	1
		NOR Yrling D	Linear	Productivity	Uniform	0.35-0.8 (min & max)
	NOR Yrling D res	NOR Yrling D	Linear	Productivity	Constant	1



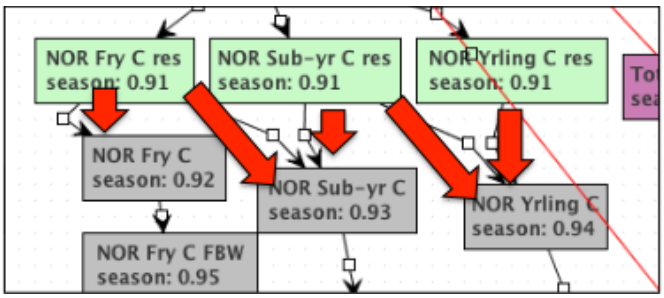
Survival parameter values for each of three juvenile life history strategies that rear in Hills Creek Dam reservoir to next life history strategy. The survival values listed below that correspond to transitions between life history strategies. These values are from parameter workshops (see Chapter 3, appendix 3.6).

Reach	From	To	Curve type	Capacity & Productivity	Distr. type	Proportion of fish that survive
E	NOR Fry E res	NOR Fry E	Linear	Productivity	Constant	1
		NOR Sub-yr E	Linear	Productivity	Triangular	0.3 (mean), 0.2 & 0.45 (min & max)
	NOR Sub-yr E res	NOR Sub-yr E	Linear	Productivity	Constant	1
		NOR Yrling E	Linear	Productivity	Uniform	0.35-0.8 (min & max)
	NOR Yrling E res	NOR Yrling E	Linear	Productivity	Constant	1



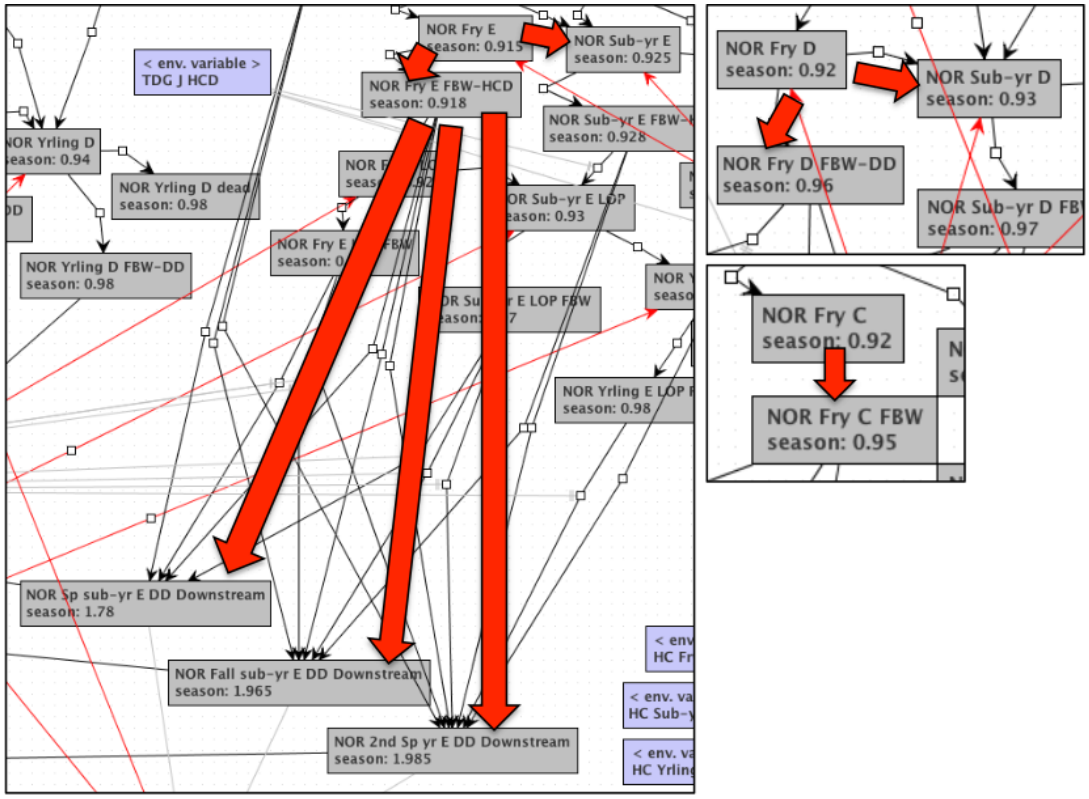
Survival parameter values for each of three life history strategy that rear in Fall Creek Dam reservoir to next life history strategy. The survival values listed below that correspond to transitions between life history strategies. These values are from parameter workshops held March 2014 (see Chapter 3, appendix 3.6).

Reach	From	To	Curve type	Capacity & Productivity	Distr. type	Proportion of fish that survive
C	NOR Fry C res	NOR Fry C	Linear	Productivity	Constant	1
		NOR Sub-yr C	Linear	Productivity	Triangular	0.2 (mean), 0.3 & 0.45 (min & max)
	NOR Sub-yr C res	NOR Sub-yr C	Linear	Productivity	Constant	1
		NOR Yrling C	Linear	Productivity	Uniform	0.35-0.8 (min & max)
	NOR Yrling C res	NOR Yrling C	Linear	Productivity	Constant	1



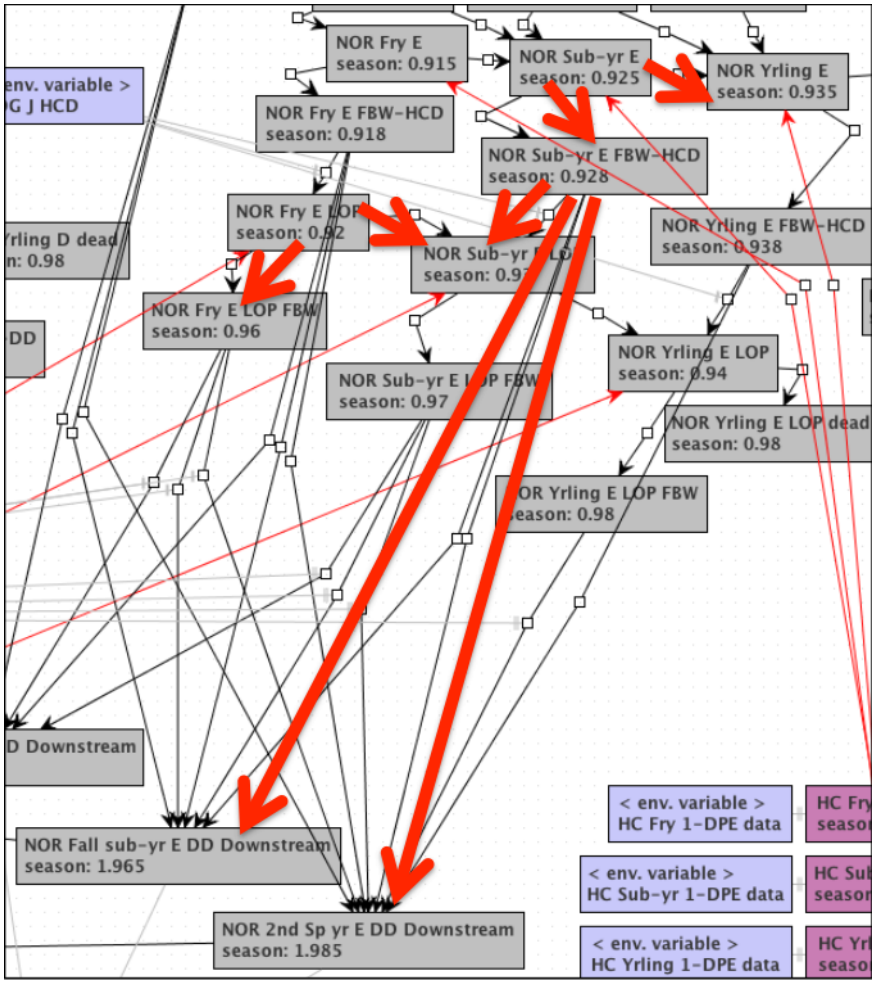
Survival parameter values for Fry in Reach E (above Hills Creek Dam) passing Hills Creek Dam and moving downstream of Dexter Dam and those Fry becoming Sub-yearlings above Hills Creek Dam. Survival parameter values for Fry in Reach D (between Dexter and Hills Creek dam) passing Dexter Dam and those Fry becoming Sub-yearlings above Dexter Dam. Survival parameter values for Fry in Reach C passing Fall Creek Dam. These values are from parameter workshops (see Chapter 3, appendix 3.6). Dam passage survival ('Passage survival' in the below table) is one of two datafiles from the Fish Benefits Workbook, the other being dam passage efficiency (DPE)(Fish Benefits Workbooks User Guide 2014), both of which are provided by USACE. Dam passage efficiency is the fraction of fish available to pass a dam that actually pass, those that do not pass remain in the reservoir.

Reach	From	To	Curve type	Capacity & Productivity	Distr. type	Proportion of fish that survive
E	NOR Fry E	NOR Sub-yr E	Linear	Productivity	Triangular	0.2 (mean), 0.15 & 0.35 (min & max)
	NOR Fry E FBW-HCD	NOR Fry E FBW-HCD	Linear	Productivity	Datafile	Passage survival
		NOR Sp sub-yr E DD Downstream	Linear	Productivity	Constant	0.1
		NOR Fall sub-yr E DD Downstream	Linear	Productivity	Constant	0.14
		NOR 2nd Sp yr E DD Downstream	Linear	Productivity	Constant	0.18
		NOR Fry E LOP	Linear	Productivity	Constant	1
D	NOR Fry D	NOR Sub-yr D	Linear	Productivity	Triangular	0.175 (mean), 0.1 & 0.4 (min & max)
		NOR Fry D FBW-HCD	Linear	Productivity	Datafile	Passage survival
C	NOR Fry C	NOR Fry C FBW	Linear	Productivity	Normal	0.862 (mean), 0.045 (stdev), 0 & 1 (min & max)



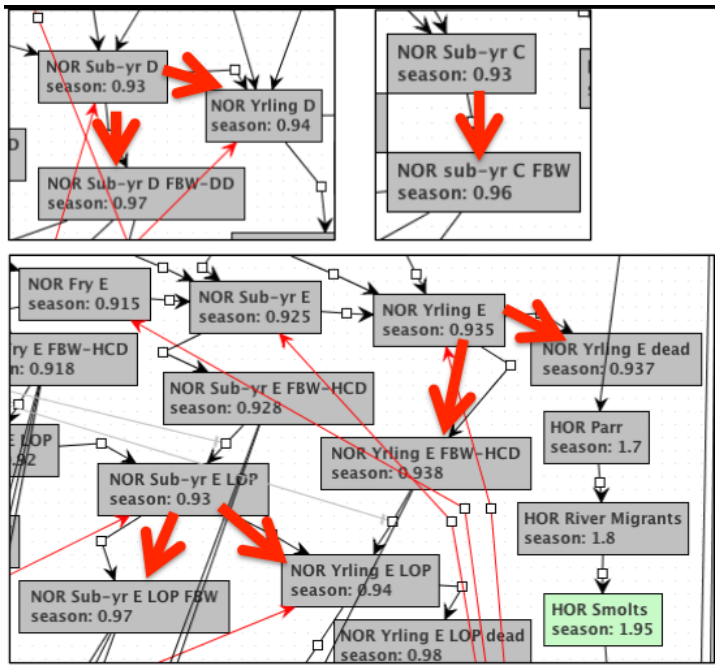
Survival parameter values for Fry that become Sub-yearlings in Reach D (between Dexter and Hills Creek dams) and those that pass Dexter Dam and move downstream of Dexter Dam. These Fry are from Reach E (above Hills Creek Dam) that have passed Hills Creek Dam and are within Reach D (between Hills Creek and Dexter dams). These values are from parameter workshops (see Chapter 3, appendix 3.6). Dam passage survival ('Passage survival' in the below table) is one of two datafiles from the Fish Benefits Workbook, the other being dam passage efficiency (DPE)(Fish Benefits Workbooks User Guide 2014), both of which are provided by USACE.

Reach	From	To	Curve type	Capacity & Productivity	Distr. type	Proportion of fish that survive
E	NOR Fry E LOP	NOR Sub-yr E LOP	Linear	Productivity	Triangular	0.175 (mean), 0.1 & 0.4 (min & max)
		NOR Fry E LOP FBW	Linear	Productivity	Datafile	Passage survival
	NOR Sub-yr E	NOR Yrling E	Linear	Productivity	Uniform	0.4-0.9 (min & max)
		NOR Sub-yr E FBW-HCD	Linear	Productivity	Datafile	Passage survival
	NOR Sub-yr E FBW-HCD	NOR Sub-yr E LOP	Linear	Productivity	Constant	1
		NOR Fall sub-yr E DD Downstream	Linear	Productivity	Constant	0.2
		NOR 2nd Spy r E DD Downstream	Linear	Productivity	Constant	0.25



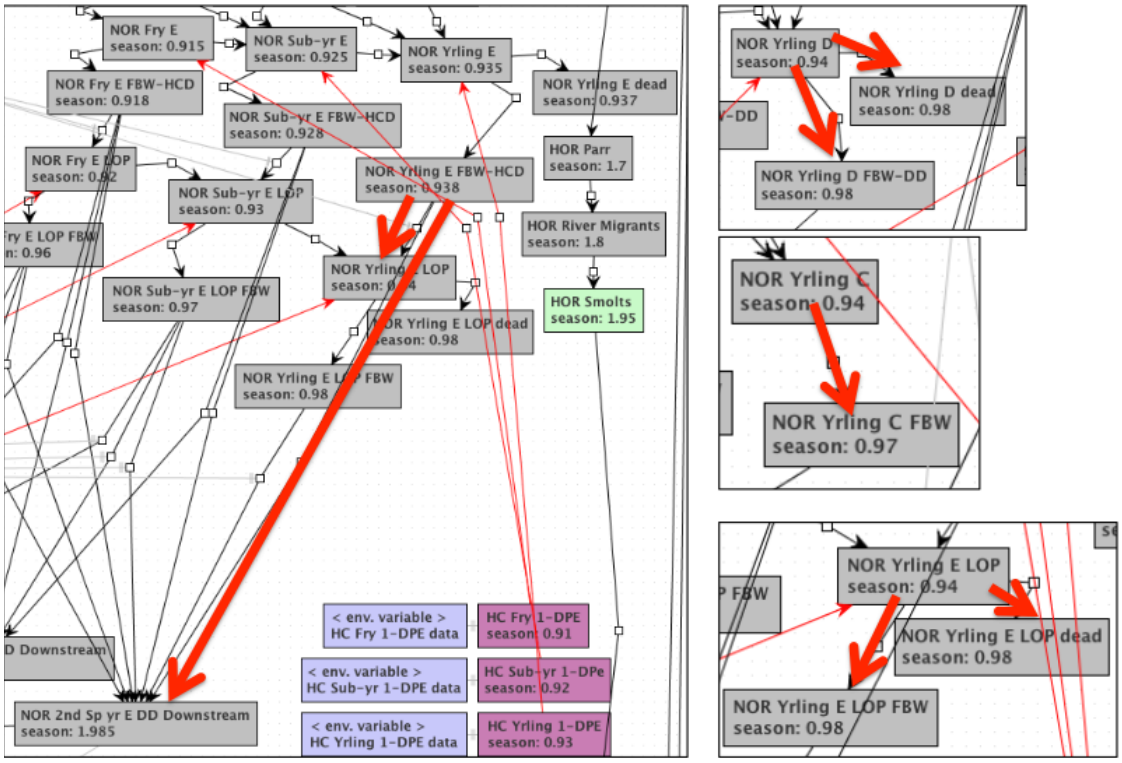
Survival parameter values of Sub-yearlings in Reach D (between Dexter and Hills Creek dams) to Yearling and those that pass Dexter Dam as Sub-yearlings. These values are from parameter workshops (see Chapter 3, appendix 3.6). Dam passage survival ('Passage survival' in the below table) is one of two datafiles from the Fish Benefits Workbook, the other being dam passage efficiency (DPE)(Fish Benefits Workbooks User Guide 2014), both of which are provided by USACE.

Reach	From	To	Curve type	Capacity & Productivity	Distr. type	Proportion of fish that survive
D	NOR Sub-yr D	NOR Yrling D	Linear	Productivity	Uniform	0.4-0.9 (min & max)
		NOR Sub-yr D FBW-DD	Linear	Productivity	Datafile	Passage survival
C	NOR Sub-yr C	NOR Sub-yr C FBW	Linear	Productivity	Normal	0.862 (mean), 0.045 (stdev), 0 & 1 (min & max)
E	NOR Sub-yr E LOP	NOR Yrling E LOP	Linear	Productivity	Uniform	0.4-0.9 (min & max)
		NOR Sub-yr E LOP FBW	Linear	Productivity	Datafile	Passage survival
	NOR Yrling E	NOR Yrling E dead	Linear	Productivity	Constant	0
		NOR Yrling E FBW-HCD	Linear	Productivity	Datafile	Passage survival



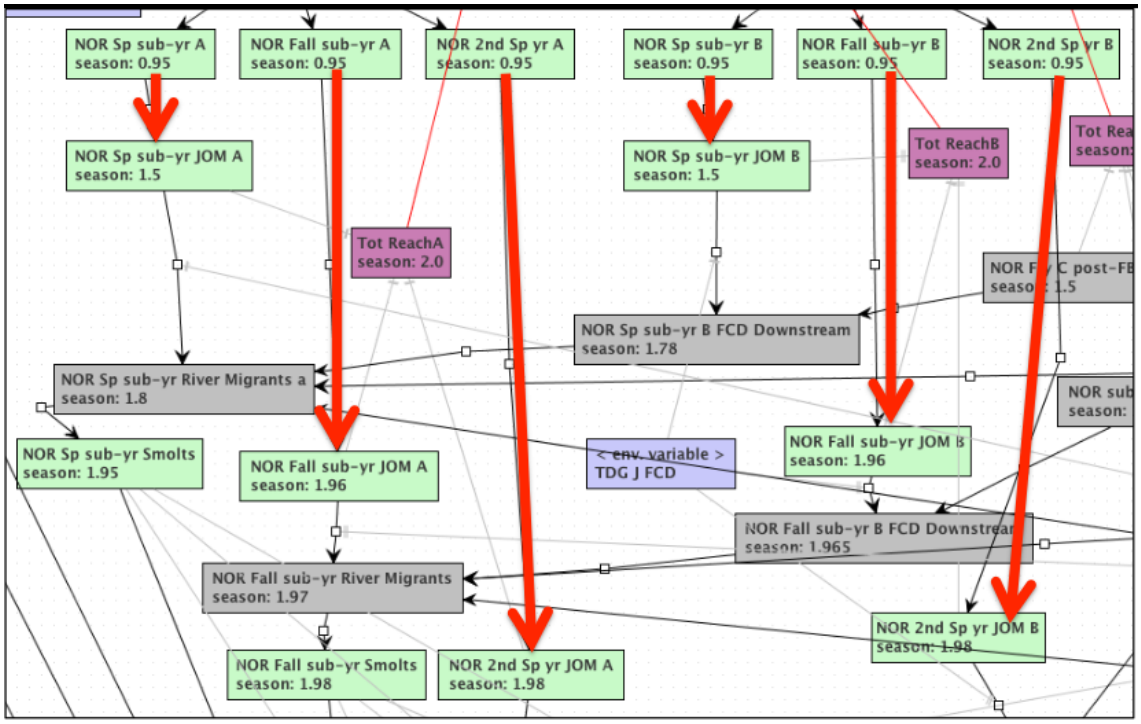
Survival parameter values of Yearlings that passed Hills Creek Dam and are transported downstream of Dexter Dam (i.e., do not pass through Lookout Point and Dexter dams) and those Yearlings that remain in Reach D (between Dexter/Lookout Point and Hills Creek dams). Survival parameter values of Yearlings in Reach D that pass Dexter Dam and that remain in the reservoir and die. Dam passage survival ('Passage survival' in the below table) is one of two datafiles from the Fish Benefits Workbook, the other being dam passage efficiency (DPE)(Fish Benefits Workbooks User Guide 2014), both of which are provided by USACE.

Reach	From	To	Curve type	Capacity & Productivity	Distr. type	Proportion of fish that survive
E	NOR Yrling E FBW-HCD	NOR 2nd Sp yr E DD Downstream	Linear	Productivity	Constant	0.35
		NOR Yrling E LOP	Linear	Productivity	Constant	1
D	NOR Yrling D	NOR Yrling D FBW-DD	Linear	Productivity	Datafile	Passage survival
		NOR Yrling D dead	Linear	Productivity	Constant	0
C	NOR Yrling C	NOR Yrling C FBW	Linear	Productivity	Normal	0.862 (mean), 0.045 (stdev), 0 & 1 (min & max)
E	NOR Yrling E LOP	NOR Yrling E LOP dead	Linear	Productivity	Constant	0
		NOR Yrling E LOP FBW	Linear	Productivity	Datafile	Passage survival



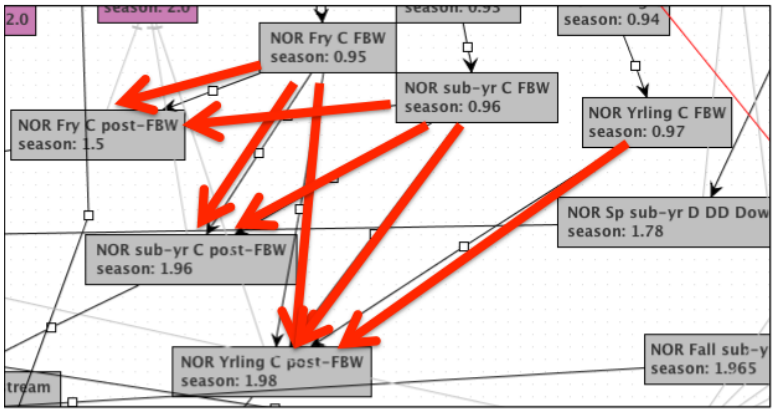
Survival parameter values of each life strategy in Reach A (below Dexter Dam) and Reach B (below Fall Creek Dam) to juvenile out migrant stage (JOM).

Reach	From	To	Curve type	Capacity & Productivity	Distr. type	Proportion of fish that survive
A	NOR Sp sub-yr A	NOR Sp sub-yr JOM A	Linear	Productivity	Constant	0.1
	NOR Fall sub-yr A	NOR Fall sub-yr JOM A	Linear	Productivity	Constant	0.25
	NOR 2nd Sp sub-yr A	NOR 2nd Sp yr JOM A	Linear	Productivity	Constant	0.35
B	NOR Sp sub-yr B	NOR Sp sub-yr JOM B	Linear	Productivity	Constant	0.125
	NOR Fall sub-yr B	NOR Fall sub-yr JOM B	Linear	Productivity	Constant	0.3
	NOR 2nd Sp sub-yr B	NOR 2nd Sp yr JOM B	Linear	Productivity	Constant	0.35



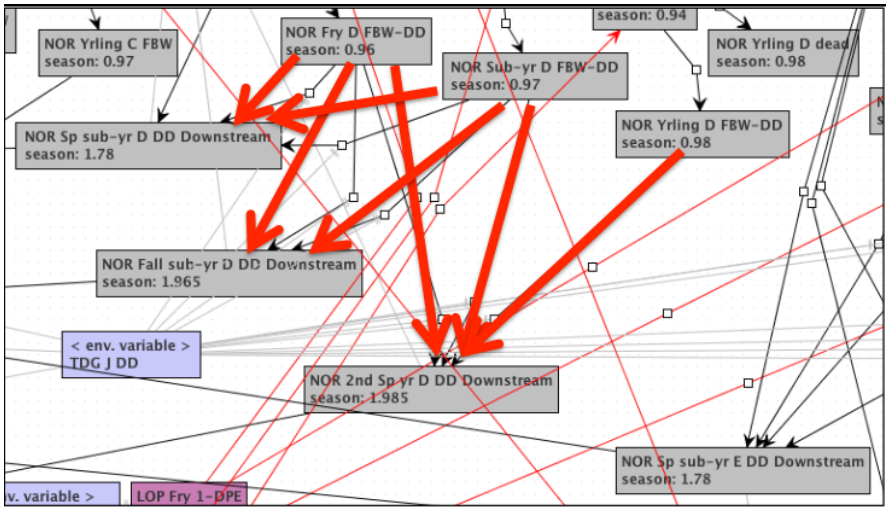
Survival parameter values of Fry, Sub-yearlings, and Yearlings from Reach C (above Fall Creek Dam) that passed Fall Creek Dam and are within Reach B (below Fall Creek Dam).

Reach	From	To	Curve type	Capacity & Productivity	Distr. type	Proportion of fish that survive
C	NOR Fry C FBW	NOR Fry C post-FBW	Linear	Productivity	Constant	0.1
		NOR Sub-yr C post-FBW	Linear	Productivity	Constant	0.13
		NOR Yrling C post-FBW	Linear	Productivity	Constant	0.16
	NOR Sub-yr C FBW	NOR Fry C post-FBW	Linear	Productivity	Constant	0.17
		NOR Sub-yr C post-FBW	Linear	Productivity	Constant	0.19
		NOR Yrling C post-FBW	Linear	Productivity	Constant	0.225
	NOR Yrling C FBW	NOR Yrling C post-FBW	Linear	Productivity	Constant	0.4



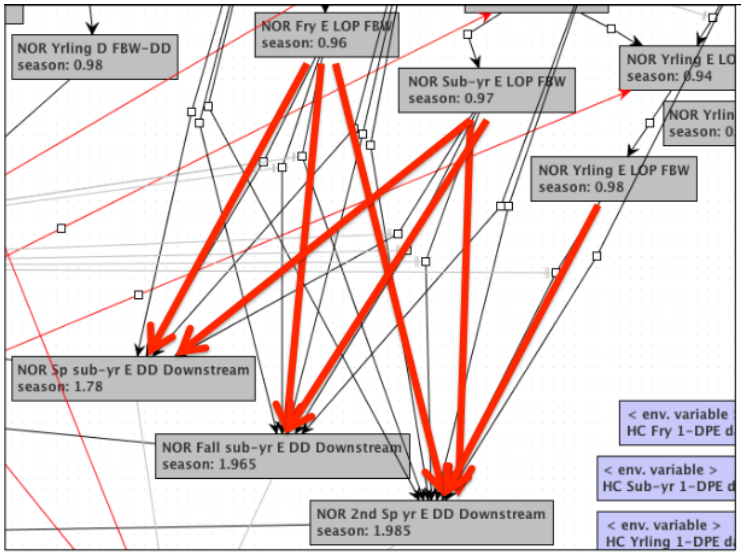
Survival parameter values of Fry, Sub-yearlings, and Yearlings from Reach D (between Lookout Point/Dexter and Hills Creek Dam) that passed Dexter Dam and are within Reach A (below Dexter Dam).

Reach	From	To	Curve type	Capacity & Productivity	Distr. type	Proportion of fish that survive
D	NOR Fry D FBW-DD	NOR Sp sub-yr D DD Downstream	Linear	Productivity	Constant	0.1
		NOR Fall sub-yr D DD Downstream	Linear	Productivity	Constant	0.14
		NOR 2nd Sp yr D DD Downstream	Linear	Productivity	Constant	0.18
	NOR Sub-yr D FBW-DD	NOR Sp sub-yr D DD Downstream	Linear	Productivity	Constant	0.15
		NOR Fall sub-yr D DD Downstream	Linear	Productivity	Constant	0.2
		NOR 2nd Sp yr D DD Downstream	Linear	Productivity	Constant	0.25
	NOR Yrling D FBW-DD	NOR 2nd Sp yr D DD Downstream	Linear	Productivity	Constant	0.35



Survival parameter values of Fry, Sub-yearlings, and Yearlings from Reach E (Hills Creek Dam) that passed Hills Creek and Lookout Point and Dexter dams and are within Reach A (below Dexter Dam).

Reach	From	To	Curve type	Capacity & Productivity	Distr. type	Proportion of fish that survive
E	NOR Fry E LOP FBW	NOR Sp sub-yr E DD Downstream	Linear	Productivity	Constant	0.1
		NOR Fall sub-yr E DD Downstream	Linear	Productivity	Constant	0.14
		NOR 2nd Sp yr E DD Downstream	Linear	Productivity	Constant	0.18
	NOR Sub-yr E LOP FBW	NOR Sp sub-yr E DD Downstream	Linear	Productivity	Constant	0.25
		NOR Fall sub-yr E DD Downstream	Linear	Productivity	Constant	0.15
		NOR 2nd Sp yr E DD Downstream	Linear	Productivity	Constant	0.2
	NOR Yrling E FBW-DD	NOR 2nd Sp yr E DD Downstream	Linear	Productivity	Constant	0.35

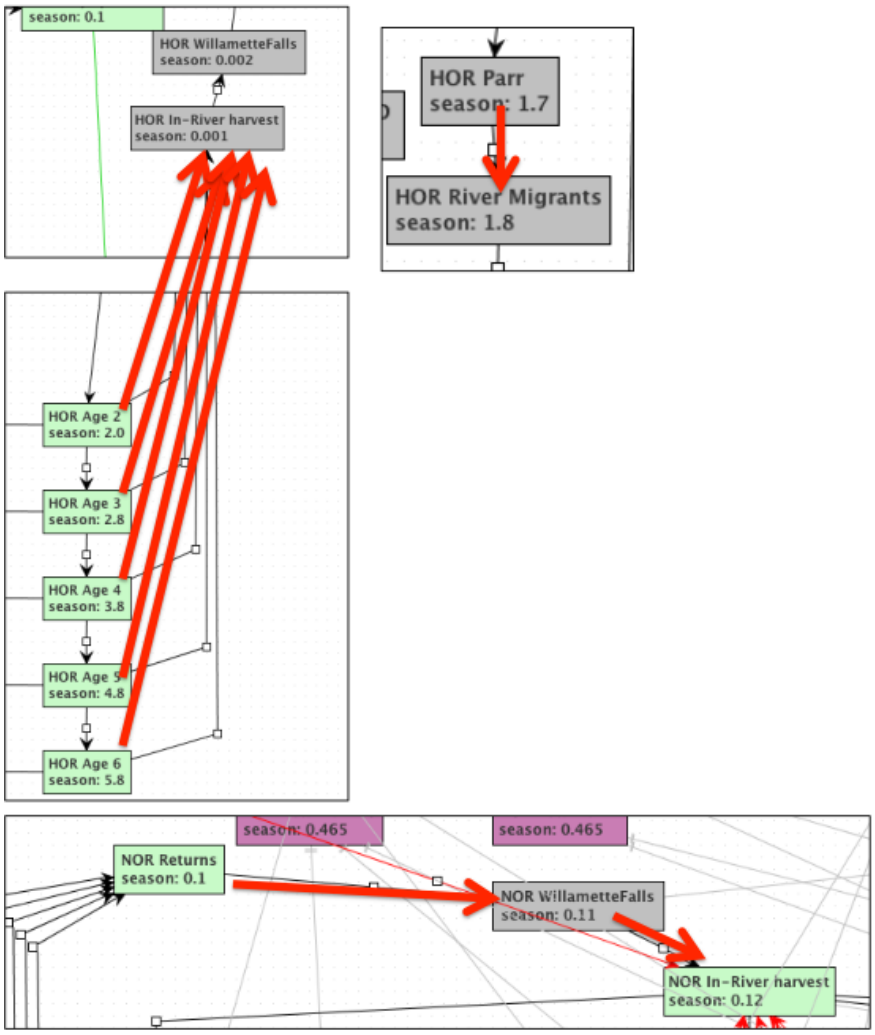


Estuary and ocean survival. Juveniles below Willamette Falls have an estuary survival time series applied, and in subsequent ocean years from, from 1, up to 4 ocean years, an ocean survival time series is applied (see Table 6.6 in Parameter variability section).

Survival parameter values associated with ocean and freshwater adult harvest and adult mainstem "loss". Hatchery origin individuals are fished. We assume that fish in the Middle Fork Willamette River experience the same harvest mortality as those in the North Santiam River. There is 45.6% mortality (average of 2006-2011) due to harvest below Willamette Falls (Fisheries Management and Evaluation for 2012 Willamette River spring Chinook 2013). This 45.6% mortality is the sum of mortality by recreational fishery at the mouth of the Columbia River to Willamette River (5.2%), lower Willamette recreational fishery (20.8%), mainstem net fishery (9%), and the recreational fishery in the North Santiam River (10.6%). This 45.6% mortality (i.e., 0.544 survival) is comparable to 30.7% and 55% mortality reported by Lindsay et al. (1998) and Ford (2011), respectively. There is also a loss of fish observed from Willamette Falls to counts within the North Santiam River, which we calculated as an average of 28.4% using data from 1995-2011 (i.e., 0.716 survival).

We assume that natural origin fish in the Middle Fork Willamette River experience the same harvest mortality as those from the North Santiam River. North Santiam River fish experience an average fishing mortality of 8.7% (range of 5% - 14.2%; 2013, Fisheries Management & Evaluation) (i.e. 0.913 survival). There is also a loss of fish observed from Willamette Falls to counts within North Santiam, which we calculated as an average of 28.4% using data from 1995-2011) (i.e., 0.716 survival) (Willis et al. 1996; Foster et al. 1997; Bennett 1998; Lindsay et al. 1998; Ford 2011; Foster & Boatner 2002).

Reach	From	To	Curve type	Capacity & Productivity	Dist. type	Proportion of fish that survive
Hatchery	HOR Age 2	HOR In-River harvest	Linear	Productivity	Constant	0.524
	HOR Age 3	HOR In-River harvest	Linear	Productivity	Constant	0.524
	HOR Age 4	HOR In-River harvest	Linear	Productivity	Constant	0.524
	HOR Age 5	HOR In-River harvest	Linear	Productivity	Constant	0.524
	HOR Age 6	HOR In-River harvest	Linear	Productivity	Constant	0.524
	HOR In-River harvest	HOR WillametteFalls	Linear	Productivity	Constant	0.716
NORs	Returning Adults	NOR WillametteFalls	Linear	Productivity	Constant	0.716
	NOR WillametteFalls	In-River harvest	Linear	Productivity	Constant	0.903



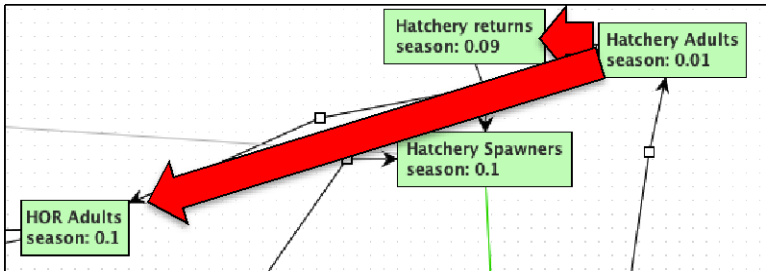
6.2. Splits

This section describes the proportion of fish directed from an individual life-stage to two or more subsequent life-stages via different pathways (splits).

Proportion of hatchery origin adults (Hatchery Adults) that return to hatchery (Hatchery Returns) or do not return to hatchery (HOR Adults). These proportions are based on abundance of natural origin fish at Willamette Falls. When fewer than 2501 natural origin Middle Fork Willamette River fish are counted at Willamette Falls, 43.6% of hatchery fish that are returning to freshwater will return to the hatchery rack (Hatchery returns), while the remaining 56.4% do not return to the hatchery and are allowed to spawn in the wild. When greater than 9308 natural origin Middle Fork Willamette River fish are counted at Willamette Falls then 95% of hatchery fish that are returning to freshwater will return to the hatchery rack (Hatchery Returns), while the remaining 5% will attempt to spawn in the wild (HOR Adults). When the number of Middle Fork Willamette River natural origin fish counted at Willamette Falls is between 2501 and 9308 individuals, then a linear relationship (below) sets the rate of return to the rack between 82 – 95%:

$$Proportion\ of\ hatchery\ fish\ that\ return\ to\ rack = 0.436\ + (0.564 \times (\frac{NORs\ at\ Willamette\ Falls - 2500}{7500})$$

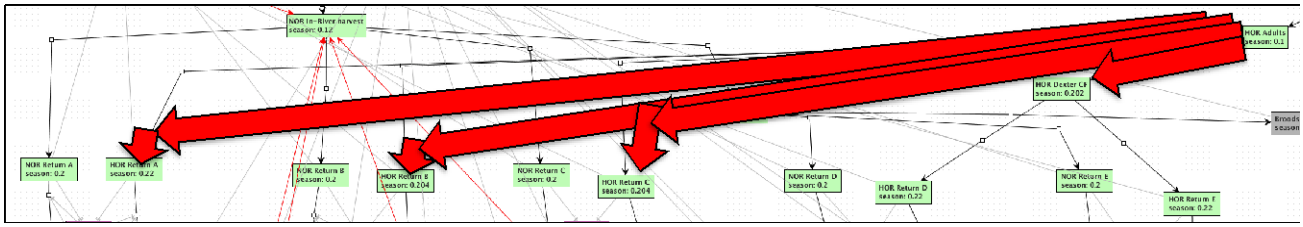
From	To	Proportion
Hatchery Adults	Hatchery returns	Split influencer (otherwise use 0.436)
	HOR Adults	Split influencer (otherwise use 0.564)



Proportion of hatchery origin adults (HOR Adults) that volitionally return to Reach A (HOR Return A), Reach B (HOR Return B), Reach C (HOR Return C), Dexter collection facility (HOR Dexter CF), or surplus (HOR surplus). 14.5% of returning fish go to Reach A, 30% to Reach B, and 0.5% to Reach C. When fewer than 1500 natural origin fish are counted at Dexter Collection Facility (Dexter CF), 55% of hatchery fish that are returning to freshwater will return to the Dexter collection facility (HOR Dexter CF) and 0% are surplus. When greater than 3000 natural origin fish are counted at Dexter CF then 0% of hatchery fish go to Dexter CF, while the remaining 55% are HOR surplus. When the number of natural origin fish counted at Dexter CF is between 1500 and 3000 individuals, then a linear relationship (below) sets the proportion of fish that go to Dexter CF (between 0 to 55%):

$$Proportion\ of\ hatchery\ fish\ that\ return\ to\ rack\ = 0.55 - (0.55 \times (\frac{NORs\ at\ Dexter\ CF - 1400}{1900}).$$

From	To	Proportion
HOR Adults	HOR Return A	0.145
	HOR Return B	0.3
	HOR Return C	0.005
	HOR Dexter CF	Split influencer (otherwise use 0.55)
	HOR surplus	Split influencer (otherwise use 0)

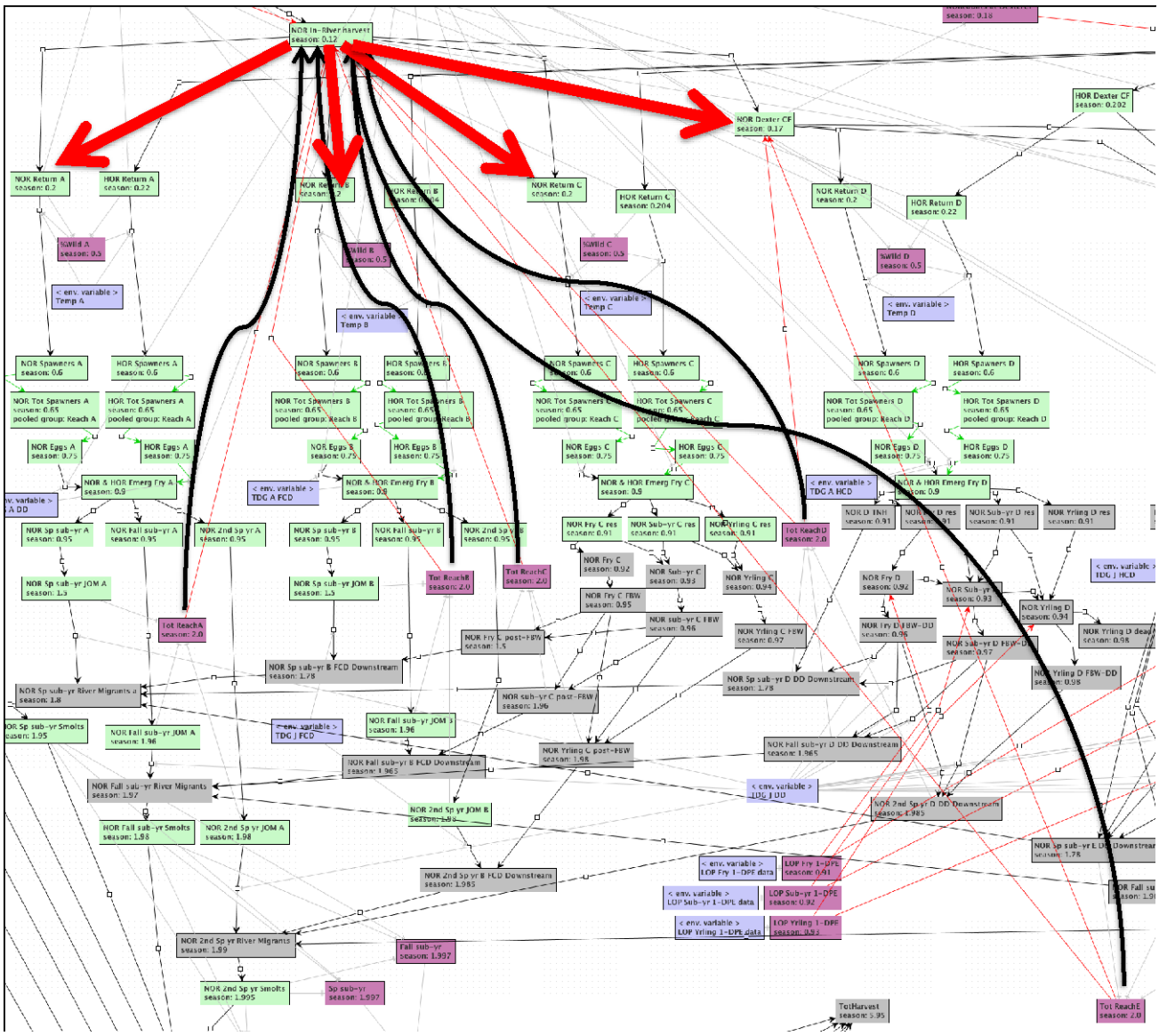


Proportion of Returning Adults that survived freshwater harvest (NOR In-River harvest) to volitionally return to Reach A (NOR Returns A), Reach B (NOR Returns B), Reach C (NOR Returns C) or to the Dexter collection facility (NOR Dexter CF). In the process of simplifying the SLAM model structure, we pooled together juveniles from all reaches starting at the estuary stage since estuary/ocean survivals and ocean and mainstem harvest were applied equally to fish from all reaches. Because of natal homing of adult Chinook it was important that we were able to model reach-specific positive or negative feedback in terms of abundance of returning adults. Specifically, for each simulated year we quantified the proportion of juveniles that exited each reach four years prior by first determining the total number of juveniles that exited each reach, the latter of which are represented as boxes named Tot ReachA, Tot ReachB, Tot ReachC, Tot ReachD, and Tot ReachE. These proportions were then used to split returning adults (four simulated years later) that survived freshwater harvest (NOR In-River harvest) to those that volitionally return to Reach A (NOR Returns A), Reach B (NOR Returns B), Reach C (NOR Returns C), and to Dexter collection facility (NOR Dexter CF). To achieve this in SLAM we used a tool called a Split Influence, which is defined as a box that influences the abundance ratios of a split (McElhany et al. 2012). This means that the abundance of the influencing box (in our case, reach-specific proportion of juvenile outmigrants) will be available as an input parameter to the scripts that calculate split ratios (in our case, the proportion of adults that return to Reach A, B, C, and the collection facility) during the simulation run. After the model was initialized with a fixed set of ratios for a split, the Split Influence determined the split from the juvenile counts four years previously:

$$Proportion\ of\ fish\ returning\ to\ NOR\ Returns\ A = \left(\frac{Tot\ ReachA}{Tot\ ReachA+Tot\ ReachB+Tot\ ReachC+Tot\ ReachD+Tot\ ReachE}\right)$$

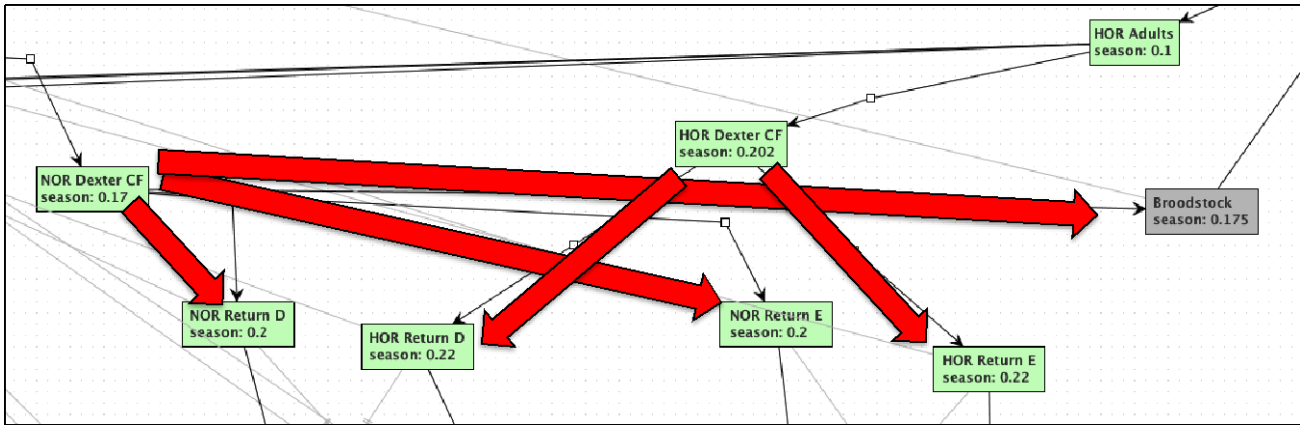
Tot ReachA, B, C, D, and E correspond to the abundance of juvenile outmigrants, when pooling life history strategies, for each reach. This equation was applied for model years 4 and onward. For the first 3 years of model runs we apportioned fish to reaches according to a fixed proportion.

From	To	Proportion
NOR In-River harvest	NOR Return A	Split influence (otherwise 0.025)
	NOR Return B	Split influence (otherwise 0.175)
	NOR Return C	Split influence (otherwise 0.6)
	NOR Dexter CF	Split influence (otherwise 0.2)


NOR In-River harvest season: 0.12
NOR Dexter CF season: 0.17
HOR Dexter CF season: 0.202
NOR Return A season: 0.2
HOR Return A season: 0.22
NOR Return B season: 0.2
HOR Return B season: 0.204
NOR Return C season: 0.2
HOR Return C season: 0.204
NOR Return D season: 0.2
HOR Return D season: 0.22
NOR Spawners A season: 0.6
HOR Spawners A season: 0.6
NOR Spawners B season: 0.6
HOR Spawners B season: 0.6
NOR Spawners C season: 0.6
HOR Spawners C season: 0.6
NOR Spawners D season: 0.6
HOR Spawners D season: 0.6
NOR Egg A season: 0.75
HOR Egg A season: 0.75
NOR Egg B season: 0.75
HOR Egg B season: 0.75
NOR Egg C season: 0.75
HOR Egg C season: 0.75
NOR Egg D season: 0.75
HOR Egg D season: 0.75
NOR & HOR Emerg Fry A season: 0.9
NOR & HOR Emerg Fry B season: 0.9
NOR & HOR Emerg Fry C season: 0.9
NOR A HOR Emerg Fry D season: 0.9
NOR Sp sub-yr A season: 0.95
NOR Fall sub-yr A season: 0.95
NOR 2nd Sp yr A season: 0.95
NOR Sp sub-yr B season: 0.95
NOR Fall sub-yr B season: 0.95
NOR 2nd Sp yr B season: 0.95
NOR Fry C res season: 0.91
NOR Sub-yr C res season: 0.91
NOR Yrling C res season: 0.91
NOR D INH season: 0.91
NOR D res season: 0.91
NOR Sub-yr D res season: 0.91
NOR Yrling D res season: 0.91
Tot ReachA season: 2.0
Tot ReachB season: 2.0
Tot ReachC season: 2.0
Tot ReachD season: 2.0
Tot ReachE season: 2.0
NOR Fry C season: 0.92
NOR Sub-yr C season: 0.93
NOR Yrling C season: 0.94
NOR Fry D season: 0.92
NOR Sub-yr D season: 0.93
NOR Yrling D season: 0.94
NOR Fry C FBW season: 0.95
NOR sub-yr C FBW season: 0.96
NOR Yrling C FBW season: 0.97
NOR Fry D FBW-DD season: 0.96
NOR sub-yr D FBW-DD season: 0.97
NOR Yrling D FBW-DD season: 0.98
NOR Yrling D dead season: 0.98
NOR Fry C post-FBW season: 1.96
NOR sub-yr C post-FBW season: 1.96
NOR Yrling C post-FBW season: 1.98
NOR Sp sub-yr B FCD Downstream season: 1.78
NOR Sp sub-yr D DD Downstream season: 1.78
NOR Fall sub-yr B FCD Downstream season: 1.965
NOR Fall sub-yr D DD Downstream season: 1.965
NOR 2nd Sp yr D DD Downstream season: 1.985
NOR 2nd Sp yr B FCD Downstream season: 1.985
NOR Sp sub-yr River Migrants season: 1.8
NOR Sp sub-yr Smolts season: 1.95
NOR Fall sub-yr JOM A season: 1.96
NOR Fall sub-yr JOM B season: 1.96
NOR Fall sub-yr River Migrants season: 1.97
HOR Fall sub-yr Smolts season: 1.98
NOR 2nd Sp yr JOM A season: 1.98
NOR 2nd Sp yr JOM B season: 1.98
NOR 2nd Sp yr River Migrants season: 1.99
NOR 2nd Sp yr Smolts season: 1.995
Fall sub-yr season: 1.997
Sp sub-yr season: 1.997
TotHarvest season: 5.95
< env. variable > Temp A
< env. variable > Temp B
< env. variable > Temp C
< env. variable > Temp D
< env. variable > TDG A FCD
< env. variable > TDG J FCD
< env. variable > TDG J DD
< env. variable > TDG A HCD
< env. variable > TDG J HCD
< env. variable > LOP Fry 1-DPE data
< env. variable > LOP Sub-yr 1-DPE data
< env. variable > LOP Yrling 1-DPE data
LOP Fry 1-DPE season: 0.91
LOP Sub-yr 1-DPE season: 0.92
LOP Yrling 1-DPE season: 0.93
NOR Tot Spawners A season: 0.65 pooled group: Reach A
HOR Tot Spawners A season: 0.65 pooled group: Reach A
NOR Tot Spawners B season: 0.65 pooled group: Reach B
HOR Tot Spawners B season: 0.65 pooled group: Reach B
NOR Tot Spawners C season: 0.65 pooled group: Reach C
NOR Tot Spawners D season: 0.65 pooled group: Reach D
HOR Tot Spawners D season: 0.65 pooled group: Reach D
NOR Sp sub-yr A season: 1.3
NOR Sp sub-yr JOM B season: 1.3
NOR Sp sub-yr JOM A season: 1.3
NOR Fry C post-FBW season: 1.96
NOR Sp sub-yr D DD Downstream season: 1.78
NOR Fall sub-yr JOM A season: 1.96
NOR Fall sub-yr JOM B season: 1.96
NOR Fall sub-yr River Migrants season: 1.97
NOR 2nd Sp yr JOM B season: 1.98
NOR 2nd Sp yr B FCD Downstream season: 1.985
NOR 2nd Sp yr River Migrants season: 1.99
NOR 2nd Sp yr Smolts season: 1.995
Fall sub-yr season: 1.997
Sp sub-yr season: 1.997
NOR Fall sub-yr D DD Downstream season: 1.985
NOR 2nd Sp yr D DD Downstream season: 1.985
NOR Sp sub-yr E DD Downstream season: 1.78
NOR Fall sub-yr E DD Downstream season: 1.97
NOR Fall sub-yr E DD Downstream season: 1.97
NOR Fall sub-yr E DD Downstream season: 1.97

Tot ReachD and E correspond to the abundance of juvenile outmigrants, when pooling life history strategies, for each reach. This equation was applied for model years 4 and onward. For the first 3 years of model runs we apportioned fish to reaches according to a fixed proportion.

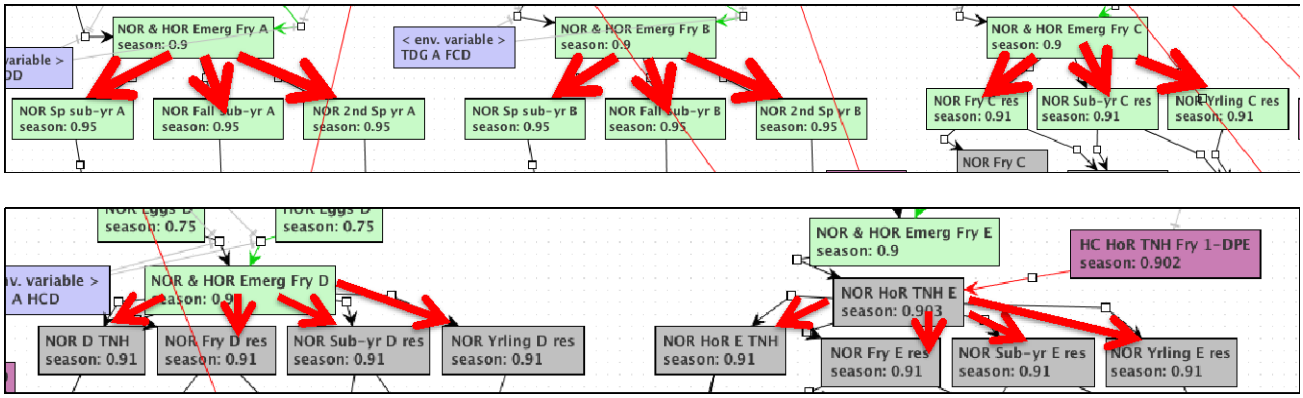
From	To	Proportion
NOR Dexter CF	NOR Return D	Split influence based on exiting fry
	NOR Return E	Split influence based on exiting fry
	Broodstock	0.05
HOR Dexter CF	HOR Return D	0.3
	HOR Return E	0.7



Proportion of emergent fry (NOR & HOR Emerg Fry) within Reach A & B that become spring sub-yearling (NOR Sp sub-yr), fall sub-yearling (NOR Fall sub-yr), and second spring yearling (NOR 2nd Sp yr). The proportions of emergent fry in reaches A and B that followed particular life history trajectories were determined based on Mattson (1962). Proportion of emergent fry within Reach C (above Fall Creek Dam) that become Fry, Sub-yearling, or Yearling were set according to the values determined from the parameter workshops (see Chap. 3). Lastly, the proportion of emergent fry within Reach D & E (above Dexter/Lookout Point and Hills Creek dams, respectively) that are transported downstream via a trap and haul (NOR D TNH & NOR HoR E TNH) or become Fry, Sub-yearling, or Yearling.

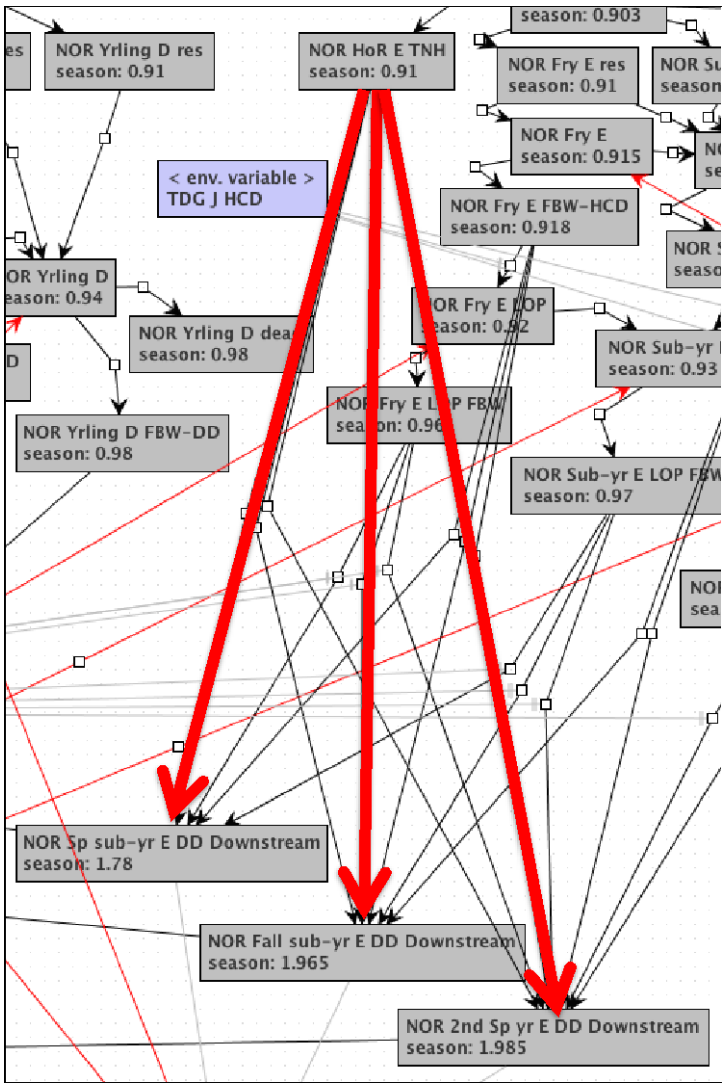
From	To	Proportion
NOR & HOR Emerg Fry A & B	NOR Sp sub-yr A & B	0.41
	NOR Fall sub-yr A & B	0.304
	NOR 2nd Sp yr A & B	0.286
NOR & HOR Emerg Fry C	NOR Sp sub-yr C res	0.95
	NOR Fall sub-yr C res	0.04
	NOR 2nd Sp yr C res	0.01
NOR & HOR Emerg Fry D	NOR D TNH	0
	NOR Fry D res	0.85
	NOR Sub-yr D res	0.1
	NOR Yrling D res	0.05
NOR & HOR Emerg Fry E	NOR HoR E TNH	0*
	NOR Fry E res	0.85^
	NOR Sub-yr E res	0.1^
	NOR Yrling E res	0.05^

*The trap and haul in Reach E is at head of reservoir (HoR) and for those alternatives that include HoR trap and haul as an option for downstream passage, USACE provides this value.
^For HoR trap and haul alternatives, values for NOR Fry E res, NOR Sub-yr E res, and NOR Yrling E res are determined by multiplying their corresponding proportion by the proportion that were not transported via the HoR (0.85 x (1-HoR)).



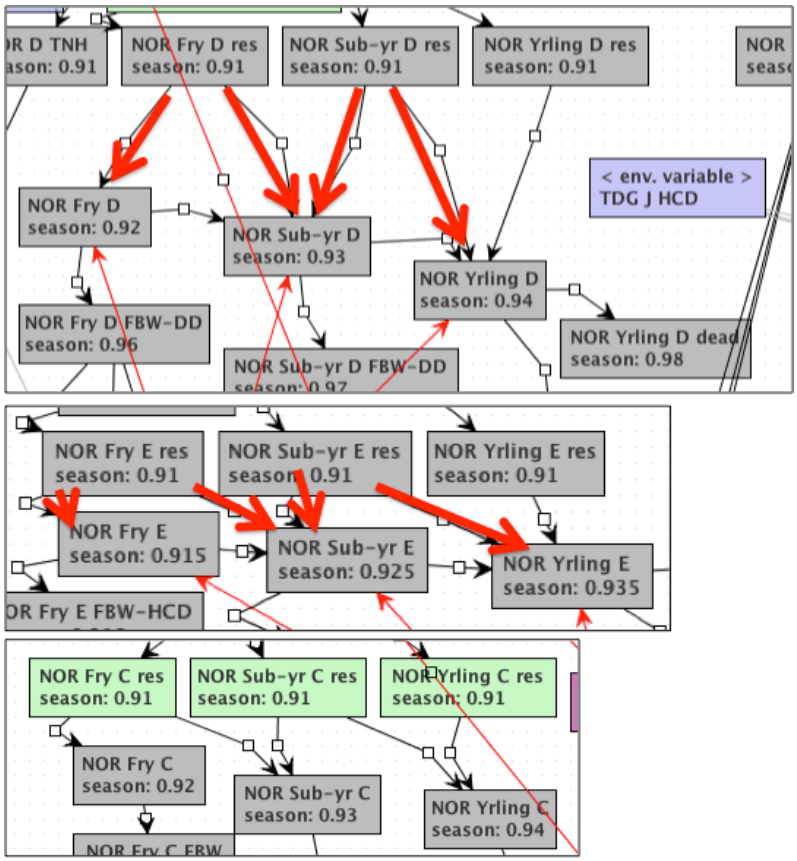
Proportion of fry that were transported downstream of Dexter Dam via Hills Creek Dam head of reservoir trap and haul (NOR HoR E TNH) that become spring sub-yearling, fall sub-yearlings, or second spring yearlings downstream of Dexter Dam.

From	To	Proportion
NOR HoR E TNH	NOR Sp sub-yr E DD Downstream	0.4
	NOR Fall sub-yr E DD Downstream	0.3
	NOR 2nd Sp yr E DD Downstream	0.



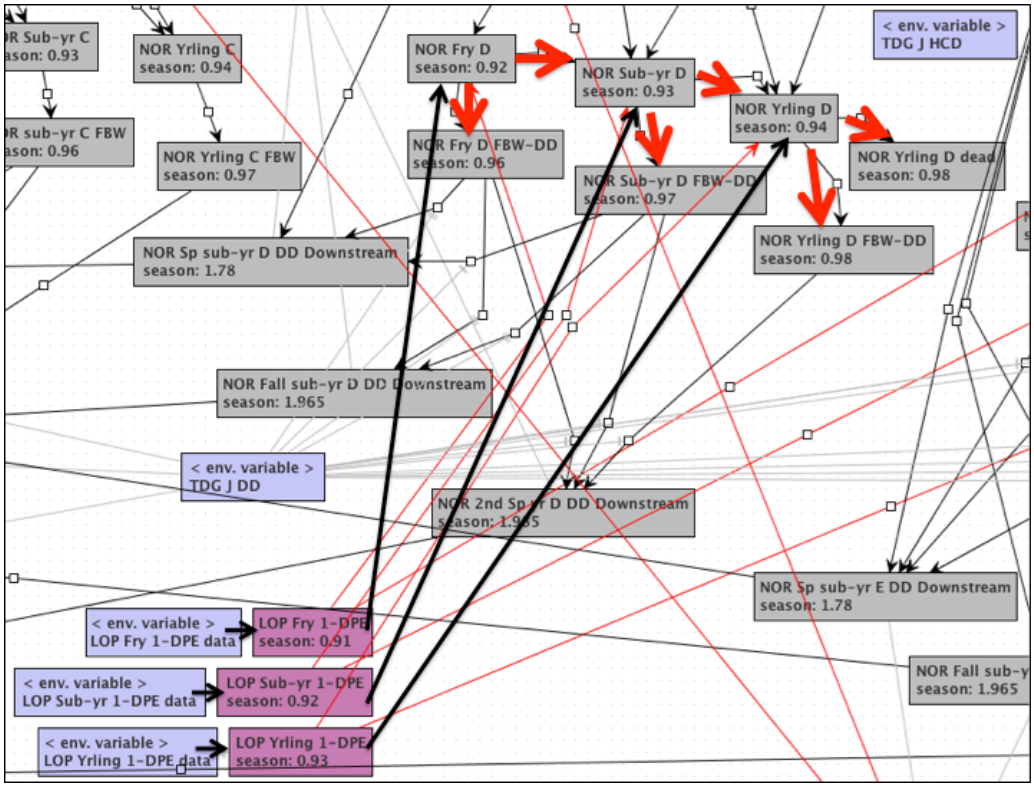
Proportion of fry in Lookout Point Dam reservoir (Reach C, D, & E) that remain as Fry or become Sub-yearling. These values are from parameter workshops held March 2014 (see Chapter 3, appendix 3.6).

From	To	Proportion
NOR Fry C res	NOR Fry C	0.75-1.0
	NOR Sub-yr C	0-0.25
NOR Sub-yr C res	NOR Sub-yr C	0.95-1.0
	NOR Yrling C	0-0.05
NOR Fry D res	NOR Fry D	0.05-0.15
	NOR Sub-yr D	0.85-0.95
NOR Sub-yr D res	NOR Sub-yr D	0.7-0.95
	NOR Yrling D	0.05-0.3
NOR Fry E res	NOR Fry E	0.03-0.05
	NOR Sub-yr E	0.95-0.97
NOR Sub-yr E res	NOR Sub-yr E	0.7-0.95
	NOR Yrling E	0.05-0.3



Proportion of individuals in Lookout Point reservoir that are available to pass Lookout Point Dam and past Dexter Dam (DD) or unavailable to pass and thus remain in the reservoir and become the next life history strategy. Fry in Lookout Point reservoir (NOR Fry D) that are available to pass Lookout Point and Dexter dams (NOR Fry D FBW-DD) or unavailable to pass and thus remain in the reservoir and become sub-yearlings (NOR Sub-yr D). Proportion of sub-yearlings in Lookout Point reservoir (NOR Sub-yr D) that are available to pass Lookout Point and Dexter dams (NOR Sub-yr D FBW-DD) or unavailable to pass and thus remain in the reservoir and become yearlings (NOR Yrling D). Proportion of yearlings in Lookout Point reservoir (NOR Yrling D) that are available to pass Lookout Point and Dexter dams (NOR Yrling D FBW-DD) or unavailable to pass, and are removed from the simulation (NOR Yrling E dead). These proportions use dam passage efficiency (DPE) data that were specific to particular dam project alternatives and were provided by USACE.

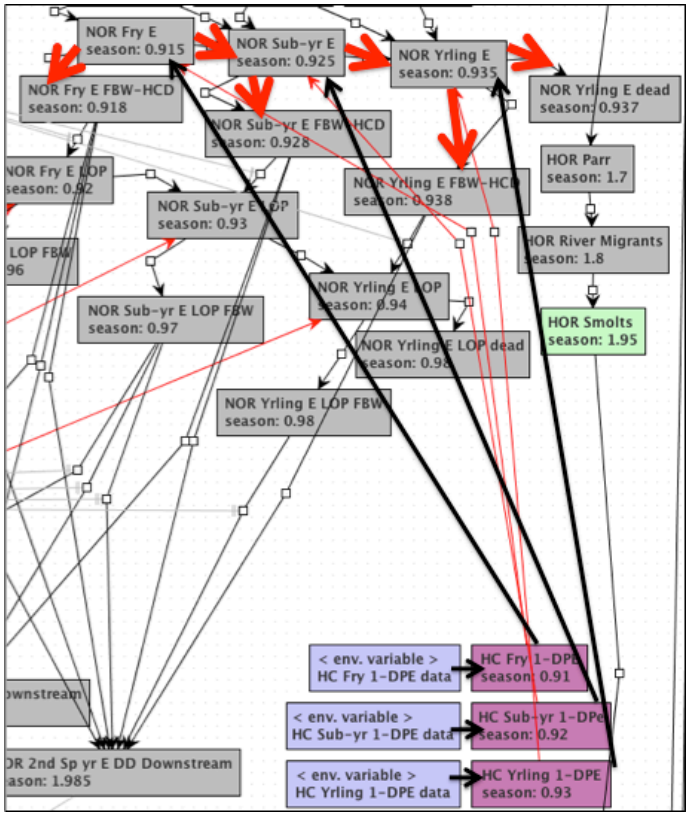
From	To	Proportion
NOR Fry D	NOR Fry D FBW-DD	Split influencer determined by DPE file
	NOR Sub-yr D	Split influencer determined by DPE file
NOR Sub-yr D	NOR Sub-yr D FBW-DD	Split influencer determined by DPE file
	NOR Yrling D	Split influencer determined by DPE file
NOR Yrling D	NOR Yrling D FBW-DD	Split influencer determined by DPE file
	NOR Yrling D dead	Split influencer determined by DPE file



Black arrows represent the split influence from dam passage efficiency data.

Proportion of individuals in Hills Creek reservoir that are available to pass Hills Creek Dam (HCD) or unavailable to pass and thus remain in the reservoir and become the next life history strategy. Fry in Hills Creek reservoir (NOR Fry E) that are available to pass Hills Creek Dam (NOR Fry E FBW-HCD) or unavailable to pass and thus remain in the reservoir and become sub-yearlings (NOR Sub-yr E). Proportion of sub-yearlings in Hills Creek reservoir (NOR Sub-yr E) that are available to pass Hills Creek Dam (NOR Sub-yr E FBW) or unavailable to pass and thus remain in the reservoir and become yearlings (NOR Yrling E). Proportion of yearlings in Hills Creek reservoir (NOR Yrling E) that are available to pass Hills Creek Dam (NOR Yrling E FBW) or unavailable to pass, and are removed from the simulation (NOR Yrling E dead). These proportions use dam passage efficiency (DPE) data that were specific to particular dam project alternatives and were provided by USACE.

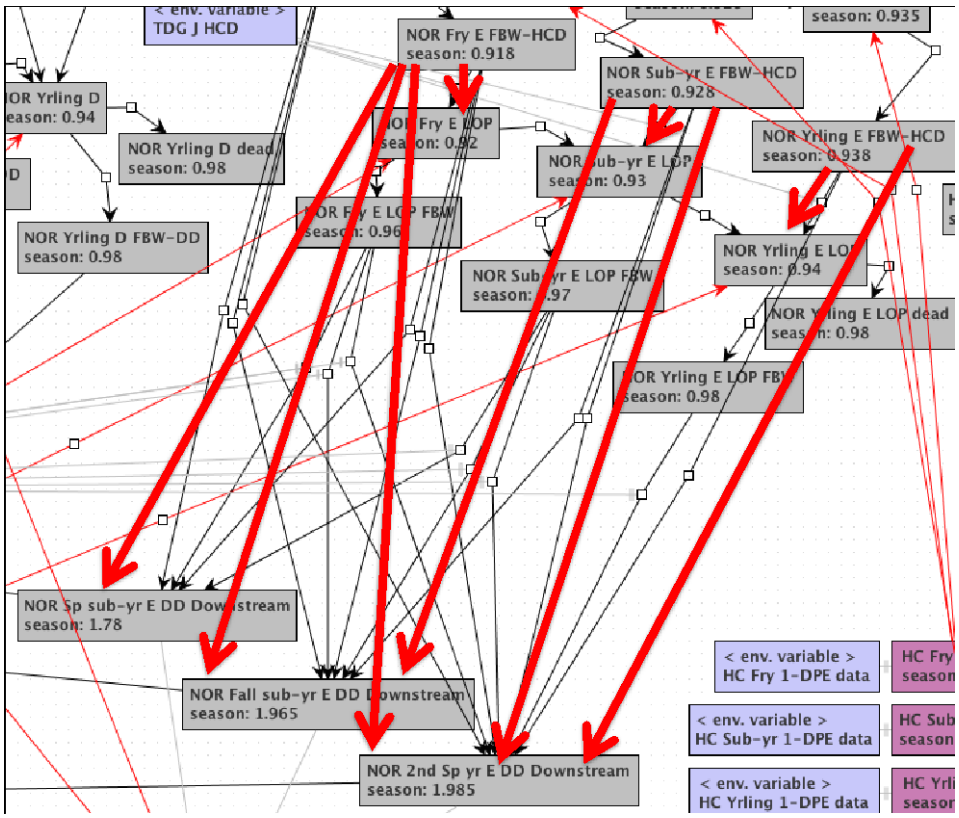
From	To	Proportion
NOR Fry E	NOR Fry E FBW-HCD	Split influencer determined by DPE file
	NOR Sub-yr E	Split influencer determined by DPE file
NOR Sub-yr E	NOR Sub-yr E FBW-HCD	Split influencer determined by DPE file
	NOR Yrling E	Split influencer determined by DPE file
NOR Yrling E	NOR Yrling E FBW-HCD	Split influencer determined by DPE file
	NOR Yrling E dead	Split influencer determined by DPE file



Black arrows represent the split influence from dam passage efficiency data.

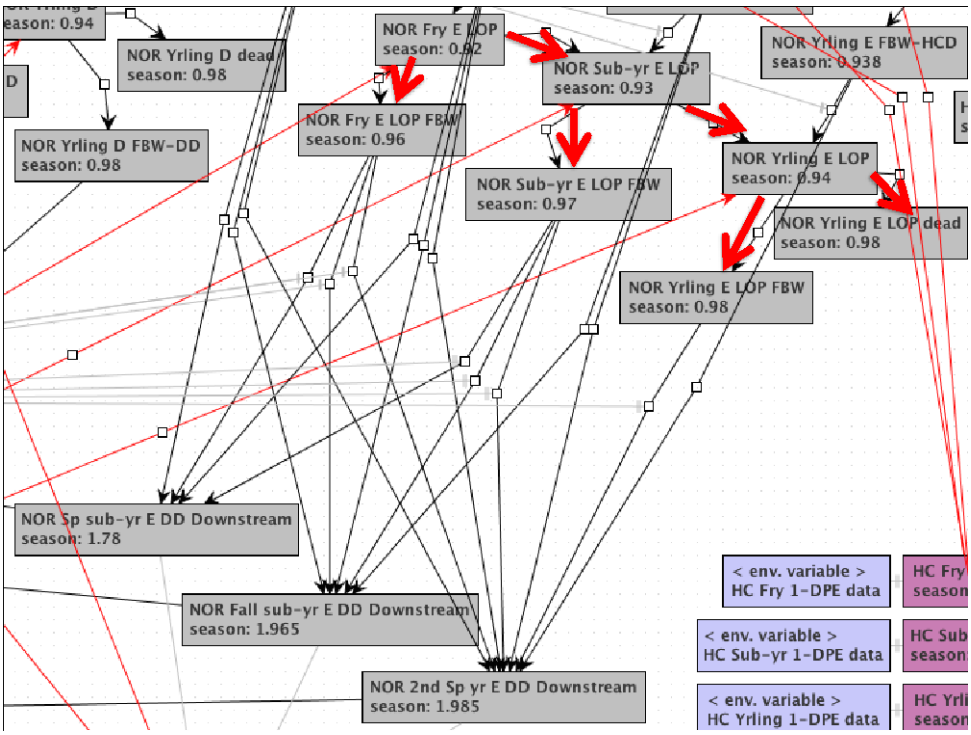
Proportion of Fry downstream of Hills Creek Dam (NOR Fry E FBW-HCD) that go to Dexter/Lookout Point reservoir (LOP) as Fry (NOR Fry E LOP) or when alternatives bypass Dexter Dam to become spring sub-yearlings (NOR Sp sub-yr E DD Downstream), fall sub-yearlings (NOR Fall sub-yr E DD Downstream), or second spring yearlings (NOR 2nd Sp yr E DD Downstream). Proportion of Sub-yearlings downstream of Hills Creek Dam (NOR Sub-yr E FBW-HCD) that go to Dexter/Lookout Point reservoir as Sub-yearlings (NOR Sub-yr E LOP) or when alternatives bypass Lookout Point and Dexter dams to become fall sub-yearlings (NOR Fall sub-yr E DD Downstream) or second spring yearlings (NOR 2nd Sp yr E DD Downstream). Proportion of Yearlings downstream of Hills Creek Dam (NOR Yrling E FBW-HCD) that go to Dexter/Lookout Point reservoir as yearlings (NOR Yrling E LOP) or when alternatives bypass Lookout Point and Dexter dams to become second spring yearlings (NOR 2nd Sp yr E DD Downstream). When using alternatives in which fish bypass Lookout Point and Dexter dams a datafile is used to define split among life history strategies. Datafile values are from parameter workshops (see Chapter 3, appendix 3.6).

From	To	Proportion
NOR Fry E FBW-HCD	NOR Sp sub-yr E DD Downstream	0
	NOR Fall sub-yr E DD Downstream	0
	NOR 2nd Sp yr E DD Downstream	0
	NOR Fry E LOP	1
NOR Sub-yr E FBW-HCD	NOR Fall sub-yr E DD Downstream	0
	NOR 2nd Sp yr E DD Downstream	0
	NOR Sub-yr E LOP	1
NOR Yrling E FBW-HCD	NOR 2nd Sp yr E DD Downstream	0
	NOR Yrling E LOP	1



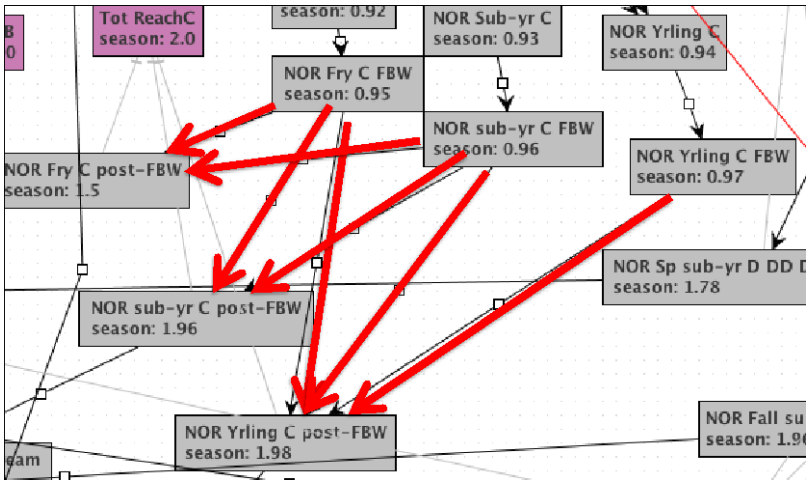
Proportion of Fry from Reach E (above Hills Creek Dam) that passed Hills Creek Dam and are in Dexter/Lookout Point (LOP) reservoir (NOR Fry E LOP) that are available to pass Dexter/Lookout Point Dam as Fry (NOR Fry E LOP FBW) or unavailable to pass, and thus remain in the reservoir to become Sub-yearling (NOR Sub-yr E LOP). Proportion of Sub-yearlings from Reach E that passed Hills Creek Dam and are in Dexter/Lookout Point reservoir (NOR Sub-yr E LOP) that are available to pass Lookout Point and Dexter dams as Sub-yearlings (NOR Sub-yr E LOP FBW) or unavailable to pass, and thus remain in the reservoir to become Yearling (NOR Yrling E LOP). Proportion of Yearlings from Reach E that passed Hills Creek Dam and are in Dexter/Lookout Point reservoir (NOR Yrling E LOP) that are available to pass Lookout Point and Dexter dams as Yearlings (NOR Yrling E LOP FBW) or unavailable to pass, and thus are removed from the simulation (NOR Yrling E LOP dead). These proportions use dam passage efficiency (DPE) data were specific to particular dam project alternatives and provided by USACE.

From	To	Proportion
NOR Fry E LOP	NOR Fry E LOP FBW	Split influencer determined by DPE file
	NOR Sub-yr E LOP	Split influencer determined by DPE file
NOR Sub-yr E LOP	NOR Yrling E LOP	Split influencer determined by DPE file
	NOR Sub-yr E LOP FBW	Split influencer determined by DPE file
NOR Yrling E LOP	NOR Yrling E LOP-dead	Split influencer determined by DPE file
	NOR Yrling E LOP-FBW	Split influencer determined by DPE file



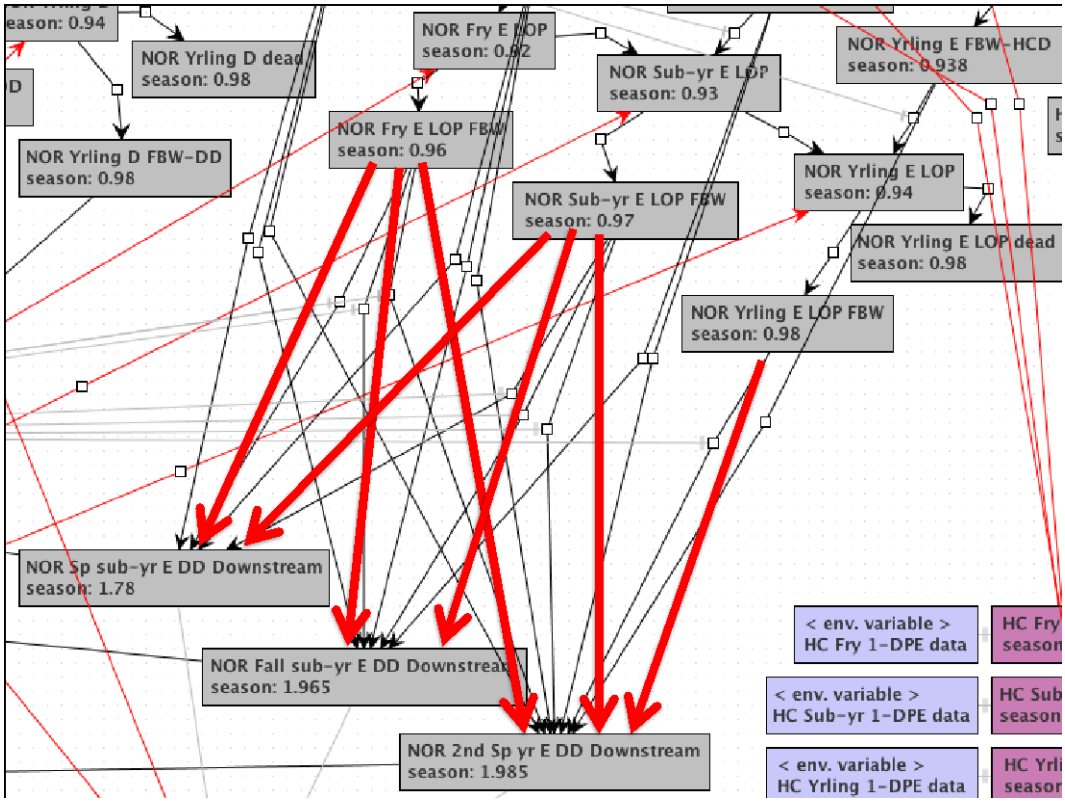
Proportion of Fry from Reach C (above Fall Creek Dam) that passed Fall Creek Dam and are in Reach B (below Fall Creek Dam) as Fry (NOR Fry C post-FBW), Sub-yearlings (NOR Sub-yr C post-FBW), or Yearlings (NOR Yrling C post-FBW). Proportion of Sub-yearlings from Reach C (above Fall Creek Dam) that passed Fall Creek Dam and are in Reach B (below Fall Creek Dam) as Sub-yearlings (NOR Sub-yr C post-FBW) or Yearlings (NOR Yrling C post-FBW). Values are from parameter workshops (see Chapter 3, appendix 3.6).

From	To	Proportion
NOR Fry C FBW	NOR Fry C post-FBW	0.15-0.35
	NOR Sub-yr C post-FBW	0.6 (0.4-0.65)
	NOR Yrling C post-FBW	0.25 (0.1-0.3)
NOR Sub-yr C FBW	NOR Fry C post-FBW	0
	NOR Sub-yr C post-FBW	0.85-1.0
	NOR Yrling C post-FBW	0-0.15
NOR Yrling C FBW	NOR Yrling C post-FBW	1.0



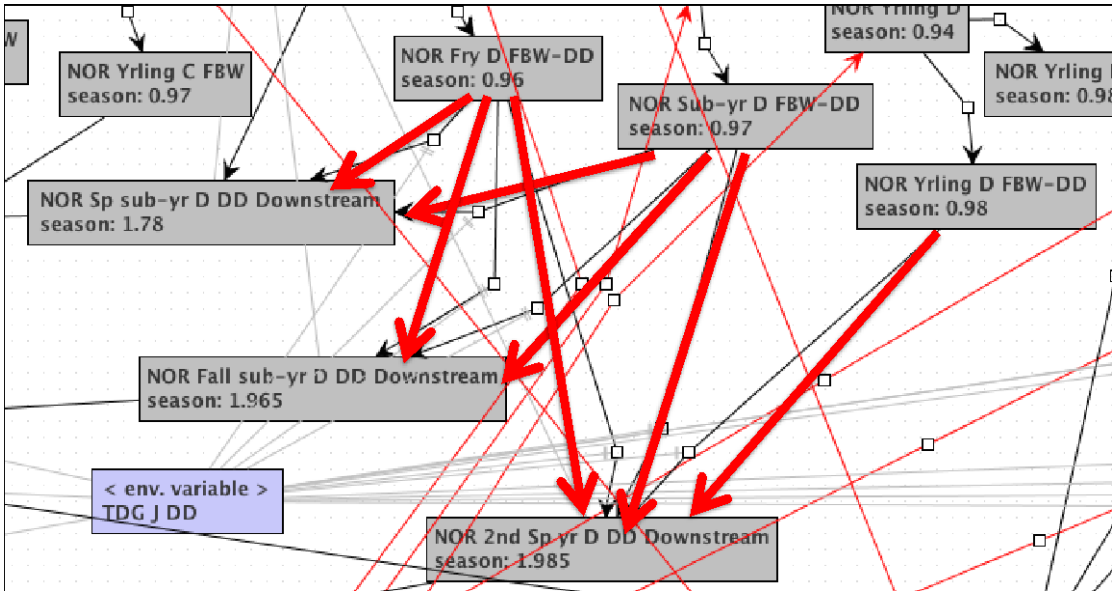
Proportion of Fry from Reach E (above Hills Creek Dam) that passed Dexter Dam (NOR Fry E LOP FBW) and are in Reach A (downstream of Dexter Dam, DD) as Spring sub-yearlings (NOR Sp sub-yr E DD Downstream), Fall sub-yearlings (NOR Fall sub-yr E DD Downstream), or 2nd spring yearlings (NOR 2nd Sp yr E DD Downstream). Proportion of Sub-yearlings from Reach E (above Hills Creek Dam) that passed Lookout Point and Dexter dam (NOR Sub-yr E LOP FBW) and are in Reach A (downstream of Dexter Dam, DD) as Fall sub-yearlings (NOR Fall sub-yr E DD Downstream) or 2nd spring yearlings (NOR 2nd Sp yr E DD Downstream). Values are from parameter workshops (see Chapter 3, appendix 3.6).

From	To	Proportion
NOR Fry E LOP FBW	NOR Sp Sub-yr E DD Downstream	0.6 (0.4-0.65)
	NOR Fall sub-yr E DD Downstream	0.3 (0.1-0.3)
	NOR 2nd Sp yr E DD Downstream	0.1-0.33
NOR Sub-yr E LOP FBW	NOR Sp Sub-yr E DD Downstream	0
	NOR Fall sub-yr E DD Downstream	0.7-0.8
	NOR 2nd Sp yr E DD Downstream	0.2-0.3
NOR Yrling E LOP FBW	NOR 2nd Sp yr E DD Downstream	1



Proportion of Fry from Reach D (above Dexter Dam) that passed Lookout Point and Dexter dams (NOR Fry D FBW-DD) and are in Reach A (downstream of Dexter Dam, DD) as Spring sub-yearlings (NOR Sp sub-yr D DD Downstream), Fall sub-yearlings (NOR Fall sub-yr D DD Downstream), or 2nd spring yearlings (NOR 2nd Sp yr D DD Downstream). Proportion of Sub-yearlings from Reach E (above Hills Creek Dam) that passed Lookout Point and Dexter dams (NOR Sub-yr E LOP FBW) and are in Reach A (downstream of Dexter Dam, DD) as Fall sub-yearlings (NOR Fall sub-yr E DD Downstream) or 2nd spring yearlings (NOR 2nd Sp yr E DD Downstream). Values are from parameter workshops (see Chapter 3, appendix 3.6).

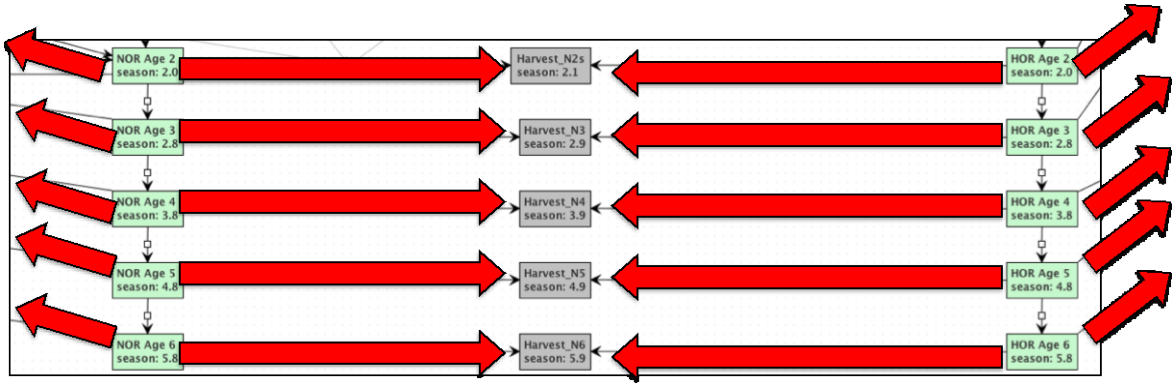
From	To	Proportion
NOR Fry D FBW-DD	NOR Sp Sub-yr D DD Downstream	0.1-0.33
	NOR Fall sub-yr D DD Downstream	0.6 (0.4-0.65)
	NOR 2nd Sp yr D DD Downstream	0.3 (0.1-0.3)
NOR Sub-yr D FBW-DD	NOR Sp Sub-yr D DD Downstream	0
	NOR Fall sub-yr D DD Downstream	0.7-0.8
	NOR 2nd Sp yr D DD Downstream	0.2-0.3
NOR Yrling D FBW-DD	NOR 2nd Sp yr D DD Downstream	1



Proportional splits of ocean adults (NOR/HOR Age 2, 3, 4, 5, & 6) that stay in the ocean for another year, are harvested in the ocean, or return to freshwater.

From	To	Proportion
NOR Age 2	NOR Age 3	1
	Harvest N2	0
	NOR Returns	0
HOR Age 2	HOR Age 3	1
	Harvest N2	0
	HOR In-River harvest	0
NOR Age 3	NOR Age 4	0.996
	Harvest N3	0.002
	NOR Returns	0.002
HOR Age 3	HOR Age 4	0.996
	Harvest N3	0.002
	HOR In-River harvest	0.002
NOR Age 4	NOR Age 5	0.58
	Harvest N4	0.065
	NOR Returns	0.355
HOR Age 4	HOR Age 5	0.58
	Harvest N4	0.065
	HOR In-River harvest	0.355
NOR Age 5	NOR Age 6	0.018
	Harvest N5	0.165
	NOR Returns	0.817
HOR Age 5	HOR Age 6	0.018
	Harvest N5	0.165
	HOR In-River harvest	0.817
NOR Age 6	Harvest N6	0
	NOR Returns	1
HOR Age 6	Harvest N6	0
	HOR In-River harvest	1

Values taken from Hendrix and Shi (2012) (page 22-31), which are based on ODFW SLAM parameter values and adjusted to fit age composition from ODFW.



6.3. Datafiles

Most parameter values are scalars or are drawn from distributions according to parameters within SLAM, however there are stage transitions within the life-cycle model where survivals or life history splits come from datafiles. For example, dam passage survival and efficiency, and environmental variables like temperature, enter into SLAM as a datafile. The following are the stages or stage transitions that call a datafile with survivals or splits.

6.3.1. Survivals

Stage at which datafile is used	Name of datafile	Name of series
NOR Fry E FBW-HCD	HillsCreek_FBW_Alternatives_toSLAM.csv	HC-Baseline-May 9 2014 FBW-Fry-146yr
NOR Fry D FBW-DD	LookoutPt_FBW_Alternatives_toSLAM.csv	LookoutPt-Baseline-May 9 2014 FBW-Fry-146yr
NOR Sub-yr E FBW-HCD	HillsCreek_FBW_Alternatives_toSLAM.csv	HC-Baseline-May 9 2014 FBW-Subyr-146yr
NOR Sub-yr D FBW-DD	LookoutPt_FBW_Alternatives_toSLAM.csv	LookoutPt-Baseline-May 9 2014 FBW-Subyr-146yr
NOR Yrling E FBW-HCD	HillsCreek_FBW_Alternatives_toSLAM.csv	HC-Baseline-May 9 2014 FBW-Yrling-146yr
NOR Yrling D FBW-DD	LookoutPt_FBW_Alternatives_toSLAM.csv	LookoutPt-Baseline-May 9 2014 FBW-Yrling-146yr
NOR Sp sub-yr Smolts	EstuaryCurrent_modified_1_2013.csv	EstuaryCurrent x 2 (200yrs)
NOR Fall sub-yr Smolts	EstuaryCurrent_modified_1_2013.csv	EstuaryCurrent x 2 (200yrs)
NOR 2nd Sp yr Smolts	EstuaryCurrent_modified_1_2013.csv	EstuaryCurrent x 2 (200yrs)
HOR Smolts	EstuaryCurrent_modified_1_2013.csv	EstuaryHatOr x 2 (200yrs)
NOR HOR Age 2	ChSOcean4thRt_modified_1_2013.csv	ChSAge2 10% down x 2 (200yrs)
NOR HOR Age 3	ChSOcean4thRt_modified_1_2013.csv	ChSAge3 10% down x 2 (200yrs)
NOR HOR Age 4	ChSOcean4thRt_modified_1_2013.csv	ChSAge4 10% down x 2 (200yrs)
NOR HOR Age 5	ChSOcean4thRt_modified_1_2013.csv	ChSAge 5 x 2 (200yrs)
NOR HOR Age 6	ChSOcean4thRt_modified_1_2013.csv	ChSAge 6 x 2 (200yrs)
TDG J FCD		0
TDF A FCD		0
Temp A	MiddleFork_Temp_Max7-DADM.csv	Reach A 200yr temp (based on 13yrs of USGS data)
Temp B	MiddleFork_Temp_Max7-DADM.csv	Reach A 200yr temp (based on 13yrs of USGS data)
Temp C	MiddleFork_Temp_Max7-DADM.csv	Reach C 200yr temp (based on 5yrs of USGS data)
Temp D	MiddleFork_Temp_Max7-DADM.csv	Reach D 200yr temp (based on 5yrs of USGS data)
Temp E	MiddleFork_Temp_Max7-DADM.csv	Reach E 200yr temp (based on 3yrs of USGS data)
TDG A DD	LookoutDexter_IRRM_Baseline_090111_TDG.csv	Baseline TDG-Dexter-Alevin (yolk sac fry) (148yrs)
TDG J DD	LookoutDexter_IRRM_Baseline_090111_TDG.csv	Baseline TDG-Dexter-Juvenile (148yrs)
TDG A HCD	HillsCreek_IRRM_Baseline_090111_TDG.csv	Baseline TDG-HillsCreek-Alevin (yolk sac fry) (148yrs)
TDG J HCD	HillsCreek_IRRM_Baseline_090111_TDG.csv	Baseline TDG-HillsCreek-Juvenile (148yrs)

6.3.2. Splits

Stage at which datafile is used	Name of datafile	Recruit stage datafile is applied	Name of series
NOR Fry D res	NOR Fry D res.csv	NOR Fry D	Baseline NOR Fry D
		NOR Sub-yr D	Baseline NOR Sub-yr D
NOR Sub-yr D res	NOR Sub-yr D res.csv	NOR Sub-yr D	Baseline NOR Sub-yr D
		NOR Yrling D	Baseline NOR Yrling D
NOR Fry E res	NOR Fry E res.csv	NOR Fry E	Baseline NOR Fry E
		NOR Sub-yr E	Baseline NOR Sub-yr E
NOR Sub-yr E res	NOR Sub-yr E res.csv	NOR Sub-yr E	Baseline NOR Sub-yr E
		NOR Yrling E	Baseline NOR Yrling E
NOR Fry C res	NOR Fry C res.csv	NOR Fry C	Baseline NOR Fry C
		NOR Sub-yr C	Baseline NOR Sub-yr C
NOR Sub-yr C res	NOR Sub-yr C res.csv	NOR Sub-yr C	Baseline NOR Sub-yr C
		NOR Yrling C	Baseline NOR Yrling C
NOR Fry C FBW	NOR Fry C FBW.csv	NOR Fry C post-FBW	NOR Fry C post-FBW
		NOR Sub-yr C post-FBW	NOR sub-yr C post-FBW
		NOR Yrling C post-FBW	NOR Yrling C post-FBW
NOR Fry D FBW-DD	NOR Fry D FBW-DD.csv	NOR Sp sub-yr DE DD Downstream	NOR Sp sub-yr DE DD Downstream
		NOR Fall sub-yr DE DD Downstream	NOR Fall sub-yr DE DD Downstream
		NOR 2nd Sp yr DE DD Downstream	NOR 2nd Sp yr DE DD Downstream
NOR sub-yr C FBW	NOR sub-yr C FBW.csv	NOR Fry C post-FBW	NOR Fry C post-FBW
		NOR Sub-yr C post-FBW	NOR sub-yr C post-FBW
		NOR Yrling C post-FBW	NOR Yrling C post-FBW
NOR Fry E LOP FBW	NOR Fry D FBW-DD.csv	NOR Sp sub-yr E DD Downstream	NOR Sp sub-yr DE DD Downstream
		NOR Fall sub-yr E DD Downstream	NOR Fall sub-yr DE DD Downstream
		NOR 2nd Sp yr E DD Downstream	NOR 2nd Sp yr DE DD Downstream
NOR Sub-yr D FBW-DD	NOR Sub-yr D FBW-DD.csv	NOR Sp sub-yr DE DD Downstream	NOR Sp sub-yr DE DD Downstream
		NOR Fall sub-yr DE DD Downstream	NOR Fall sub-yr DE DD Downstream
		NOR 2nd Sp yr DE DD Downstream	NOR 2nd Sp yr DE DD Downstream
NOR Sub-yr E LOP FBW	NOR Sub-yr D FBW-DD.csv	NOR 2nd Sp yr E DD Downstream	NOR Sp sub-yr DE DD Downstream
		NOR Sp sub-yr E DD Downstream	NOR Fall sub-yr DE DD Downstream
		NOR Fall sub-yr E DD Downstream	NOR 2nd Sp yr DE DD Downstream

USACE provided R2 Consultants, who in turn provided NWFSC, with the following SLAM datafiles; EstuaryCurrent, ChSOcean4thRt, LookoutDexter_IRRM_Baseline_090111_TDG, HillsCreek_IRRM_Baseline_090111_TDG, and MiddleFork_Temp_Max7-DADM. Each of the aforementioned files was expanded by NWFSC by repeating from the beginning, such that the files that were 74 years became 146 years, and those that were 100 years became 200 years. USACE provided Fish Benefits Workbooks datafiles that correspond to dam passage survival (e.g. HillsCreek_FBW_Alternatives_toSLAM, LookoutPt_FBW_Alternatives_toSLAM) and dam passage efficiency (e.g., HillsCreek_1-DPE_Alternatives_toSLAM, LookoutPt_1-DPE_Alternatives_toSLAM) (Fish Benefits Workbooks User Guide 2014).

6.4. Dynamic Drivers and Influence Scripts

In some cases we used scripts to influence life stage transitions and splits. These were written in a Java-compatible syntax and are called groovy script. These gave us the ability to dynamically influence splits such as apportioning adults to natal reaches based on juvenile outmigrants four years earlier, or for applying the dam passage efficiency (DPE) to juveniles attempting to pass the dam. Below is a list of boxes where dynamic drivers are applied.

Box where dynamic driver is located	Dynamic driver file name	What does dynamic driver do?
pNOB	pNOB.groovy	Calculates proportion of natural origin broodstock.
pNI	pNI.groovy	Calculates proportion of natural influence.
NOR Adults	NORs.groovy	Calculates total number of natural adults returning to Willamette Falls.
NORcounts at Dexter CF	NORs.groovy	Calculates total number of natural adults returning to Dexter CF.
NOR & HOR Returns DE	NOR HOR Returns DE.groovy	Calculates total number of natural or hatchery origin adults that returned to Reach D, & E.
NOR & HOR Returns ABC	NOR HOR Returns ABC.groovy	Calculates total number of natural or hatchery origin adults that returned to Reach A, B, & C.
ctr incr	ctr_incr.groovy	A counter to keep track of the year number being simulated.
%Wild ABCDE	%Wild.groovy	Calculates percent of natural origin fish with each Reach.
NOR HoR TNH Fry 1-DPE	1-DPE.groovy	Takes proportion from DPE datafile and calculates the proportion of fry that pass head of reservoir collection.
LOP Fry 1-DPE	1-DPE.groovy	Takes proportion from DPE datafile and calculates the proportion of fry that pass dam.
HC Fry 1-DPE	1-DPE.groovy	Takes proportion from DPE datafile and calculates the proportion of fry that pass dam.
LOP Sub-yr1-DPE	1-DPE.groovy	Takes proportion from DPE datafile and calculates the proportion of sub-yearlings that pass dam.
HC Sub-yr 1-DPE	1-DPE.groovy	Takes proportion from DPE datafile and calculates the proportion of sub-yearlings that pass dam.
LOP Yrling 1-DPE	1-DPE.groovy	Takes proportion from DPE datafile and calculates the proportion of yearlings that pass dam.
HC Yrling 1-DPE	1-DPE.groovy	Takes proportion from DPE datafile and calculates the proportion of yearlings that pass dam.
Fall sub-yr	Prop per Strategy-at Smolt.groovy	Calculates proportion of smolts that are fall sub-yearlings.
Sp sub-yr	Prop per Strategy-at Smolt.groovy	Calculates proportion of smolts that are spring sub-yearlings.
2nd Sp yr	Prop per Strategy-at Smolt.groovy	Calculates proportion of smolts that are second spring yearlings.
Tot Reach A, B, C, D, E	Tot ReachABCDE.groovy	Calculates total number of juveniles that exit each Reach (A, B, C, D, & E) separately, and these values are then used to calculate proportion of adults that enter each reach (see Split Influencer below).

Stage where influence script is located	Groovy script file name	What does script do?
NOR or HOR Spawners ABCDE	PSM.groovy	Calculates prespawn survival by using reach specific temperature and % wild as inputs PSM=((-9.5789)+(%wild * -2.39)+(Temp * 0.5492)); modified from Roumasset (2012) equation.
pHOS ABCDEF 2	pHOS ABCDEF 2.groovy	Calculates proportion of hatchery origin spawners.
pNI counter	PNI counter.groovy	A counter to keep track of the year number being simulated.
pHOS ABCDEF 3	pHOS ABCDEF 3.groovy	Calculates proportion of hatchery origin spawners.
NOR Emerg Fry C & E	pNI_NORs Eggs to Emerg Fry.groovy	Calculates proportion of eggs that survive.
HOR Emerg Fry C & E	pNI_HORs Eggs to Emerg Fry.groovy	Calculates proportion of eggs that survive.
NOR Emerg Fry A, B, & D	pNI_NORs Eggs To Emerg Fry w TDG.groovy	Calculates proportion of eggs that survive w TDG influence.
HOR Emerg Fry A, B, & D	pNI_HORs Eggs To Emerg Fry w TDG.groovy	Calculates proportion of eggs that survive w TDG influence.
NOR Sp sub-yr River Migrants a	TDGJ.groovy	Calculates proportion of juveniles that survive the total dissolved gas.
NOR Fall sub-yr River Migrants	TDGJ.groovy	Calculates proportion of juveniles that survive the total dissolved gas.
NOR 2nd Sp yr River Migrants	TDGJ.groovy	Calculates proportion of juveniles that survive the total dissolved gas.
NOR Sp sub-yr D DD Downstream	TDGJ.groovy	Calculates proportion of juveniles that survive the total dissolved gas.
NOR Fall sub-yr D DD Downstream	TDGJ.groovy	Calculates proportion of juveniles that survive the total dissolved gas.
NOR 2nd Sp yr D DD Downstream	TDGJ.groovy	Calculates proportion of juveniles that survive the total dissolved gas.
NOR Sp sub-yr E DD Downstream	TDGJ.groovy	Calculates proportion of juveniles that survive the total dissolved gas.
NOR Fall sub-yr E DD Downstream	TDGJ.groovy	Calculates proportion of juveniles that survive the total dissolved gas.
NOR 2nd Sp yr E DD Downstream	TDGJ.groovy	Calculates proportion of juveniles that survive the total dissolved gas.
Harvest_N2	Harvest_N2s.groovy	

Split where split influencer is located	Stage where groovy script is located	Groovy script file name	What does script do?
Hatchery Adults	HOR Adults	HOR Adults.groovy	Calculates the proportion of Hatchery Adults that stay in river.
	Hatchery returns	Hatchery returns.groovy	Calculates the proportion of Hatchery Adults that return to hatchery.
HOR Adults	HOR Return A	HOR Return A.groovy	Calculates the proportion of HOR Adults that go to Reach A.
	HOR Return B	HOR Return B.groovy	Calculates the proportion of HOR Adults that go to Reach B.
	HOR Return C	HOR Return C.groovy	Calculates the proportion of HOR Adults that go to Reach C.
	HOR Dexter CF	HOR Dexter CF.groovy	Calculates the proportion of HOR Adults that go to Dexter CF.
	HOR surplus	HOR surplus.groovy	Calculates the proportion of HOR Adults that are surplus.
NOR In-River harvest	NOR Return A	NOR Return A.groovy	Calculates the proportion of returning NOR Adults that go to Reach A.
	NOR Return B	NOR Return B.groovy	Calculates the proportion of returning NOR Adults that go to Reach B.
	NOR Return C	NOR Return C.groovy	Calculates the proportion of returning NOR Adults that go to Reach C.
	NOR Dexter CF	NOR Dexter CF.groovy	Calculates the proportion of returning NOR Adults that go Dexter CF.
NOR Dexter CF	NOR Return D	NOR Return D.groovy	Calculates the proportion of NORs at Dexter CF that go to Reach D.
	NOR Return E	NOR Return E.groovy	Calculates the proportion of NORs at Dexter CF that go to Reach E.
	Broodstock	Broodstock.groovy	Calculates the proportion of NORs at Dexter CF that are used in hatchery as broodstock.
NOR Fry E	NOR Sub-yr E	DPE to stay in res.groovy	Calculates the proportion of fry in Hills Creek reservoir that stay in Hills Creek reservoir to become sub-yearlings.
	NOR Fry E FBW-HCD	DPE to go to FBW.groovy	Calculates the proportion of fry in Hills Creek reservoir that attempt to pass Hills Creek Dam.
NOR Fry D	NOR Sub-yr D	DPE to stay in res.groovy	Calculates the proportion of fry in Dexter reservoir that stay in Dexter reservoir to become sub-yearlings.
	NOR Fry D FBW-DD	DPE to go to FBW.groovy	Calculates the proportion of fry in Dexter reservoir that attempt to pass Dexter Dam.
NOR Sub-yr E	NOR Yrling E	DPE to stay in res.groovy	Calculates the proportion of sub-yearlings in Hills Creek reservoir that stay in Hills Creek reservoir to become yearlings.
	NOR Sub-yr E FBW-HCD	DPE to go to FBW.groovy	Calculates the proportion of sub-yearlings in Hills Creek reservoir that attempt to pass Hills Creek Dam.
NOR Sub-yr D	NOR Yrling D	DPE to stay in res.groovy	Calculates the proportion of sub-yearlings in Dexter reservoir that stay in Dexter reservoir to become yearlings.
	NOR Sub-yr D FBW-DD	DPE to go to FBW.groovy	Calculates the proportion of sub-yearlings in Dexter reservoir that attempt to pass Dexter Dam.
NOR Yrling E	NOR Yrling E dead	DPE to stay in res.groovy	Calculates the proportion of yearlings in Hills Creek reservoir that do not pass Hills Creek Dam.
	NOR Yrling E FBW-HCD	DPE to go to FBW.groovy	Calculates the proportion of yearling in Hills Creek reservoir that attempt to pass Hills Creek Dam.
NOR Yrling D	NOR Yrling D dead	DPE to stay in res.groovy	Calculates the proportion of yearlings in Dexter reservoir that do not pass Dexter Dam.
	NOR Yrling D FBW-DD	DPE to go to FBW.groovy	Calculates the proportion of yearlings in Dexter reservoir that attempt to pass Dexter Dam.

6.5. Initialization Values

When SLAM begins a simulation not all of the boxes are populated with fish. As a result, the first several simulated years can show large fluctuations in abundance and frequent extinctions. To reduce these fluctuations many of the boxes are initialized with a number of fish at the start of the model. The values used to initialize these boxes were taken from the 100th year in a previous baseline simulation..

Stage	Initialized
Hatchery Adults	2,100
Hatchery returns	400
NOR Returns	200
Hatchery Spawners	400
HOR Adults	1,500
pNOB	100
pNI	231
NOR Adults	1
NOR In-River harvest	300
NOR Dexter CF	1
NORcounts at DexterCF	100
NOR Return A	1
NOR Return B	1
NOR Return C	1
NOR Return D	1
NOR Return E	1
HOR Dexter CF	1
HOR Return A	1
HOR Return B	1
HOR Return C	1
HOR Return D	1
HOR Return E	1
pHOS ABCDEF 1	60
ctr incr	-
pNI counter	-
HOR Returns DE	700
NOR Returns DE	6
HOR Returns ABC	700
NOR Returns ABC	300
%Wild B	300
%Wild C	500
%Wild A	40
%Wild D	40
%Wild E	40
NOR Spawners A	1
HOR Spawners A	1
NOR Spawners B	1
HOR Spawners B	1
NOR Spawners C	1
HOR Spawners C	1
NOR Spawners D	1
HOR Spawners D	1
NOR Spawners E	1
HOR Spawners E	1
NOR Tot Spawners A	1
HOR Tot Spawners A	1
NOR Tot Spawners B	1
HOR Tot Spawners B	1
NOR Tot Spawners C	1
HOR Tot Spawners C	1
NOR Tot Spawners D	1
HOR Tot Spawners D	1
NOR Tot Spawners E	1
HOR Tot Spawners E	1
HOR Eggs D	1
NOR Eggs D	1
HOR Eggs C	1
NOR Eggs C	1
HOR Eggs B	1
NOR Eggs B	1
HOR Eggs A	1
NOR Eggs A	1
NOR Eggs E	1
HOR Eggs E	1
NOR & HOR Emerg Fry A	1
NOR & HOR Emerg Fry B	1
NOR & HOR Emerg Fry C	1
NOR & HOR Emerg Fry D	1
NOR & HOR Emerg Fry E	1
HC HoR TNH Fry 1-DPE	-
LOP Fry 1-DPE	54
HC Fry 1-DPE	92
NOR Fry C res	1
NOR Yrling C res	1
NOR Sub-yr C res	1
LOP Sub-yr 1-DPE	40
HC Sub-yr 1-DPE	79
LOP Yrling 1-DPE	49
HC Yrling 1-DPE	75
NOR Sp sub-yr A	1
NOR Fall sub-yr A	1

NOR 2nd Sp yr A	1
NOR Sp sub-yr B	1
NOR Fall sub-yr B	1
NOR 2nd Sp yr B	1
NOR Sp sub-yr JOM B	1,000
NOR Sp sub-yr JOM A	1,000
NOR Sp sub-yr Smolts	400
HOR Smolts	250,000
NOR Fall sub-yr JOM A	1
NOR Fall sub-yr JOM B	1
NOR 2nd Sp yr JOM B	1
NOR Fall sub-yr Smolts	400
NOR 2nd Sp yr JOM A	1
NOR 2nd Sp yr Smolts	400
Sp sub-yr	1,000
Fall sub-yr	1,000
2nd yr	1,000
NOR Age 2	1,000

HOR Age 2	45,000
Tot Reach A	100
Tot Reach B	250
Tot Reach C	1,000
Tot Reach DE	-
Count FryD	-
Count FryE	-
NOR Age 3	750
HOR Age 3	35,000
NOR Age 4	350
HOR Age 4	22,500
NOR Age 5	275
HOR Age 5	17,500
NOR Age 6	5
HOR Age 6	250

6.5.1. Model Demonstration & Alternative Scenarios

Here we report results from SLAM model runs that evaluated potential population responses to a set of the most recent dam project alternatives (received May 9, 2014) provided by the USACE. Below (Table 6.3) is a list of alternatives that represent various operational and structural modifications to Dexter and Hills Creek dams whose goal is to improve access to Reach D and E (above Dexter and Hills Creek dams). Each alternative was run in SLAM and estimates were produced of several variables including abundance of natural origin spawners and each life history strategy, and percent wild. Each alternative was run 500 times, and each run is 100 years long. We used 500 runs because output stabilized at this level. USACE provided datafiles of dam passage survival and efficiency (Fish Benefit Workbook), which were time series of 73 years in length, and we duplicated them to produce time series that were 146 years in length. All alternatives were provided by USACE.

Table 6.3: List of alternatives run in the SLAM model of Middle Fork River Chinook salmon. Alternatives vary in terms of dam passage survival, efficiency, the influence of total dissolved gas (TDG) (it is assumed that trap and haul alternatives will release fish below any TDG influence), and for two alternatives temperature is lowered to adjust PSM to current conditions. Abbreviations: Lookout Point Dam (LOP), Hills Creek Dam (HC), selective withdrawal structure (SWS), floating surface collector (FSC), Floating screen structure (FSS), turbine & regulating outlet (TurbRO), and head of reservoir (HoR). Description of each alternative can be found in Appendix D.

	Lookout Point Alternative Description	Hills Creek Alternative Description	SLAM output name	PSM adjustment?	Lookout Pt hauled below Dexter TDG?	Hills Creek hauled below Dexter TDG? (i.e., fish don't pass thru dexter)	Lookout Point Dam Passage survival (average %)			Lookout Point Dam 1-DPE (average %)			Hills Creek Dam Passage survival (average %)			Hills Creek Dam 1-DPE (average %)			Hills Creek HoR Passage Survival (%)	Hills Creek HoR 1-DPE (%)
							Fry	Sub-yr	Yrling	Fry	Sub-yr	Yrling	Fry	Sub-yr	Yrling	Fry	Sub-yr	Yrling		
1	Baseline (with Op temp spill)	Baseline	Baseline	NA	N	N	51	33	29	54	40	49	64	36	34	92	79	75	0	0
2	Baseline (with Op temp spill)	Selective Withdrawal Struct	LOP_Baseline-HC_SWS	NA	N	N	51	33	29	54	40	49	64	31	33	29	29	29	0	0
3	Baseline (with Op temp spill)	Floating Surface Collector	LOP_Baseline-HC_FSC	NA	N	Y	51	33	29	54	40	49	73	49	52	29	29	29	0	0
4	Baseline (with Op temp spill)	Selective Withdrawal Struct & Floating Screen Str	LOP_Baseline-HC_SWS-FSS	NA	N	Y	51	33	29	54	40	49	97	82	96	29	29	29	0	0
5	Baseline (with Op temp spill)	HoR Opt 2: DPE 80%; Passage survival 90%	LOP_Baseline-HC_Baseline-HoR2	NA	N	Y	51	33	29	54	40	49	64	36	34	92	79	75	90	20
6	Floating Surface Collector	Baseline	LOP_FSC-HC_Baseline	NA	Y	N	69	56	59	31	31	31	64	36	34	92	79	75	0	0
7	Selective Withdrawal Struct & Floating Screen Str	Baseline	LOP_SWS-FSS-HC_Baseline	-1C at ReachD	Y	N	95	92	93	31	31	31	64	36	34	92	79	75	0	0
8	Selective Withdrawal Struct & Turbine/RO	Baseline	LOP_SWS TurbRO-HC_Baseline	NA	N	N	45	20	21	31	31	31	64	36	34	92	79	75	0	0
9	Baseline (no temp spill)	Baseline	LOP_Baseline nSpill-HC_Baseline	NA	N	N	45	20	21	55	40	49	64	36	34	92	79	75	0	0
10	Selective Withdrawal Struct & Floating Screen Str	Floating Surface Collector	LOP_SWS-FSS-HC_FSC	NA	Y	Y	95	92	93	31	31	31	73	49	52	29	29	29	0	0
11	Floating Surface Collector	HoR Opt 2: DPE 80%; Passage survival 90%	LOP_FSC-HC_Baseline HoR2	NA	Y	Y	69	56	59	31	31	31	64	36	34	92	79	75	90	20
12	Floating Surface Collector	Selective Withdrawal Struct & Floating Screen Str	LOP_FSC-HC_SWS-FSS	-1C at ReachC	Y	Y	69	56	59	31	31	31	97	82	96	29	29	29	0	0

6.5.2. Parameter Variability

The following tables identify parameters that vary among years in each model run. In all the parameters listed below (except passage survival and estuary and ocean survival) values are randomly selected each model year from the specified distribution and these distributions and parameters defining them do not vary among alternatives (Table 6.4). For any given alternative, passage survival values vary among years of a model run, but do not vary among the 500 model runs (passage survival values are taken from a datafile). Values of passage survival vary among alternatives (Table 6.5). For any given alternative, estuary and ocean survival values vary among years of a model run, but do not vary among the 500 model runs (estuary and ocean survival values are taken from a datafile). Values of estuary and ocean survival do not vary among alternatives (Table 6.6).

Table 6.4: Capacity and survival parameters whose values vary among years in each model run and vary among model runs.

Location in Life Cycle	From	To	Curve type	Capacity &/or Productivity	Distribution type	Mean	SD	Min	Max
Reach A mainstem downstream of Dexter Dam	NOR Tot Spawners	Eggs	Beverton-Holt	Capacity	Normal	150,000	33,000	75,000	200,000
Reach B Fall Creek downstream of Fall Creek Dam	NOR Tot Spawners	Eggs	Beverton-Holt	Capacity	Normal	500,000	50,000	300,000	1,000,000
Reach C Fall Creek upstream of Fall Creek Dam	NOR Tot Spawners	Eggs	Beverton-Holt	Capacity	Normal	2,000,000	50,000	1,000,000	3,000,000
Reach D mainstem upstream of Lookout Dam & downstream of Hills Creek Dam	NOR Tot Spawners	Eggs	Beverton-Holt	Capacity	Normal	20,000,000	200,000	10,000,000	22,500,000
Reach E upstream of Hills Creek Dam	NOR Tot Spawners	Eggs	Beverton-Holt	Capacity	Normal	10,000,000	200,000	6,000,000	13,000,000
Reach A mainstem downstream of Dexter Dam	HOR Tot Spawners	Eggs	Beverton-Holt	Capacity	Normal	150,000	33,000	75,000	200,000
Reach B Fall Creek downstream of Fall Creek Dam	HOR Tot Spawners	Eggs	Beverton-Holt	Capacity	Normal	500,000	50,000	300,000	1,000,000
Reach C Fall Creek upstream of Fall Creek Dam	HOR Tot Spawners	Eggs	Beverton-Holt	Capacity	Normal	2,000,000	50,000	1,000,000	3,000,000
Reach D mainstem upstream of Lookout Dam & downstream of Hills Creek Dam	HOR Tot Spawners	Eggs	Beverton-Holt	Capacity	Normal	20,000,000	200,000	10,000,000	22,500,000
Reach E upstream of Hills Creek Dam	HOR Tot Spawners	Eggs	Beverton-Holt	Capacity	Normal	10,000,000	200,000	6,000,000	13,000,000
Hatchery	Hatchery returns	Hatchery Spawners	Hockey-Stick	Capacity	Normal	1,500	100	1,400	2,000
Hatchery	Hatchery Spawners	HOR IOM	Hockey-Stick	Capacity	Normal	1,800,000	25,000	1,600,000	2,000,000
Reach D	NOR Fry D res	NOR Sub-yr D	Linear	Productivity	Triangular	0.175		0.100	0.400
Reach D	NOR Sub-yr D res	NOR Yrling D	Linear	Productivity	Uniform			0.350	0.800
Reach E	NOR Fry E res	NOR Sub-yr E	Linear	Productivity	Triangular	0.300		0.200	0.450
Reach E	NOR Sub-yr E res	NOR Yrling E	Linear	Productivity	Uniform			0.350	0.800
Reach C	NOR Fry C res	NOR Sub-yr C	Linear	Productivity	Triangular	0.300		0.200	0.450
Reach C	NOR Sub-yr C res	NOR Yrling C	Linear	Productivity	Uniform			0.350	0.800
Reach E	NOR Fry E	NOR Sub-yr E	Linear	Productivity	Triangular	0.200		0.150	0.350
Reach D	NOR Fry D	NOR Sub-yr D	Linear	Productivity	Triangular	0.175		0.100	0.400
Reach C	NOR Fry C	NOR Fry C FBW	Linear	Productivity	Normal	0.862	0.045	0.000	1.000
Reach E	NOR Fry E LOP	NOR Sub-yr E LOP	Linear	Productivity	Triangular	0.175		0.100	0.400
Reach E	NOR Sub-yr E	NOR Yrling E	Linear	Productivity	Uniform			0.400	0.900
Reach D	NOR Sub-yr D	NOR Yrling D	Linear	Productivity	Uniform			0.400	0.900
Reach C	NOR Sub-yr C	NOR Sub-yr C FBW	Linear	Productivity	Normal	0.862	0.045	0.000	1.000
Reach E	NOR Sub-yr E LOP	NOR Yrling E LOP	Linear	Productivity	Uniform			0.400	0.900
Reach C	NOR Yrling C	NOR Yrling C FBW	Linear	Productivity	Normal	0.862	0.045	0.000	1.000

Table 6.5: Average, minimum, and maximum passage survival for each alternative and life history strategy. These values vary among years of a model run but do not vary among model runs.

FBW		Average Passage Survival			Min Passage Survival			Max Passage Survival		
Output File name	Alternative	Fry	Sub-yr	Yrling	Fry	Sub-yr	Yrling	Fry	Sub-yr	Yrling
Ch_LOP_1-9may2014	Lookout Point-Baseline	0.51	0.33	0.29	0.45	0.20	0.20	0.53	0.35	0.33
Ch_LOP_2-9may2014	Lookout Point-Floating Surface Collector	0.69	0.56	0.59	0.61	0.48	0.45	0.78	0.70	0.69
Ch_LOP_3-9may2014	Lookout Point-Selective Withdrawal Struct & Floating Screen Str	0.95	0.92	0.93	0.90	0.90	0.70	0.98	0.95	0.97
Ch_LOP_4-9may2014	Lookout Point-Selective Withdrawal Struct & Turbine/RO	0.45	0.20	0.21	0.45	0.20	0.20	0.47	0.22	0.24
Ch_LOP_6-9may2014	Lookout Point-Baseline (no temp spill)	0.45	0.20	0.21	0.45	0.20	0.20	0.47	0.21	0.24
Ch_HCR_1-9may2014	Hills Creek-Baseline	0.64	0.36	0.34	0.63	0.30	0.29	0.69	0.51	0.49
Ch_HCR_2-9may2014	Hills Creek-Selective Withdrawal Struct	0.64	0.31	0.33	0.63	0.29	0.29	0.68	0.35	0.44
Ch_HCR_3-9may2014	Hills Creek-Floating Surface Collector	0.73	0.49	0.52	0.71	0.47	0.48	0.76	0.55	0.57
Ch_HCR_5-9may2014	Hills Creek-Selective Withdrawal Struct & Floating Screen Str	0.97	0.82	0.96	0.94	0.77	0.87	0.98	0.84	0.99

Table 6.6: Average, minimum, and maximum survival values during estuary and ocean stages. Age-specific time series of estuary and ocean survival were generated by ODFW, and incorporated into SLAM as datafiles.

Stage	Min	Average	Max
Estuary	0.61	0.66	0.70
Ocean 2yr olds	0.22	0.35	0.51
Ocean 3yr olds	0.28	0.46	0.67
Ocean 4yr olds	0.33	0.54	0.78
Ocean 5yr olds	0.42	0.68	0.99
Ocean 6yr olds	0.47	0.76	1

6.5.3. SLAM Output and VSP Scores

For each alternative run in SLAM, four categories of model output are produced; abundance and productivity, proportion of hatchery origin spawners, life history diversity, and spatial structure (see Chapter 3, Parameterization of VSP Criteria). For each of these categories we generate VSP scores, and then use the following equation to produce a Total VSP score:

$$Total\ VSP\ score = \frac{2(Abundance) + 2(Productivity) + Diversity + Spatial\ Structure}{6}$$

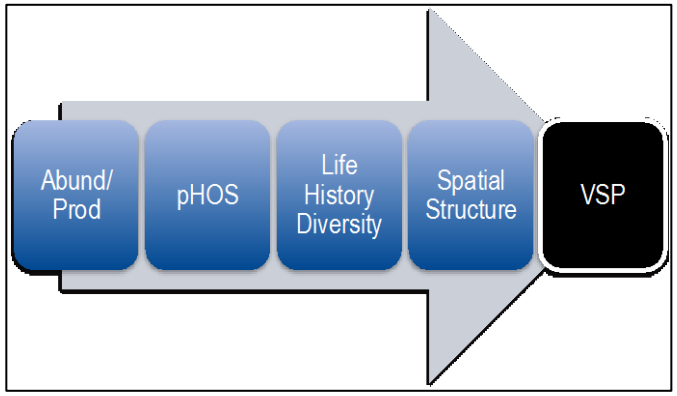


Figure 6.3: Representation of the four components (abundance and productivity, proportion of hatchery origin spawners, life history diversity, and spatial structure) that comprise VSP score.

Abundance and Productivity

Under Baseline (i.e., current) conditions a median of 385 natural origin spawners was estimated for the Middle Fork Willamette River, while the alternative that had a Selective Withdrawal Structure and Floating Screen Structure at Lookout Point Dam (SWS-FSS) and Floating Surface Collector (FSC) at Hills Creek Dam (LOP_SWS-FSS-HC_FSC) was estimated to have a median of 11,032 individuals (Figure 6.4 and Table 6.3).

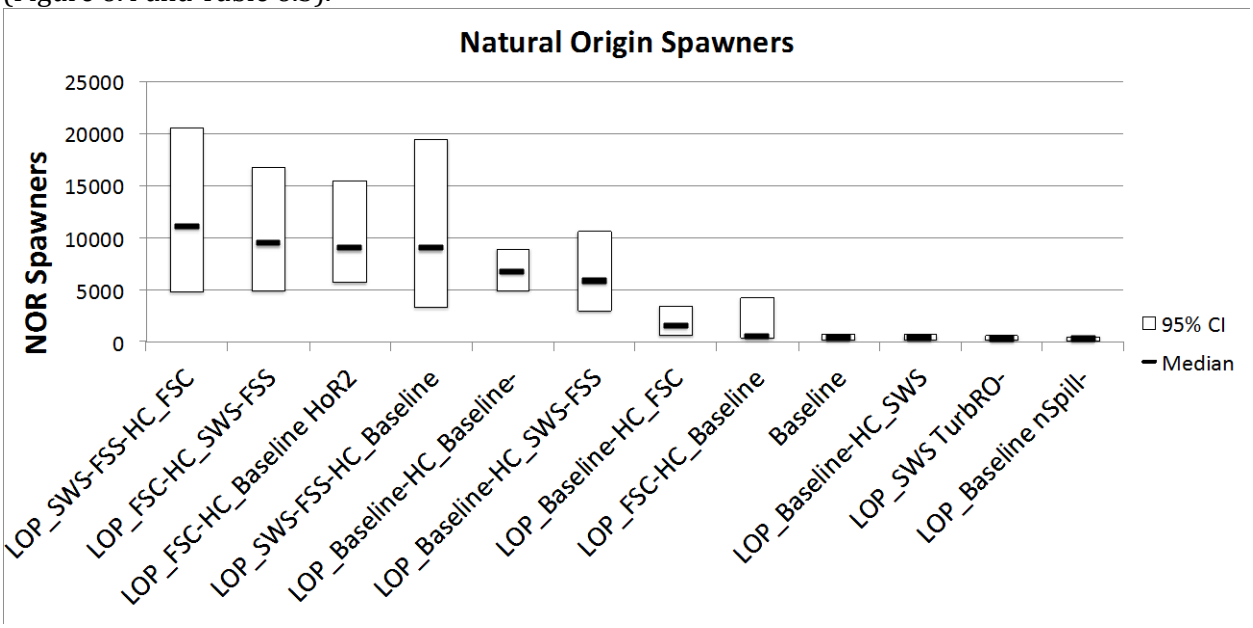


Figure 6.4: Abundance of natural origin spawners among Middle Fork Willamette River alternatives (see

Table 6.3). Median and 95% confidence limits (line and box, respectively) were calculated from the 500 geomeans (1 geomean per run) of abundance, each of which was for a 100-year period.

We estimated the probability quasi-extinction threshold (QET) for each alternative under the following conditions; critical abundance was set as 250 individuals (set by the Lower Columbia/Willamette TRT), a four-year moving average was used over a 100-year period (from year 6 to year 105). We started QET calculation at year 6 because the model was fully initialized beyond this point and reflected system dynamics rather than the influences of starting values. Under Baseline (i.e., current) conditions, QET was estimated as 100% for the Middle Fork Willamette River, while it was 0.8% for the alternative that had a Selective Withdrawal Structure and Floating Screen Structure at Lookout Point Dam (SWS-FSS) and Floating Surface Collector (FSC) at Hills Creek Dam (LOP_SWS-FSS-HC_FSC) (Figure 6.5).

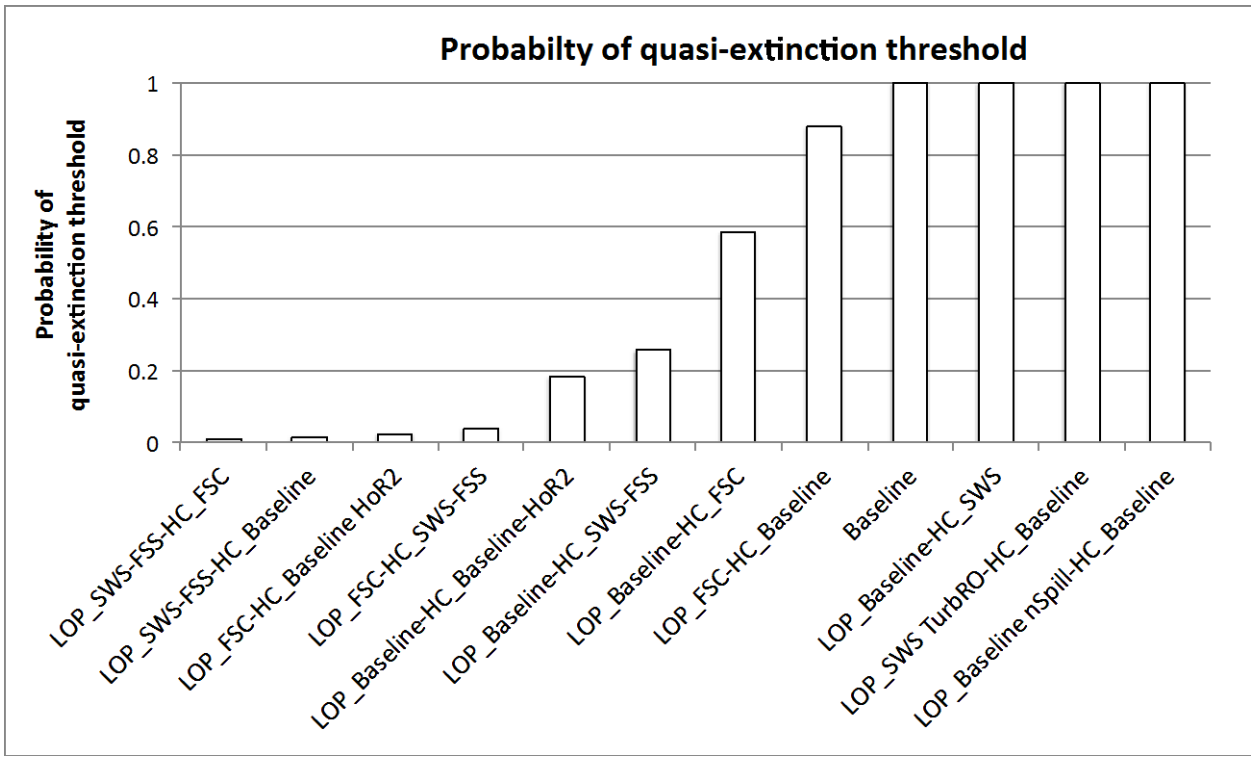


Figure 6.5: Probability of quasi-extinction among Middle Fork Willamette River alternatives.

Based on a relationship between VSP score and abundance and productivity (see Chapter 3, Parameterization of VSP Criteria), the Baseline (i.e., current) conditions received a median VSP score of 0.003, while the alternative that had a Selective Withdrawal Structure and Floating Screen Structure at Lookout Point Dam (SWS-FSS) and Floating Surface Collector (FSC) at Hills Creek Dam (LOP_SWS-FSS-HC_FSC) yielded a median VSP score of 3.6 (Figure 6.6).

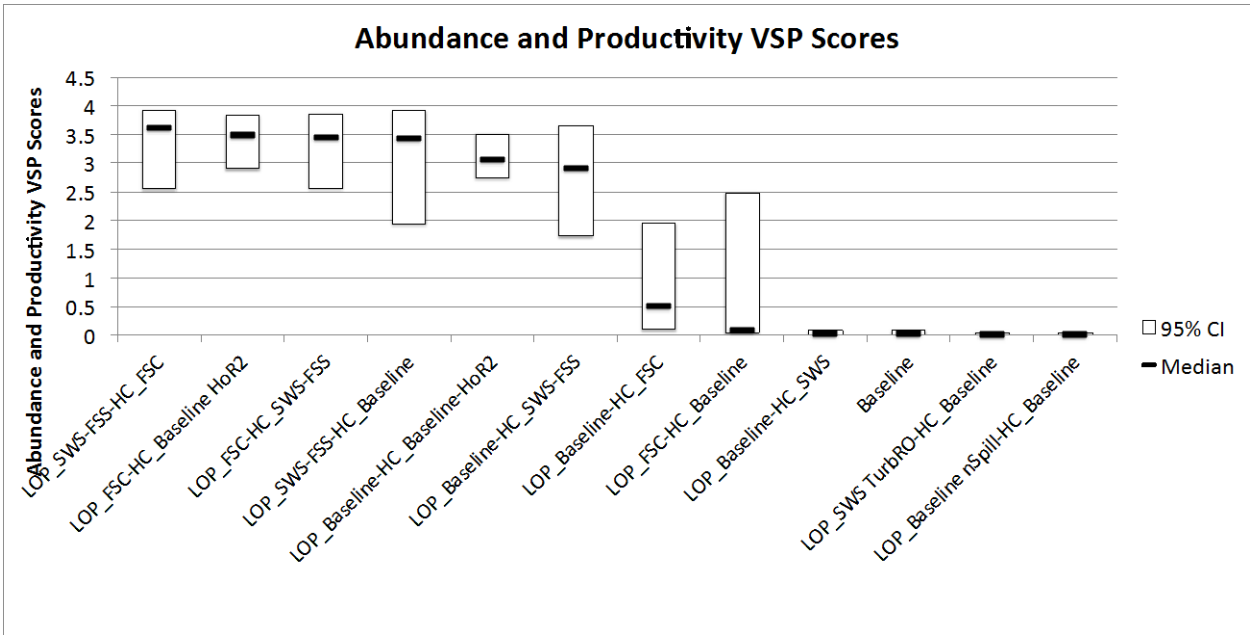


Figure 6.6: Abundance and Productivity VSP scores among Middle Fork Willamette River alternatives.

Proportion of Hatchery Origin Spawners

Under Baseline (i.e., current) conditions, the median proportion of hatchery origin spawners was estimated as 0.88, while the alternative that had a Selective Withdrawal Structure and Floating Screen Structure at Lookout Point Dam (SWS-FSS) and Floating Surface Collector (FSC) at Hills Creek Dam (LOP_SWS-FSS-HC_FSC) was estimated to have a median of 0.02 (also for LOP_SWS-FSS-HC_Baseline, LOP_FSC-HC_Baseline HoR2, and LOP_FSC-HC_SWS-FSS). This decline in the proportion of hatchery origin spawners for the LOP_SWS-FSS-HC_FSC alternative (also for LOP_SWS-FSS-HC_Baseline, LOP_FSC-HC_Baseline HoR2, and LOP_FSC-HC_SWS-FSS) is due to an increase in natural origin spawners that resulted from improved dam passage efficiency and survival relative to the Baseline (Figure 6.7).

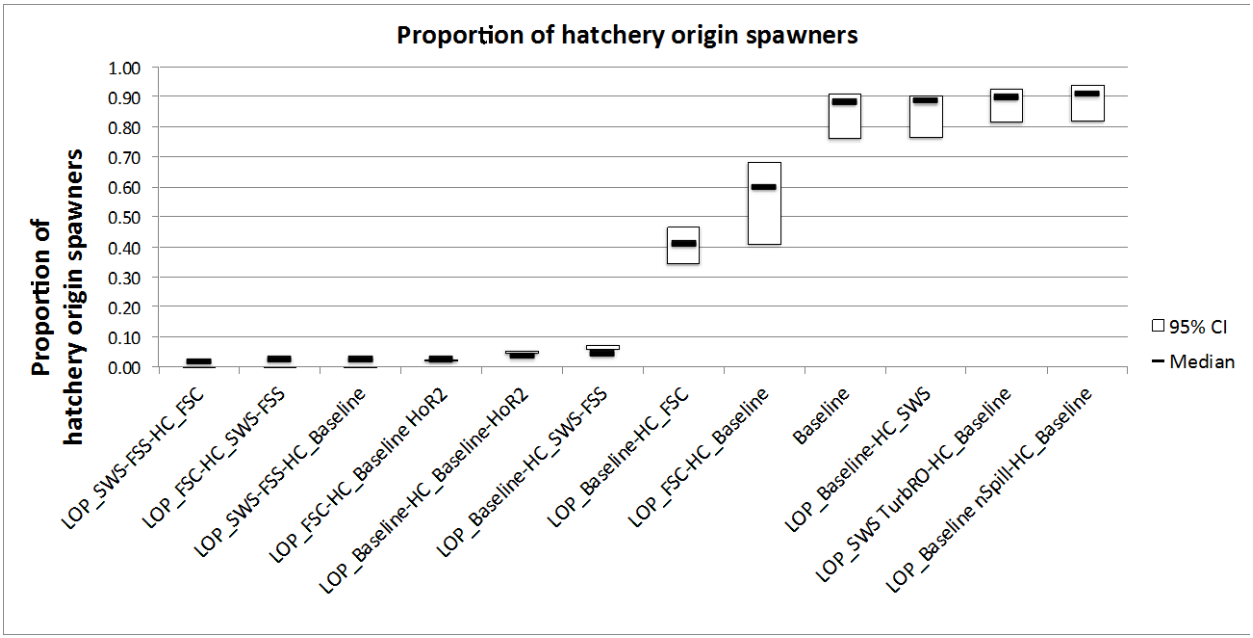


Figure 6.7: Proportion of hatchery origin spawners among Middle Fork Willamette River alternatives (see Table 6.3). Median and standard deviation are shown (line and box, respectively), which were calculated at the final simulated year using all 500 SLAM trajectories.

The VSP score for proportion of hatchery origin spawners is calculated based on a combination of proportion of natural influence and proportion of hatchery origin spawners (see Chapter 3, Parameterization of VSP Criteria). Under Baseline (i.e., current) conditions, a median VSP score of 0.3 was estimated, while the alternative that had a Selective Withdrawal Structure and Floating Screen Structure at Lookout Point Dam (SWS-FSS) and Floating Surface Collector (FSC) at Hills Creek Dam (LOP_SWS-FSS-HC_FSC) had a median VSP score of 3.9 (also for LOP_SWS-FSS-HC_Baseline, LOP_FSC-HC_Baseline HoR2, and LOP_FSC-HC_SWS-FSS) (Figure 6.8).

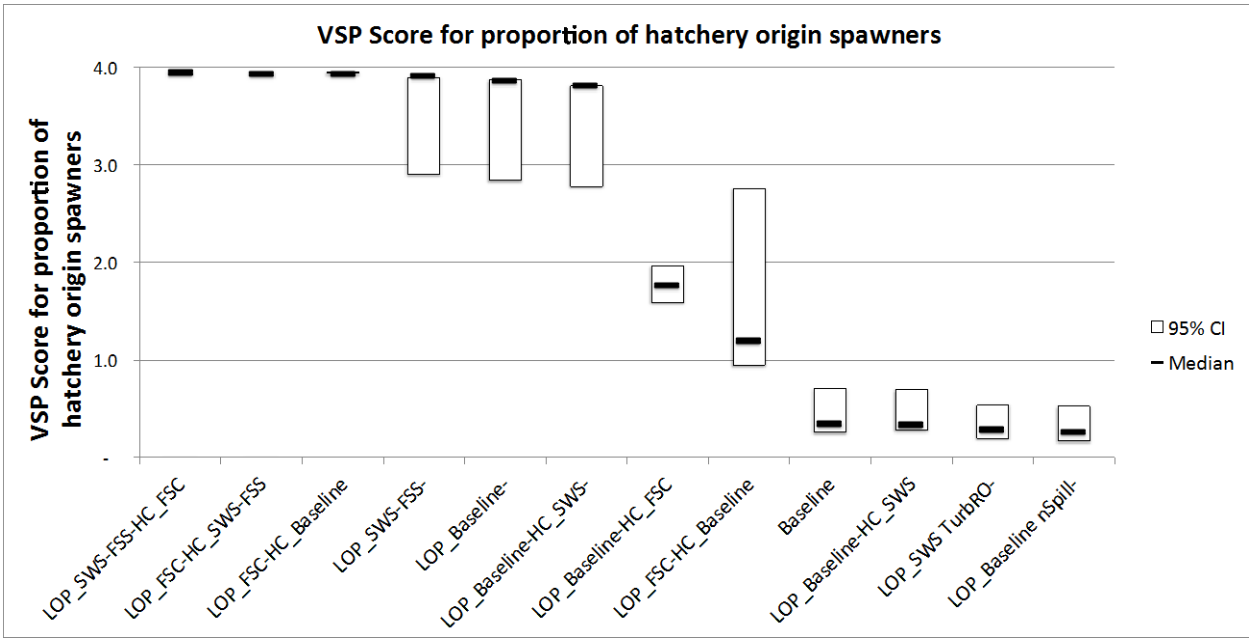


Figure 6.8: Proportion of Hatchery Origin Spawners VSP scores among Middle Fork Willamette River

alternatives. Median and standard deviation are shown (line and box, respectively), which were calculated using the median and standard deviation of PNI and pHOS.

Life History Diversity

Moving from baseline conditions to LOP_Baseline-HC_Baseline-HoR2, the number of spring subyearlings increased but not as much as the numbers of fall subyearlings and spring yearlings (Fig. 6.9). The composition of each life history was most similar to baseline conditions in the LOP_SWS-FSS-HC_Baseline and LOP_Baseline nSpill-HC_Baseline alternatives.

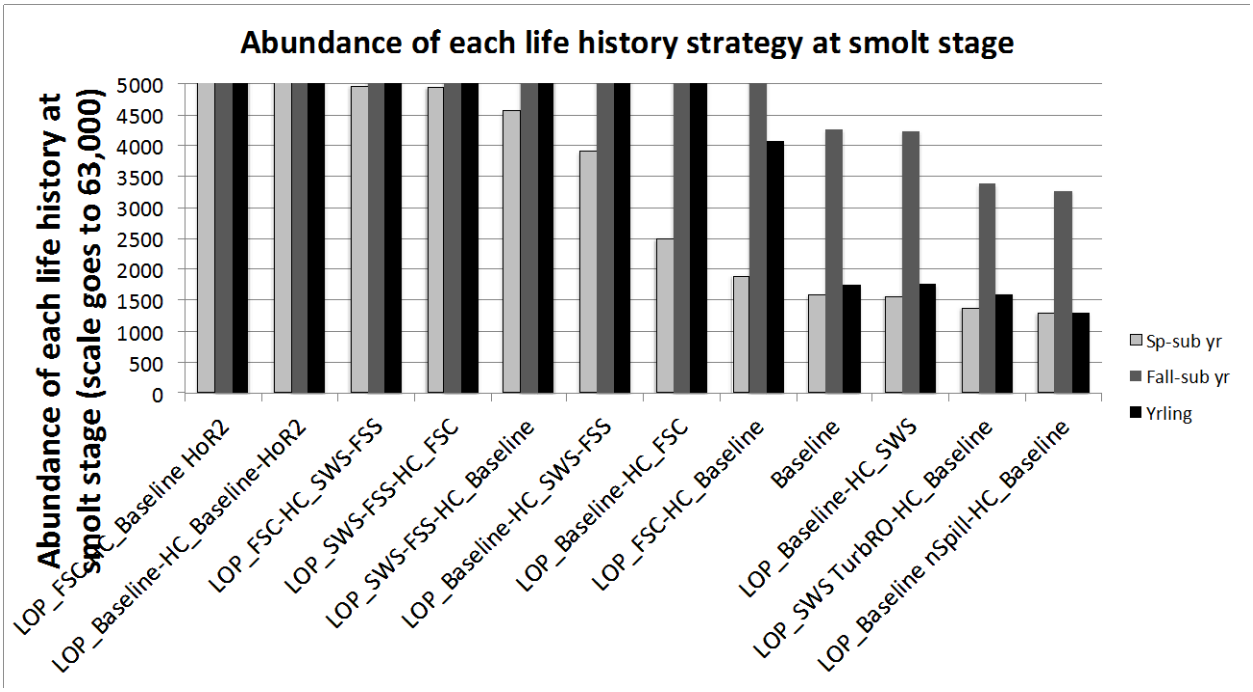


Figure 6.9: Median smolt abundance for each life history strategy among alternatives (see Table 6.3). Median was calculated at the final simulated year using all 500 SLAM trajectories. Standard deviation is excluded to improve clarity.

If number of individuals of a given life history strategy falls below 5,000 then 0.5 VSP points was subtracted from 4.0 VSP points, and if number of individuals falls below 1000 then 1.0 VSP point is subtracted from 4.0 VSP points. This is determined for each life history strategy (Figure 6.10).

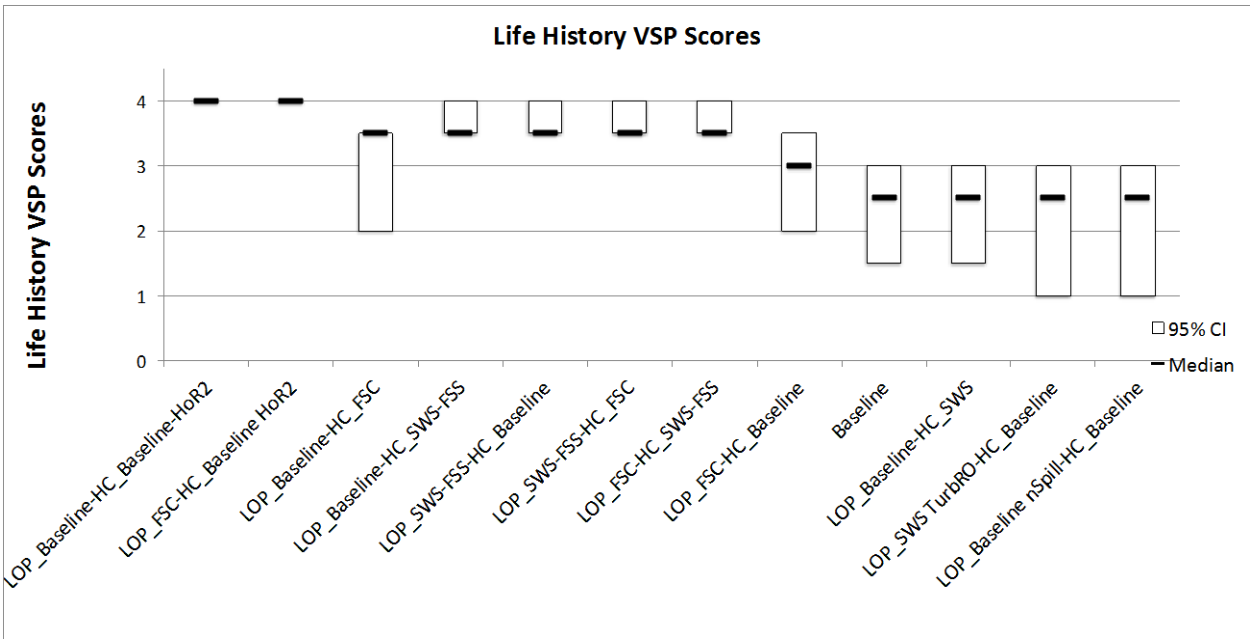


Figure 6.10: Life History Diversity VSP scores among Middle Fork Willamette River alternatives. Median and standard deviation are shown (line and box, respectively), which were calculated using the median and standard deviation of abundance of smolts among life history strategies.

Spatial Structure

Spatial structure is a measure of population replacement above Fall Creek Dam (Reach C), Dexter/Lookout Point Dam (Reach D) and above Hills Creek Dam (Reach E). To assess replacement above dams we used median recruits per spawner, measured as returning spawners referenced to the median of the spawning brood that produced them (i.e., the spawner to spawner).

$$Spawner{:}\,Spawner = \frac{Natural\ origin\ spawners\ in\ Reach\ C\ at\ time\ y + 4yrs}{Hatchery\ origin\ spawners\ in\ Reach\ C\ at\ time\ y + Natural\ origin\ spawners\ in\ Reach\ C\ at\ time\ y}$$

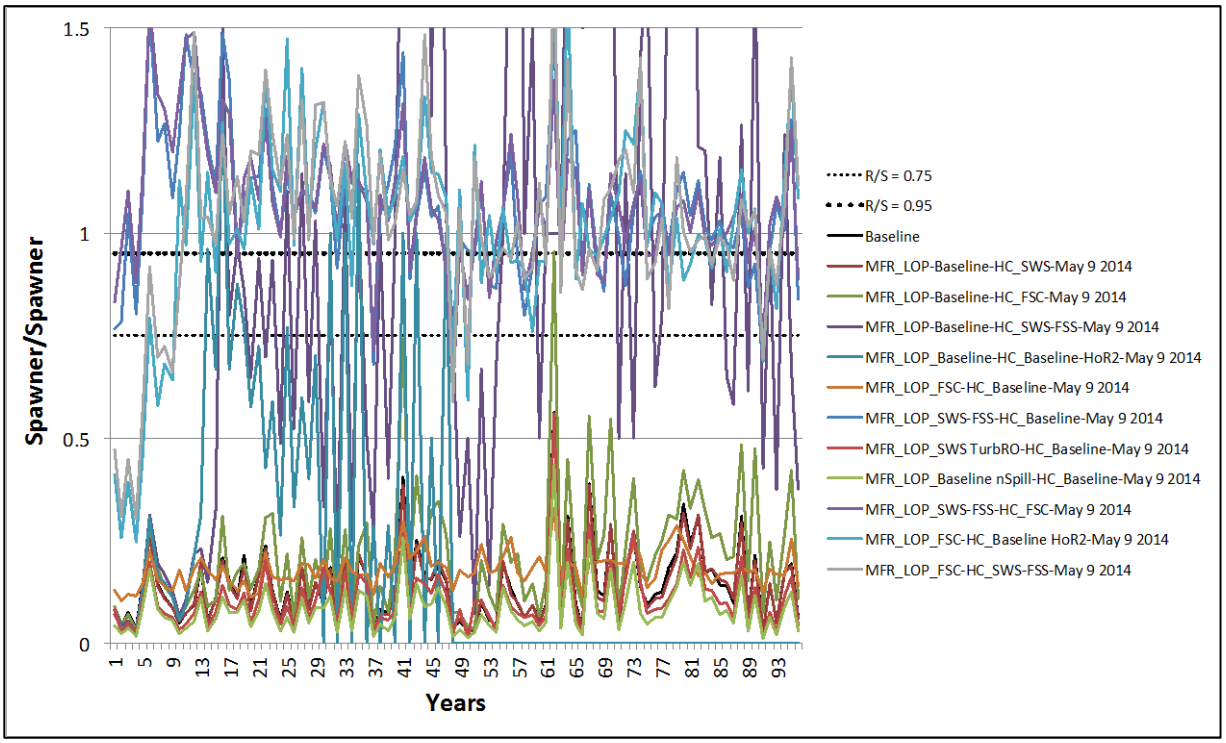


Figure 6.11: Times series of spawner-to-spawner ratio for Reach D (above Dexter/Lookout Point Dam and below Hills Creek Dam) for each Middle Fork Willamette River alternative. See text above for the equation used to calculate spawner-to-spawner ratio.

For each alternative and for each of three Reaches (C, D, & E), we calculated a median spawner-to-spawner ratio over all simulated years. The overall VSP score was determined by a combination of spawner-to-spawner ratios for all Reaches (see Table 6.4 and Chapter 3, Parameterization of VSP Criteria, for more details).

Table 6.4: VSP scores associated with spawner-to-spawner ratios for Reach C, D, and E.

		Reach E (HC)		
		<0.75	0.75<x<0.95	>0.95
	<0.75	0.5	2.00	2.75
Reach D (MF/NF)	0.75<x<0.95	2.0	2.5	3
	>0.95	2.75	3	3.5
Plus				
Middle Fork Willamette (Fall Creek)	+0.0	+0.33	+0.5	

Under Baseline conditions, the median VSP score for Spatial Structure was 0.5, while the alternative that had a Selective Withdrawal Structure and Floating Screen Structure at Lookout Point Dam (SWS-FSS) and Floating Surface Collector (FSC) at Hills Creek Dam (LOP_SWS-FSS-HC_FSC) was estimated as 4.0 (as was LOP_FSC-HC_SWS-FSS) (Figure 6.12).

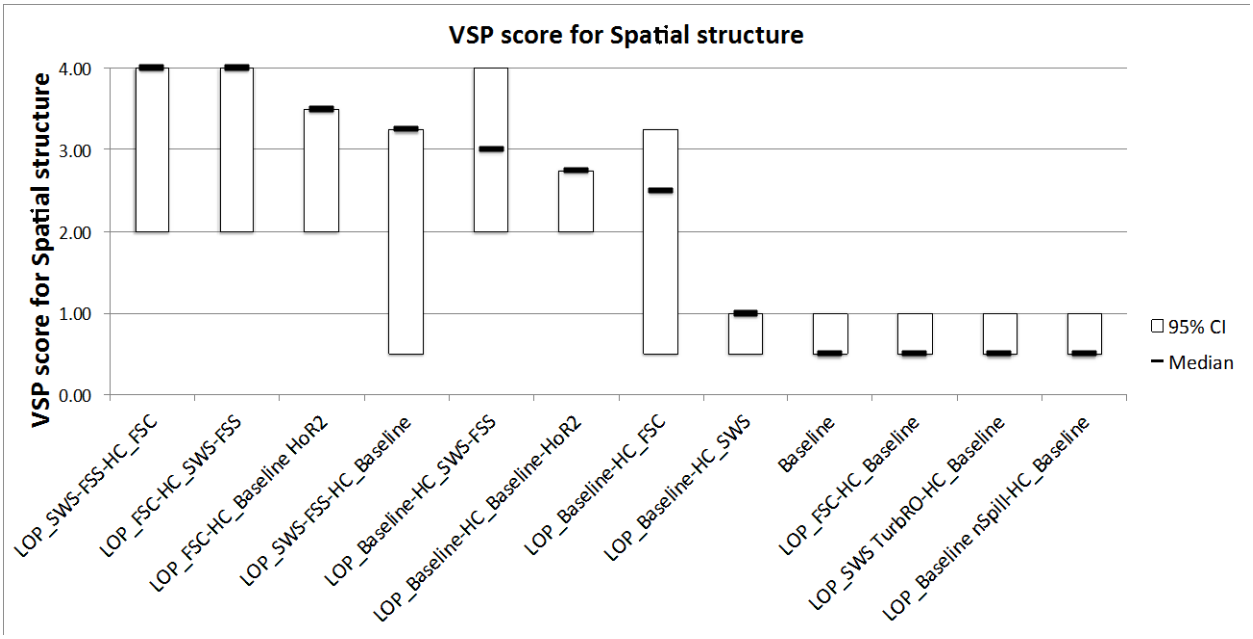


Figure 6.12: Spatial Structure VSP scores among Middle Fork Willamette River alternatives. Median and standard deviation are shown (line and box, respectively), which were calculated using the median and standard deviation of spawner-to-spawner ratio.

Total VSP Score

To estimate the Total VSP score, we combined all the component VSP scores according to the following equation:

$$Total\ VSP\ score = \frac{2(Abundance) + 2(Productivity) + Diversity + Spatial\ Structure}{6}$$

Of the Middle Fork Willamette River alternatives, the greatest Total VSP Score of 3.7 came from the alternative that had a Selective Withdrawal Structure and Floating Screen Structure at Lookout Point Dam (SWS-FSS) and Floating Surface Collector (FSC) at Hills Creek Dam (LOP_SWS-FSS-HC_FSC), followed by 3.6 (LOP_FSC-HC_SWS-FSS), while Baseline conditions yielded a score of 0.3 (Figure 6.13).

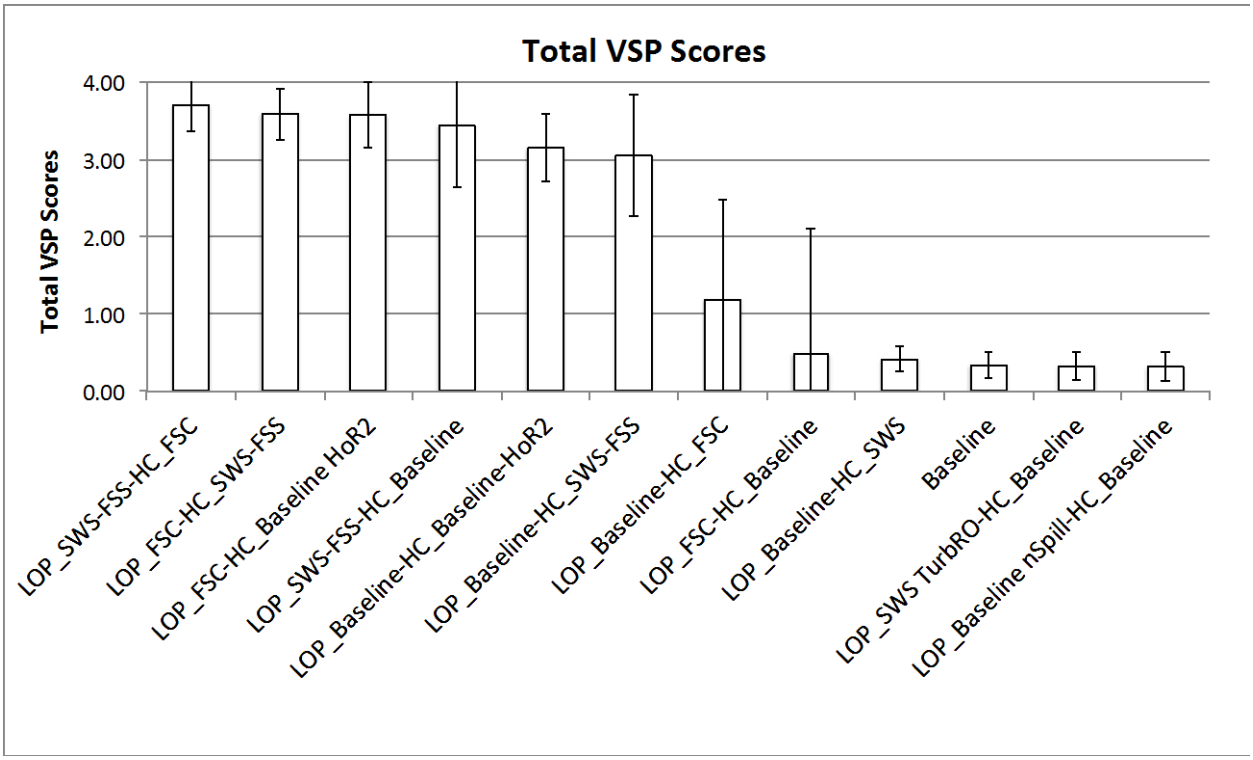


Figure 6.13: Total VSP scores among Middle Fork Willamette alternatives. Whiskers denote +/- one standard deviation.

6.6. References

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CHAPTER 7. SLAM MODEL OF SOUTH SANTIAM RIVER CHINOOK SALMON

This chapter provides a description of the parameter values being considered in the South Santiam River SLAM model. Below, we provide a short description of the model parameters used in each of five categories (1. Productivity, capacity, & survivals, 2. Splits, 3. Datafiles, 4. Dynamic drivers & influencers, and 5. Initialized). For reference purposes, a map of South Santiam River (Figure 7.1) is provided that highlights each reach used in SLAM. Figure 7.2 shows how the life-cycle model is modeled within SLAM. Lastly, Table 7.1 is a list of definitions corresponding to each box within the life-cycle model, while Table 7.2 is a list of abbreviations used throughout this chapter.

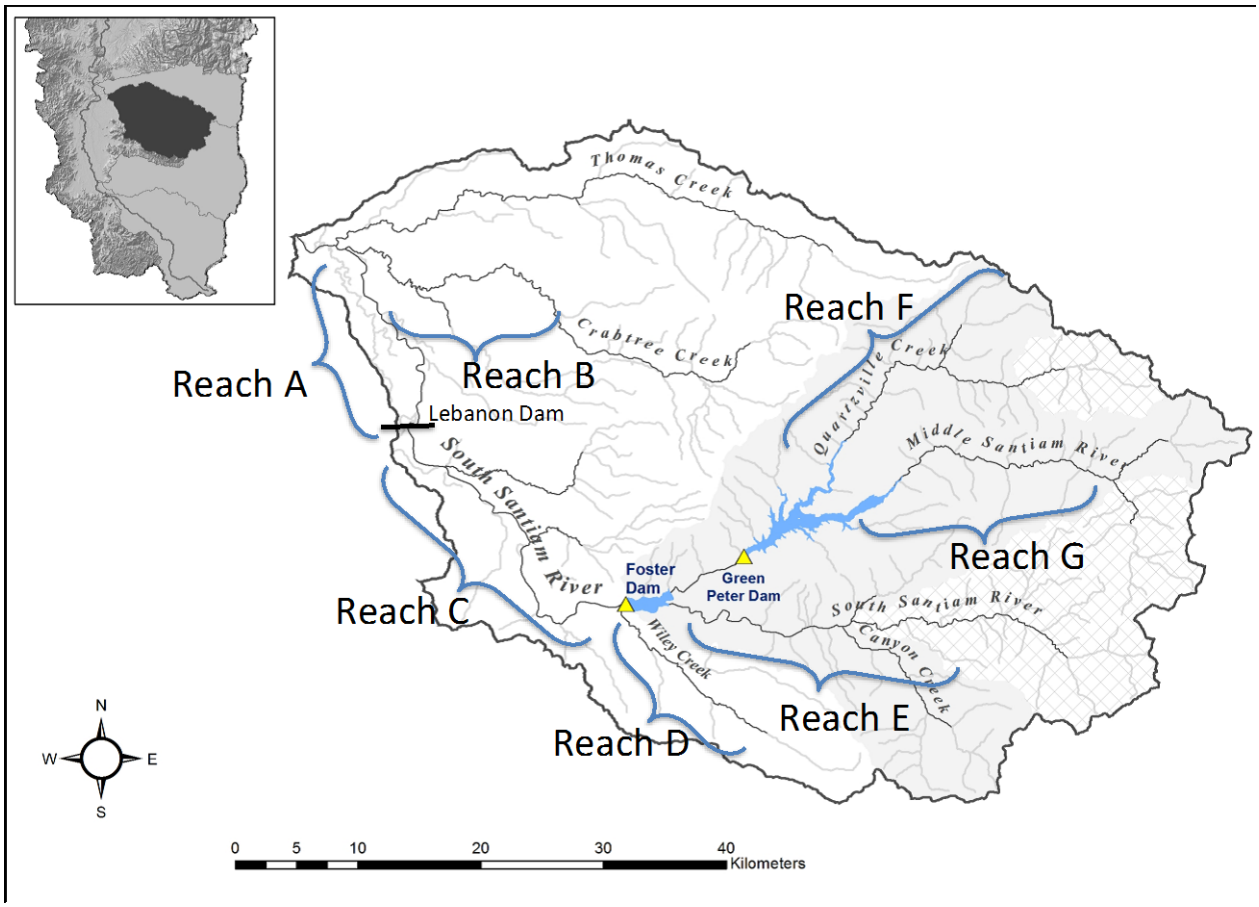


Figure 7.1: Map showing South Santiam River and the seven reaches (A-G) that are modeled in SLAM; Reach A corresponds to mainstem South Santiam River downstream of Lebanon Diversion Dam, Reach B corresponds to tributaries off of the mainstem, including Thomas Creek and Crabtree Creek, Reach C corresponds to mainstem South Santiam River between Lebanon Diversion Dam and Foster Dam, Reach D corresponds to Wiley Creek, Reach E corresponds South Santiam River upstream of Foster Reservoir, and upstream of Green Peter Dam are Reach F and G that correspond to Quartzville Creek and Middle Santiam River, respectively.

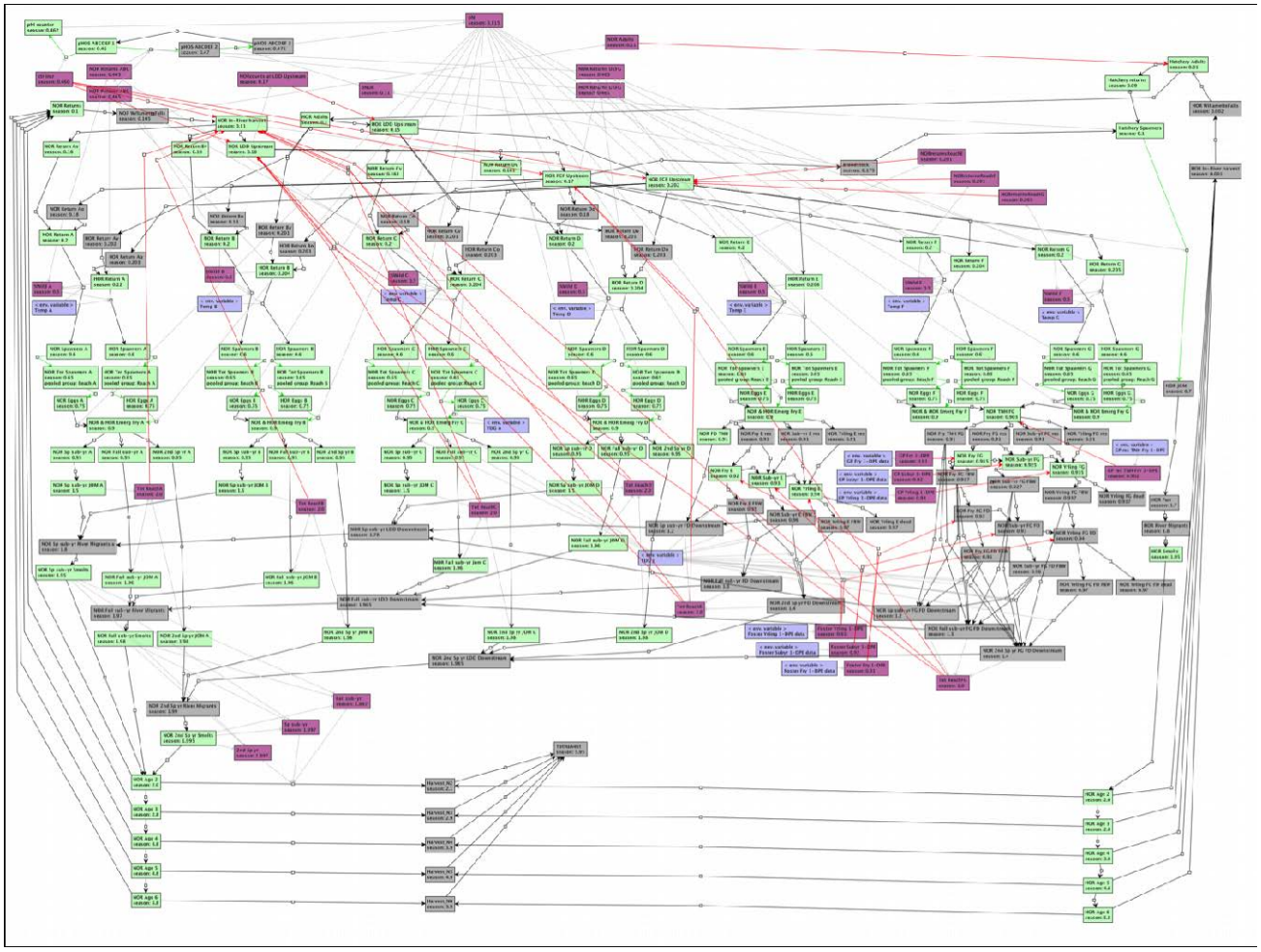


Figure 7.2: Life cycle model (used in SLAM) of spring Chinook salmon from South Santiam River. See Table 7.1 for a description of each box.

Table 7.1: Life history stages and transitions for the South Santiam River Chinook salmon life cycle model (Figure 7.2). Reaches correspond to those in Figure 7.1.

Life Stage	Definition
HOR In-River harvest	Freshwater harvest of hatchery fish
Hatchery Adult	Hatchery origin adults
Hatchery returns	Hatchery fish that return to the hatchery rack
NOR Returns	Returning adults of natural origin
Hatchery Spawners	Adults that spawn in hatchery, including some natural origin adults for brood stock improvement
HOR Adults	Hatchery origin adults that spawn in wild
NOR In-River Harvest	Freshwater harvest of natural origin
HOR LDD Upstream	Hatchery origin adults at Lebanon Diversion Dam
NOR LDD Upstream	Natural origin adults at Lebanon Diversion Dam
NOR Returns Av	Natural origin adults that volitionally return to Reach A
NOR Returns Bv	Natural origin adults that volitionally return to Reach B
NOR Returns Cv	Natural origin adults that volitionally return to Reach C
NOR Returns Dv	Natural origin adults that volitionally return to Reach D
NOR FCF Upstream	Natural origin adults that return to Foster Collection Facility

Broodstock	Natural origin individuals supplied to brood supply at hatchery program
NOR Returns Ao	Natural origin adults outplanted to Reach A
NOR Returns Bo	Natural origin adults outplanted to Reach B
NOR Returns Co	Natural origin adults outplanted to Reach C
NOR Returns Do	Natural origin adults outplanted to Reach D
NOR Returns A	Natural origin adults that return to Reach A
NOR Returns B	Natural origin adults that return to Reach B
NOR Returns C	Natural origin adults that return to Reach C
NOR Returns D	Natural origin adults that return to Reach D
NOR Returns E	Natural origin adults that return to Reach E
NOR Returns F	Natural origin adults that return to Reach F
NOR Returns E	Natural origin adults that return to Reach G
HOR Returns Av	Hatchery origin adults that volitionally return to Reach A
HOR Returns Bv	Hatchery origin adults that volitionally return to Reach B
HOR Returns Cv	Hatchery origin adults that volitionally return to Reach C
HOR Returns Dv	Hatchery origin adults that volitionally return to Reach D
HOR FCF Upstream	Hatchery origin adults that return to Foster Collection Facility
HOR Returns Ao	Hatchery origin adults outplanted to Reach A
HOR Returns Bo	Hatchery origin adults outplanted to Reach B
HOR Returns Co	Hatchery origin adults outplanted to Reach C
HOR Returns Do	Hatchery origin adults outplanted to Reach D
HOR Returns A	Hatchery origin adults that return to Reach A
HOR Returns B	Hatchery origin adults that return to Reach B
HOR Returns C	Hatchery origin adults that return to Reach C
HOR Returns D	Hatchery origin adults that return to Reach D
HOR Returns E	Hatchery origin adults that return to Reach E
HOR Returns F	Hatchery origin adults that return to Reach F
HOR Returns E	Hatchery origin adults that return to Reach G
NOR Spawners A	Natural origin spawners that spawn in Reach A
HOR Spawners A	Hatchery origin spawners that spawn in Reach A
NOR Spawners B	Natural origin spawners that spawn in Reach B
HOR Spawners B	Hatchery origin spawners that spawn in Reach B
NOR Spawners C	Natural origin spawners that spawn in Reach C
HOR Spawners C	Hatchery origin spawners that spawn in Reach C
NOR Spawners D	Natural origin spawners that spawn in Reach D
HOR Spawners D	Hatchery origin spawners that spawn in Reach D
NOR Spawners E	Natural origin spawners that spawn in Reach E
HOR Spawners E	Hatchery origin spawners that spawn in Reach E
NOR Spawners F	Natural origin spawners that spawn in Reach F
HOR Spawners F	Hatchery origin spawners that spawn in Reach F
NOR Spawners G	Natural origin spawners that spawn in Reach G
HOR Spawners G	Hatchery origin spawners that spawn in Reach G
NOR Tot Spawners A	Natural origin and hatchery origin spawners that spawn in Reach A
HOR Tot Spawners A	Natural origin and hatchery origin spawners that spawn in Reach A
NOR Tot Spawners B	Natural origin and hatchery origin spawners that spawn in Reach B
HOR Tot Spawners B	Natural origin and hatchery origin spawners that spawn in Reach B
NOR Tot Spawners C	Natural origin and hatchery origin spawners that spawn in Reach C
HOR Tot Spawners C	Natural origin and hatchery origin spawners that spawn in Reach C
NOR Tot Spawners D	Natural origin and hatchery origin spawners that spawn in Reach D
HOR Tot Spawners D	Natural origin and hatchery origin spawners that spawn in Reach D
NOR Tot Spawners E	Natural origin and hatchery origin spawners that spawn in Reach E
HOR Tot Spawners E	Natural origin and hatchery origin spawners that spawn in Reach E
NOR Tot Spawners F	Natural origin and hatchery origin spawners that spawn in Reach F

HOR Tot Spawners F	Natural origin and hatchery origin spawners that spawn in Reach F
NOR Tot Spawners G	Natural origin and hatchery origin spawners that spawn in Reach G
HOR Tot Spawners G	Natural origin and hatchery origin spawners that spawn in Reach G
NOR Egg A	Eggs in Reach A produced by natural origin spawners in Reach A
HOR Egg A	Eggs in Reach A produced by hatchery origin spawners in Reach A
NOR Egg B	Eggs in Reach B produced by natural origin spawners in Reach B
HOR Egg B	Eggs in Reach B produced by hatchery origin spawners in Reach B
NOR Egg C	Eggs in Reach C produced by natural origin spawners in Reach C
HOR Egg C	Eggs in Reach C produced by hatchery origin spawners in Reach C
NOR Egg D	Eggs in Reach D produced by natural origin spawners in Reach D
HOR Egg D	Eggs in Reach D produced by hatchery origin spawners in Reach D
NOR Egg E	Eggs in Reach E produced by natural origin spawners in Reach E
HOR Egg E	Eggs in Reach E produced by hatchery origin spawners in Reach E
NOR Egg F	Eggs in Reach E produced by natural origin spawners in Reach F
HOR Egg F	Eggs in Reach E produced by hatchery origin spawners in Reach F
NOR Egg G	Eggs in Reach E produced by natural origin spawners in Reach G
HOR Egg G	Eggs in Reach E produced by hatchery origin spawners in Reach G
NOR & HOR Emerg Fry A	Natural and hatchery produced emergent fry in Reach A
NOR & HOR Emerg Fry B	Natural and hatchery produced emergent fry in Reach B
NOR & HOR Emerg Fry C	Natural and hatchery produced emergent fry in Reach C
NOR & HOR Emerg Fry D	Natural and hatchery produced emergent fry in Reach D
NOR & HOR Emerg Fry E	Natural and hatchery produced emergent fry in Reach E
NOR & HOR Emerg Fry F	Natural and hatchery produced emergent fry in Reach F
NOR & HOR Emerg Fry G	Natural and hatchery produced emergent fry in Reach G
NOR TNH FG	Downstream movement of Natural origin Fry towards Green Peter reservoir, from Reaches F & G
NOR FD TNH	Downstream movement of Natural origin juveniles above Foster Dam (Reach E) via trap and haul program
NOR Fry E res	Natural origin Fry from Reach E in Foster reservoir.
NOR Sub-yr E res	Natural origin Sub-yearlings from Reach E in Foster reservoir.
NOR Yrling E res	Natural origin Yearlings from Reach E in Foster reservoir.
NOR Fry FG res	Natural origin Fry from Reaches F & G in Green Peter reservoir.
NOR Sub-yr FG res	Natural origin Sub-yearlings from Reaches F & G in Green Peter reservoir.
NOR Yrling FG res	Natural origin Yearlings from Reaches F & G in Green Peter reservoir.
NOR Fry TNH FG	Downstream movement of Natural origin Fry above Green Peter Dam (Reaches F & G) via trap and haul program
NOR Fry FG	Natural origin Fry from Reach FG available to pass Green Peter Dam as Fry or become Sub-yearlings in Green Peter reservoir
NOR Fry FG FBW	Natural origin Fry from Reach FG that pass Green Peter Dam as Fry
NOR Fry E	Natural origin Fry from Reach E available to pass Foster Dam as Fry or become Sub-yearlings in Foster reservoir
NOR Fry FG FD	Natural origin Fry from Reach FG available to pass Foster Dam as Fry or become Sub-yearlings in Foster reservoir
NOR Sub-yr FG	Natural origin Sub-yearlings from Reach FG available to pass Green Peter Dam as Sub-yearlings or become Yearlings in Green Peter reservoir
NOR Sub-yr FG FBW	Natural origin Sub-yearlings from Reach FG that pass Green Peter Dam as Sub-yearlings
NOR Sub-yr E	Natural origin Sub-yearlings from Reach E available to pass Foster Dam as Sub-yearlings or become Yearlings in Foster reservoir
NOR Sub-yr FG FD	Natural origin Sub-yearlings from Reach FG available to pass Foster Dam as Sub-yearlings or become Yearlings in Foster reservoir
NOR Yrling FG	Natural origin Yearlings from Reach FG available to pass Green Peter Dam as Yearlings or die in Green Peter reservoir
NOR Yrling FG FBW	Natural origin Yearlings from Reach FG that pass Green Peter Dam as Yearlings
NOR Yrling E	Natural origin Yearlings from Reach E available to pass Foster Dam as Yearlings or die in Foster reservoir

NOR Yrling FG FD	Natural origin Yearlings from Reach FG available to pass Foster Dam as Yearlings or die in Foster reservoir
NOR Sp sub-yr A	Natural origin fry in Reach A that express a Spring sub-yearling life history strategy
NOR Fall sub-yr A	Natural origin fry in Reach A that express a Fall sub-yearling life history strategy
NOR 2nd Sp yr A	Natural origin fry in Reach A that express a 2nd Spring yearling life history strategy
NOR Sp sub-yr B	Natural origin fry in Reach B that express a spring sub-yearling life history strategy
NOR Fall sub-yr B	Natural origin fry in Reach B that express a fall sub-yearling life history strategy
NOR 2nd Sp yr B	Natural origin fry in Reach B that express a 2nd spring yearling life history strategy
NOR Sp sub-yr C	Natural origin fry in Reach C that express a spring sub-yearling life history strategy
NOR Fall sub-yr C	Natural origin fry in Reach C that express a fall sub-yearling life history strategy
NOR 2nd Sp yr C	Natural origin fry in Reach C that express a 2nd spring yearling life history strategy
NOR Sp sub-yr D	Natural origin fry in Reach D that express a spring sub-yearling life history strategy
NOR Fall sub-yr D	Natural origin fry in Reach D that express a fall sub-yearling life history strategy
NOR 2nd Sp yr D	Natural origin fry in Reach D that express a 2nd spring yearling life history strategy
NOR Fry E FBW	Natural origin Fry from Reach E that pass Foster Dam to become Spring Sub-yearlings, Fall Sub-yearlings, or 2nd Spring yearlings
NOR Fry FG FD FBW	Natural origin Fry from Reach FG that pass Foster Dam to become Spring Sub-yearlings, Fall Sub-yearlings, or 2nd Spring yearlings
NOR Sub-yr E FBW	Natural origin Sub-yearlings from Reach E that pass Foster Dam to become Spring Sub-yearlings, Fall Sub-yearlings, or 2nd Spring yearlings
NOR Sub-yr FG FD FBW	Natural origin Sub-yearlings from Reach FG that pass Foster Dam to become Spring Sub-yearlings, Fall Sub-yearlings, or 2nd Spring yearlings
NOR Yrling E FBW	Natural origin Yearlings from Reach E that pass Foster Dam to become 2nd Spring yearlings
NOR Yrling FG FD FBW	Natural origin Yearlings from Reach FG that pass Foster Dam to become 2nd Spring yearlings
NOR Sp sub-yr FD Downstream	Natural origin Spring Sub-yearlings from Reach E that are downstream of Foster Dam
NOR Sp sub-yr FG FD Downstream	Natural origin Spring Sub-yearlings from Reach FG that are downstream of Foster Dam
NOR Fall sub-yr FD Downstream	Natural origin Fall Sub-yearlings from Reach E that are downstream of Foster Dam
NOR Fall sub-yr FG FD Downstream	Natural origin Fall Sub-yearlings from Reach FG that are downstream of Foster Dam
NOR 2nd Sp yr FD Downstream	Natural origin 2nd Spring yearlings from Reach E that are downstream of Foster Dam
NOR 2nd Sp yr FG FD Downstream	Natural origin 2nd Spring yearlings from Reach FG that are downstream of Foster Dam
NOR Sp sub-yr JOM C	Natural origin Spring Sub-yearlings in Reach C that are juvenile out migrants
NOR Sp sub-yr JOM B	Natural origin Spring Sub-yearlings in Reach B that are juvenile out migrants
NOR Sp sub-yr JOM A	Natural origin Spring Sub-yearlings in Reach A that are juvenile out migrants
NOR Sp sub-yr JOM D	Natural origin Spring Sub-yearlings in Reach D that are juvenile out migrants
HOR Parr	Hatchery origin parr downstream of Foster Dam
NOR Sp sub-yr LDD Downstream	Natural origin Spring Sub-yearlings downstream of Lebanon Dam
NOR Sp sub-yr River Migrants a	Natural origin spring sub-yearlings leaving South Santiam River
HOR River Migrants	Hatchery origin juvenile out-migrants leaving South Santiam River
NOR Sp sub-yr Smolts	Natural origin smolts that are spring sub-yearlings
HOR Smolt	Hatchery origin smolts
NOR Fall sub-yr JOM C	Natural origin Fall Sub-yearlings in Reach C that are juvenile out migrants
NOR Fall sub-yr JOM B	Natural origin Fall Sub-yearlings in Reach B that are juvenile out migrants
NOR Fall sub-yr JOM A	Natural origin Fall Sub-yearlings in Reach A that are juvenile out migrants
NOR Fall sub-yr JOM D	Natural origin Fall Sub-yearlings in Reach D that are juvenile out migrants
NOR Fall sub-yr LDD Downstream	Natural origin Fall Sub-yearlings downstream of Lebanon Dam
NOR Fall sub-yr River Migrants	Natural origin Fall sub-yearlings leaving South Santiam River
NOR 2nd Sp yr JOM C	Natural origin 2nd Spring Yearlings in Reach C that are juvenile out migrants
NOR 2nd Sp yr JOM B	Natural origin 2nd Spring Yearlings in Reach B that are juvenile out migrants
NOR 2nd Sp yr JOM A	Natural origin 2nd Spring Yearlings in Reach A that are juvenile out migrants

NOR 2nd Sp yr JOM D	Natural origin 2nd Spring Yearlings in Reach D that are juvenile out migrants
NOR Fall sub-yr Smolts	Natural origin smolts that are Fall Sub-yearlings
NOR 2nd Sp yr LDD Downstream	Natural origin 2nd Spring Yearlings downstream of Lebanon Dam
NOR 2nd Sp yr River Migrants	Natural origin 2nd Spring Yearlings leaving South Santiam River
NOR 2nd Sp yr Smolts	Natural origin smolts that are 2nd Spring Yearlings
NOR Age 2	Age 2 natural origin adults
HOR Age 2	Second generation age 2 hatchery origin adults, indistinguishable from natural origin age 2 adults
NOR Age 3	Age 3 natural origin adults
HOR Age 3	Second generation age 3 hatchery origin adults, indistinguishable from natural origin age 3 adults
NOR Age 4	Age 4 natural origin adults
HOR Age 4	Second generation age 4 hatchery origin adults, indistinguishable from natural origin age 4 adults
NOR Age 5	Age 5 natural origin adults
HOR Age 5	Second generation hatchery origin age 5 adults, indistinguishable from natural origin age 5 adults
NOR Age 6	Age 6 natural origin adults
HOR Age 6	Second generation hatchery origin age 6 adults, indistinguishable from natural origin age 6 adults
Harvest_N2	Adults (both natural and hatchery origin) harvested at age 2
Harvest_N3	Adults (both natural and hatchery origin) harvested at age 3
Harvest_N4	Adults (both natural and hatchery origin) harvested at age 4
Harvest_N5	Adults (both natural and hatchery origin) harvested at age 5
Harvest_N6	Adults (both natural and hatchery origin) harvested at age 6

Table 7.2: List of Acronyms and Abbreviations.

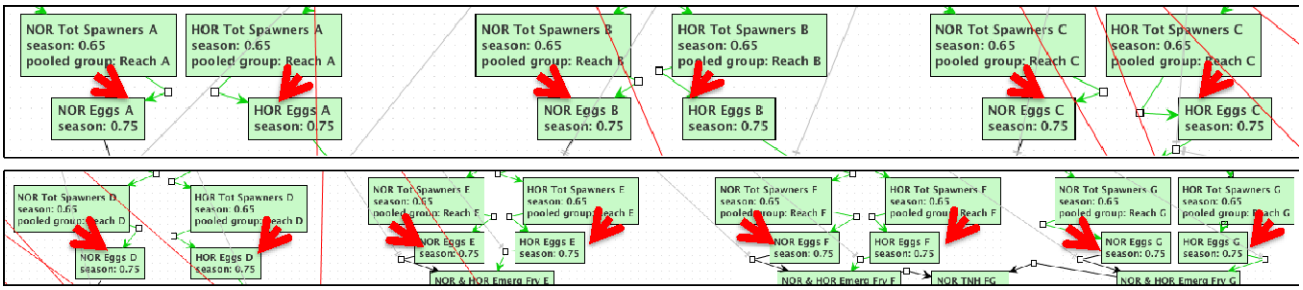
Abbreviation	**Definition**
0+	Juveniles less than one year old
1+	Juveniles older than one year but less than two years old
Beverton-Holt	Beverton-Holt spawner-recruit relationship
LDD	Lebanon Diversion Dam
FD	Foster Dam
GPD	Green Peter Dam
d/s	Downstream
Harvest_N#	Fishery harvest of age N# fish (# = 2, 3, 4, 5, & 6 for spring Chinook)
FBW	Fish Benefit Workbook
Hockey-Stick	Spawner-recruit relationship in the Hockey-stick shape
HOR	Hatchery origin
HoR	Head of reservoir
JOM	Juvenile out-migrant
NOR	Natural origin
ODFW	Oregon Department of Fish and Wildlife
SE	Standard Error
PSS, PSM	Prespawning survival, prespawning mortality
SLAM	Species Life-Cycle Analysis Modules
u/s	Upstream
TDG	Total Dissolved Gas
DPE	Dam Passage Efficiency
TNH	Trap and Haul

7.1. Productivity, Capacity, & Survivals

This section describes the reproductive capability of spawners within each reach and hatchery, reach-specific capacity, and the proportion of individuals that survive as they move among stages in the life-cycle model.

Productivity and capacity parameter values of wild spawning natural and hatchery origin individuals. Within each reach natural and hatchery origin spawners are pooled by reach, and a reach-specific Beverton-Holt capacity function is applied to determine the number of eggs. The Beverton-Holt productivity term is fixed at 0.5 times fecundity, with the assumption that the sex ratio of spawning fish is 50:50. The productivity to 2,250 eggs/individual is a slightly more conservative estimate than the 5000 eggs per female noted by Willis et al. (1995) (see Chapter 3, Fecundity). Egg capacity is stochastic, and each year reach-specific egg capacity is drawn from a normal distribution according to the following parameters.

Reach	From	To	Curve type	Capacity & Productivity	Mean	SD	Min	Max
A	NOR Tot Spawners	Eggs	Beverton-Holt	Capacity	150,000	33,000	75,000	200,000
				Productivity				2,250
B	NOR Tot Spawners	Eggs	Beverton-Holt	Capacity	1,000,000	200,000	500,000	2,500,000
				Productivity				2,250
C	NOR Tot Spawners	Eggs	Beverton-Holt	Capacity	3,000,000	250,000	1,000,000	5,500,000
				Productivity				2,250
D	NOR Tot Spawners	Eggs	Beverton-Holt	Capacity	500,000	33,000	250,000	700,000
				Productivity				2,250
E	NOR Tot Spawners	Eggs	Beverton-Holt	Capacity	7,000,000	250,000	4,000,000	9,000,000
				Productivity				2,250
F	NOR Tot Spawners	Eggs	Beverton-Holt	Capacity	2,000,000	250,000	1,000,000	12,000,000
				Productivity				2,250
G	NOR Tot Spawners	Eggs	Beverton-Holt	Capacity	4,500,000	250,000	4,000,000	12,000,000
				Productivity				2,250
A	HOR Tot Spawners	Eggs	Beverton-Holt	Capacity	150,000	33,000	75,000	200,000
				Productivity				2,000
B	HOR Tot Spawners	Eggs	Beverton-Holt	Capacity	1,000,000	200,000	500,000	2,500,000
				Productivity				2,000
C	HOR Tot Spawners	Eggs	Beverton-Holt	Capacity	3,000,000	250,000	1,000,000	5,500,000
				Productivity				2,000
D	HOR Tot Spawners	Eggs	Beverton-Holt	Capacity	500,000	33,000	250,000	700,000
				Productivity				2,000
E	HOR Tot Spawners	Eggs	Beverton-Holt	Capacity	7,000,000	250,000	4,000,000	9,000,000
				Productivity				2,000
F	HOR Tot Spawners	Eggs	Beverton-Holt	Capacity	2,000,000	250,000	1,000,000	12,000,000
				Productivity				2,000
G	HOR Tot Spawners	Eggs	Beverton-Holt	Capacity	4,500,000	250,000	4,000,000	12,000,000
				Productivity				2,000

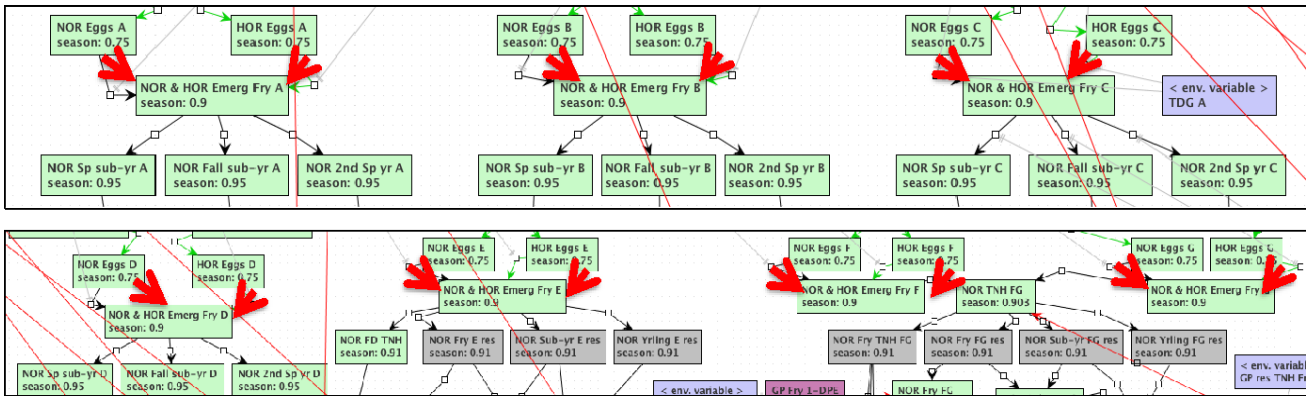


Productivity and capacity parameter values of hatchery spawners. Hatchery origin fish (up to 700-1,000 individuals; see Splits section below) are spawned in the hatchery, based on productivity of 2,000 eggs/individual (Willis et al. 1995), using a Hockey-Stick capacity function to determine the number of hatchery origin juveniles released in the South Santiam River (HOR JOM).

Reach	From	To	Curve type	Capacity & Productivity	Mean	SD	Min	Max
Hatchery	Hatchery returns	Hatchery Spawners	Hockey-Stick	Capacity	1,000	100	700	1,000
				Productivity				1
Hatchery	Hatchery Spawners	HOR JOM	Hockey-Stick	Capacity	1,021,000	25,000	950,000	1,100,000
				Productivity				2,000

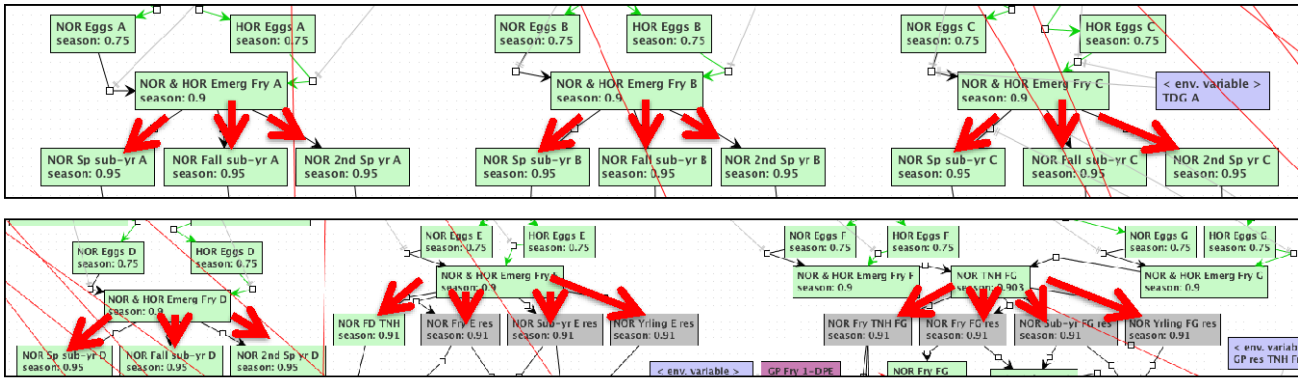
Survival parameter values from Egg to Emergent Fry stage. The below values correspond to the reach-specific proportion of eggs that survive to become emergent fry (see Chapter 3, Survival).

Reach	From	To	Curve type	Capacity & Productivity	Distribution type	Proportion of fish that survive
A	NOR/HOR Eggs	NOR & HOR Emerg Fry	Linear	Productivity	Constant	0.25
B	NOR/HOR Eggs	NOR & HOR Emerg Fry	Linear	Productivity	Constant	0.35
C	NOR/HOR Eggs	NOR & HOR Emerg Fry	Linear	Productivity	Constant	0.35
D	NOR/HOR Eggs	NOR & HOR Emerg Fry	Linear	Productivity	Constant	0.25
E	NOR/HOR Eggs	NOR & HOR Emerg Fry	Linear	Productivity	Constant	0.425
F	NOR/HOR Eggs	NOR & HOR Emerg Fry	Linear	Productivity	Constant	0.525
G	NOR/HOR Eggs	NOR & HOR Emerg Fry	Linear	Productivity	Constant	0.525



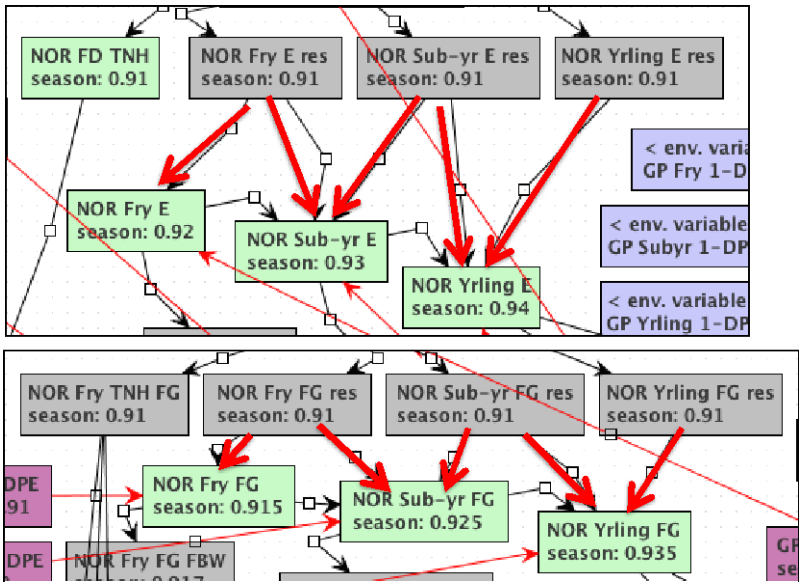
Survival parameter values from Emergent Fry stage to each juvenile life history strategy. The below values correspond to the reach-specific proportion of emergent fry that survive to become spring sub-yearlings, fall sub-yearlings, and 2nd spring yearlings. Survival parameter value associated with head of reservoir (HoR) passage is provided by USACE (Fish Benefit Workbook).

Reach	From	To	Curve type	Capacity & Productivity	Dist. type	Proportion of fish that survive
A	NOR & HOR Emerg Fry	NOR Sp sub-yr A	Linear	Productivity	Constant	0.15
		NOR Fall sub-yr A	Linear	Productivity	Constant	0.13
		NOR 2nd Sp yr A	Linear	Productivity	Constant	0.09
B	NOR & HOR Emerg Fry	NOR Sp sub-yr B	Linear	Productivity	Constant	0.225
		NOR Fall sub-yr B	Linear	Productivity	Constant	0.16
		NOR 2nd Sp yr B	Linear	Productivity	Constant	0.125
C	NOR & HOR Emerg Fry	NOR Sp sub-yr C	Linear	Productivity	Constant	0.21
		NOR Fall sub-yr C	Linear	Productivity	Constant	0.15
		NOR 2nd Sp yr C	Linear	Productivity	Constant	0.125
D	NOR & HOR Emerg Fry	NOR Sp sub-yr D	Linear	Productivity	Constant	0.19
		NOR Fall sub-yr D	Linear	Productivity	Constant	0.15
		NOR 2nd Sp yr D	Linear	Productivity	Constant	0.125
E	NOR & HOR Emerg Fry	NOR FD TNH	Linear	Productivity	Constant	0.8
		NOR Fry E res	Linear	Productivity	Constant	0.6
		NOR Sub-yr E res	Linear	Productivity	Constant	0.3
		NOR Yrling E res	Linear	Productivity	Constant	0.25
FG	NOR TNH FG	NOR Fry FG res	Linear	Productivity	Constant	0.75
		NOR Sub-yr FG res	Linear	Productivity	Constant	0.4
		NOR Yrling FG res	Linear	Productivity	Constant	0.3
		NOR Fry TNH FG	Linear	Productivity	Constant	HoR passage survival



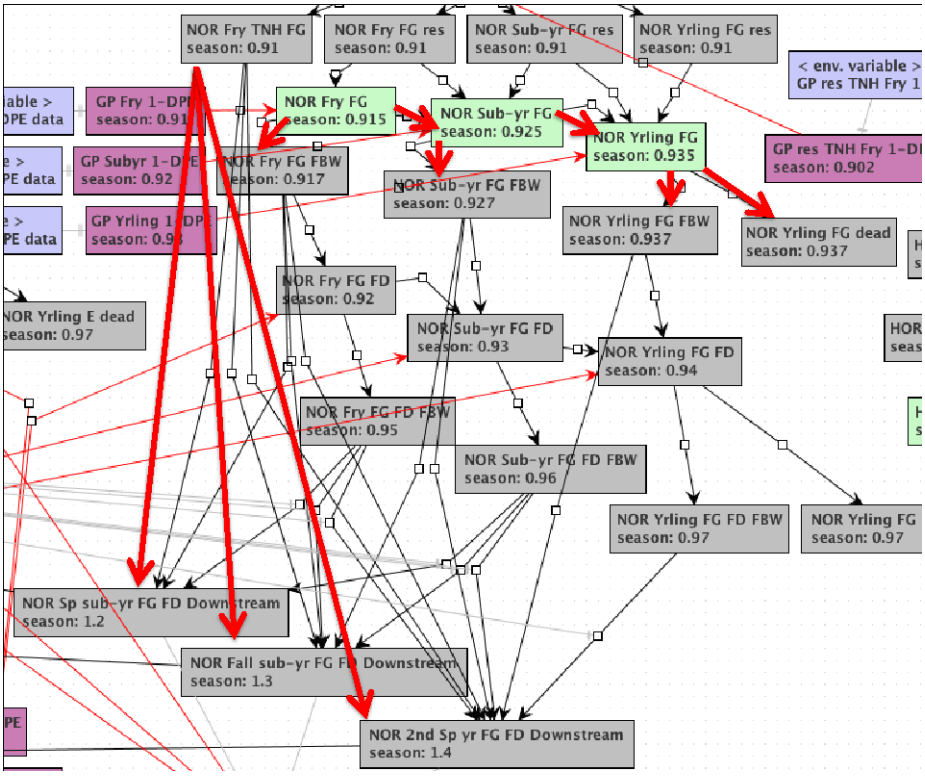
Survival parameter values for each of three life history strategy that rear in Foster reservoir (Reach E) and Green Peter reservoir (Reach FG) to the next life history strategy. These values are from parameter workshops (see Chapter 3, appendix 3.6).

Reach	From	To	Curve type	Capacity & Productivity	Distr. type	Proportion of fish that survive
E	NOR Fry E res	NOR Fry E	Linear	Productivity	Constant	1
		NOR Sub-yr E	Linear	Productivity	Triangular	0.2 (mean), 0.15 & 0.35 (min & max)
	NOR Sub-yr E res	NOR Sub-yr E	Linear	Productivity	Constant	1
		NOR Yrling E	Linear	Productivity	Uniform	0.4-0.9 (min & max)
	NOR Yrling E res	NOR Yrling E	Linear	Productivity	Constant	1
FG	NOR Fry FG res	NOR Fry FG	Linear	Productivity	Constant	1
		NOR Sub-yr FG	Linear	Productivity	Triangular	0.2 (mean), 0.15 & 0.35 (min & max)
	NOR Sub-yr FG res	NOR Sub-yr FG	Linear	Productivity	Constant	1
		NOR Yrling FG	Linear	Productivity	Triangular	0.75 (mean), 0.6 & 0.9 (min & max)
	NOR Yrling FG res	NOR Yrling FG	Linear	Productivity	Constant	1



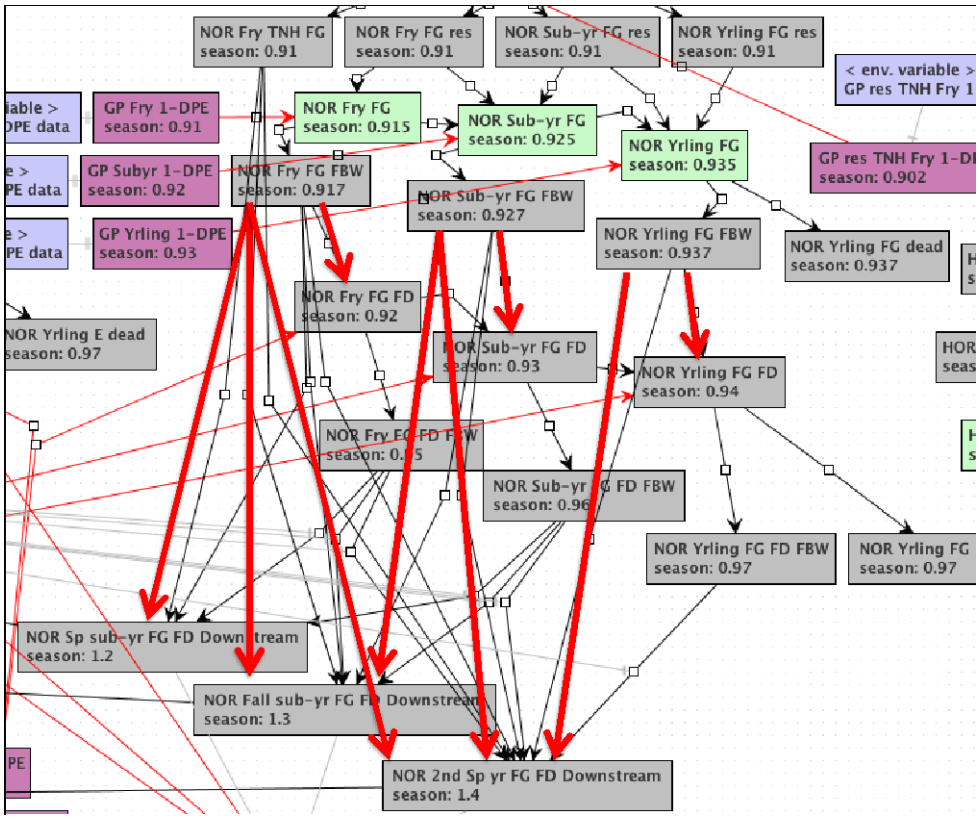
Survival parameter values for Fry in Reach FG (above Green Peter Dam) moving downstream of Foster Dam via a head of reservoir (HoR) trap and haul and becoming any of three life history strategies. Survival parameter values for Fry in Reach FG (above Green Peter Dam) passing Green Peter Dam and those Fry becoming Sub-yearlings above Green Peter Dam. Survival parameter values for Sub-yearlings in Reach FG (above Green Peter Dam) passing Green Peter Dam and those Sub-yearlings becoming Yearlings above Green Peter Dam. Survival parameter values for Yearlings in Reach FG (above Green Peter Dam) passing Green Peter Dam and those Yearlings remaining above Green Peter Dam. These values are from parameter workshops (see Chapter 3, appendix 3.6). Dam passage survival ('Passage survival' in the below table) is one of two datafiles from the Fish Benefits Workbook, the other being dam passage efficiency (DPE)(Fish Benefits Workbooks User Guide 2014), both of which are provided by USACE. Dam passage efficiency is the fraction of fish available to pass a dam that actually pass, those that do not pass remain in the reservoir.

Reach	From	To	Curve type	Capacity & Productivity	Distr. type	Proportion of fish that survive
FG	NOR Fry TNH FG	NOR Sp sub-yr FG FD Downstream	Linear	Productivity	Constant	0.06
		NOR Fall sub-yr FG FD Downstream	Linear	Productivity	Constant	0.0925
		NOR 2nd Sp yr FG FD Downstream	Linear	Productivity	Constant	0.115
	NOR Fry FG	NOR Sub-yr FG	Linear	Productivity	Triangular	0.2 (mean), 0.15 & 0.35 (min & max)
		NOR Fry FG FBW	Linear	Productivity	Datafile	Passage survival
	NOR Sub-yr FG	NOR Yrling FG	Linear	Productivity	Triangular	0.75 (mean), 0.6 & 0.9 (min & max)
		NOR Sub-yr FG FBW	Linear	Productivity	Datafile	Passage survival
	NOR Yrling FG	NOR Yrling FG dead	Linear	Productivity	Constant	0
		NOR Yrling FG FBW	Linear	Productivity	Datafile	Passage survival



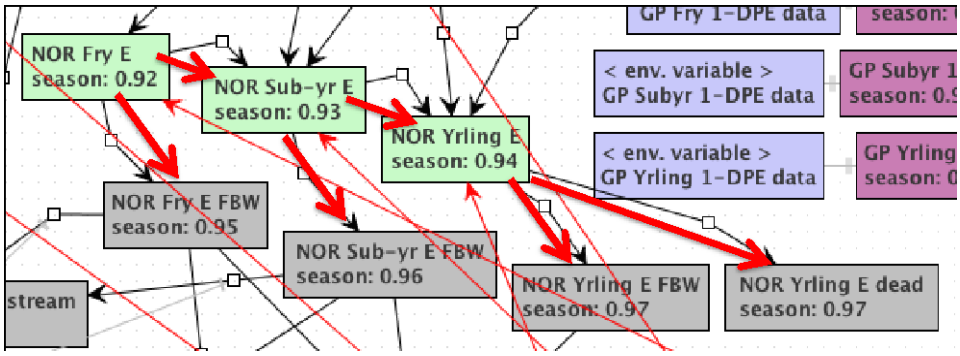
Survival parameter values for Fry in Reach FG (above Green Peter Dam) moved downstream of Foster Dam and becoming one of three life history strategies.

Reach	From	To	Curve type	Capacity & Productivity	Distr. type	Proportion of fish that survive
FG	NOR Fry FG FBW	NOR Fry FG FD	Linear	Productivity	Constant	1
		NOR Sp sub-yr FG FD Downstream	Linear	Productivity	Constant	0.135
		NOR Fall sub-yr FG FD Downstream	Linear	Productivity	Constant	0.325
		NOR 2nd Sp yr FG FD Downstream	Linear	Productivity	Constant	0.425
	NOR Sub-yr FG FBW	NOR Sub-yr FG FD	Linear	Productivity	Constant	1
		NOR Fall sub-yr FG FD Downstream	Linear	Productivity	Constant	0.375
		NOR 2nd Sp yr FG FD Downstream	Linear	Productivity	Constant	0.45
	NOR Yrling FG FBW	NOR Yrling FG FD	Linear	Productivity	Constant	1
		NOR 2nd Sp yr FG FD Downstream	Linear	Productivity	Constant	0.5



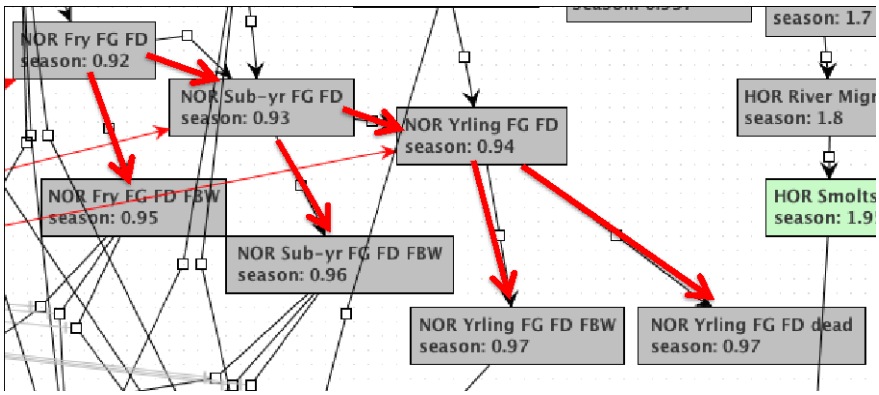
Survival parameter values for Fry in Reach E (above Foster Dam) passing Foster Dam and those Fry becoming Sub-yearlings above Foster Dam. Survival parameter values for Sub-yearlings in Reach E (above Foster Dam) passing Foster Dam and those Sub-yearlings becoming Yearlings above Foster Dam. Survival parameter values of Yearlings in Reach E that pass Foster Dam and that remain in the reservoir and die. These values are from parameter workshops (see Chapter 3, appendix 3.6). Dam passage survival ('Passage survival' in the below table) is one of two datafiles from the Fish Benefits Workbook, the other being dam passage efficiency (DPE)(Fish Benefits Workbooks User Guide 2014), both of which are provided by USACE.

Reach	From	To	Curve type	Capacity & Productivity	Distr. type	Proportion of fish that survive
E	NOR Fry E	NOR Sub-yr E	Linear	Productivity	Triangular	0.2 (mean), 0.15 & 0.35 (min & max)
		NOR Fry E FBW	Linear	Productivity	Datafile	Passage survival
	NOR Sub-yr E	NOR Yrling E	Linear	Productivity	Uniform	0.4-0.9
		NOR Sub-yr E FBW	Linear	Productivity	Datafile	Passage survival
	NOR Yrling E	NOR Yrling E FBW	Linear	Productivity	Datafile	Passage survival
		NOR Yrling E dead	Linear	Productivity	Constant	0



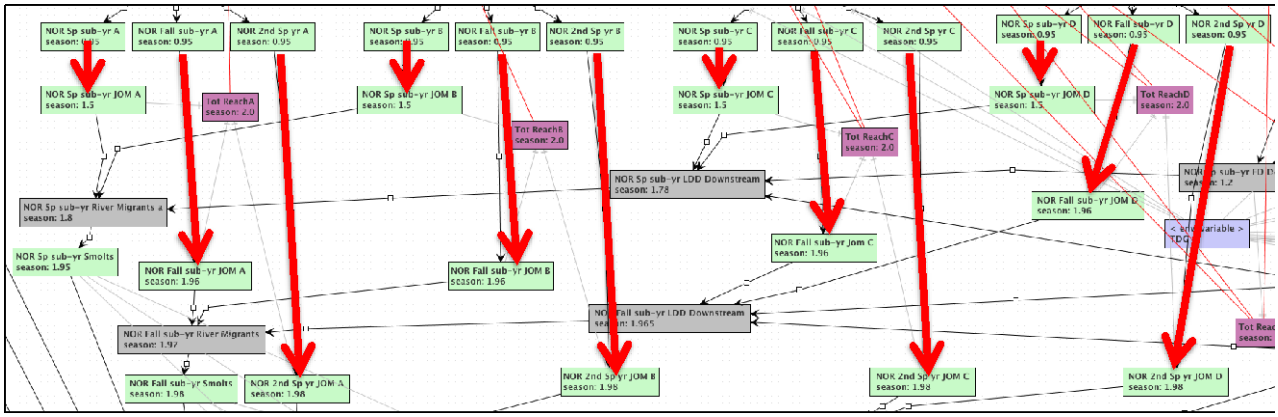
Survival parameter values for Fry from Reach FG (above Green Peter Dam) passing Foster Dam and those Fry becoming Sub-yearlings above Foster Dam. Survival parameter values for Sub-yearlings from Reach FG (above Green Peter Dam) passing Foster Dam and those Sub-yearlings becoming Yearlings above Foster Dam. Survival parameter values of Yearlings from Reach FG (above Green Peter) that pass Foster Dam and those that remain in the reservoir. These values are from parameter workshops (see Chapter 3, appendix 3.6). Dam passage survival ('Passage survival' in the below table) is one of two datafiles from the Fish Benefits Workbook, the other being dam passage efficiency (DPE)(Fish Benefits Workbooks User Guide 2014), both of which are provided by USACE.

Reach	From	To	Curve type	Capacity & Productivity	Distr. type	Proportion of fish that survive
FG	NOR Fry FG FD	NOR Sub-yr FG FD	Linear	Productivity	Triangular	0.2 (mean), 0.15 & 0.35 (min & max)
		NOR Fry FG FD FBW	Linear	Productivity	Datafile	Passage survival
	NOR Sub-yr FG FD	NOR Yrling FG FD	Linear	Productivity	Uniform	0.4-0.9
		NOR Sub-yr FG FD FBW	Linear	Productivity	Datafile	Passage survival
	NOR Yrling FG FD	NOR Yrling FG FD FBW	Linear	Productivity	Datafile	Passage survival
		NOR Yrling FG FD dead	Linear	Productivity	Constant	0



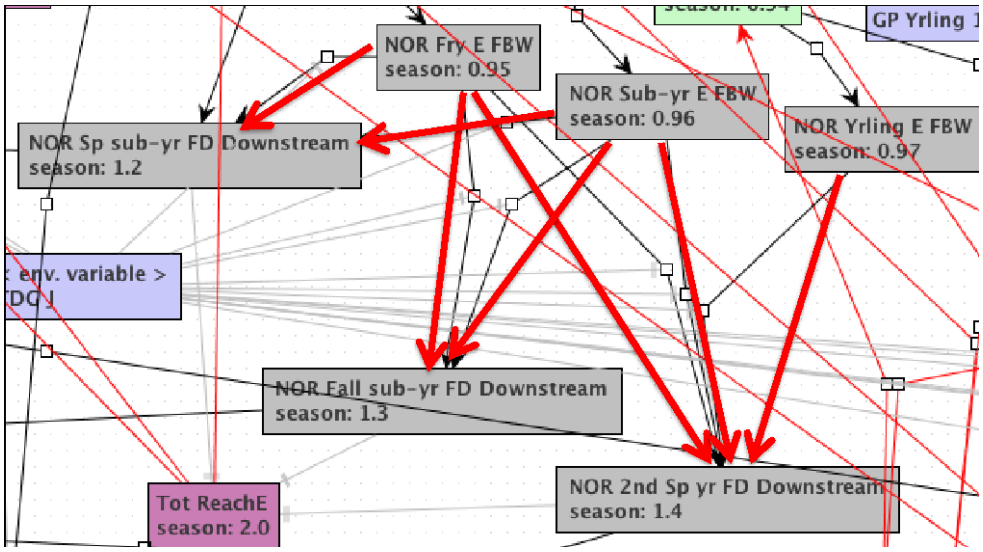
Survival parameter values of each life strategy in Reach A (below Lebanon Dam), B (tributaries of mainstem), C (between Lebanon Dam and Foster Dam), and D (Wiley Creek) to juvenile out migrant stage (JOM).

Reach	From	To	Curve type	Capacity & Productivity	Distr. type	Proportion of fish that survive
A	NOR Sp sub-yr A	NOR Sp sub-yr JOM A	Linear	Productivity	Constant	0.1
	NOR Fall sub-yr A	NOR Fall sub-yr JOM A	Linear	Productivity	Constant	0.3
	NOR 2nd Sp yr A	NOR 2nd Sp yr JOM A	Linear	Productivity	Constant	0.4
B	NOR Sp sub-yr B	NOR Sp sub-yr JOM B	Linear	Productivity	Constant	0.15
	NOR Fall sub-yr B	NOR Fall sub-yr JOM B	Linear	Productivity	Constant	0.35
	NOR 2nd Sp sub-yr B	NOR 2nd Sp yr JOM B	Linear	Productivity	Constant	0.45
C	NOR Sp sub-yr C	NOR Sp sub-yr JOM C	Linear	Productivity	Constant	0.15
	NOR Fall sub-yr C	NOR Fall sub-yr JOM C	Linear	Productivity	Constant	0.35
	NOR 2nd Sp sub-yr C	NOR 2nd Sp yr JOM C	Linear	Productivity	Constant	0.45
D	NOR Sp sub-yr D	NOR Sp sub-yr JOM D	Linear	Productivity	Constant	0.15
	NOR Fall sub-yr D	NOR Fall sub-yr JOM D	Linear	Productivity	Constant	0.35
	NOR 2nd Sp sub-yr D	NOR 2nd Sp yr JOM D	Linear	Productivity	Constant	0.45



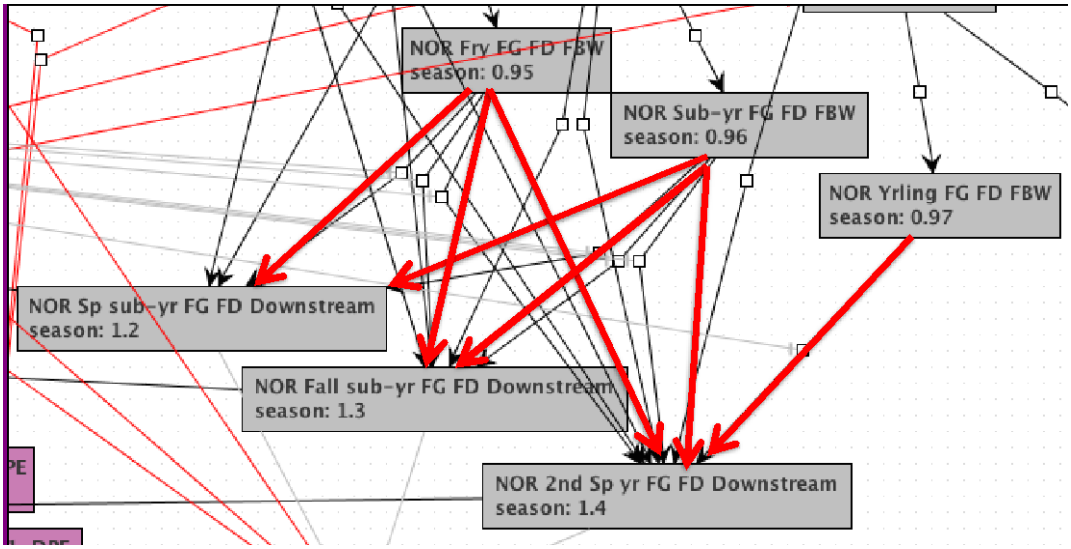
Survival parameter values for Fry from Reach E (above Foster Dam) passing Foster Dam and moving downstream as Spring Sub-yearlings, Fall Sub-yearlings, and Yearlings. Survival parameter values for Sub-yearlings from Reach E (above Foster Dam) passing Foster Dam and moving downstream as Spring Sub-yearlings, Fall Sub-yearlings, and Yearlings. Survival parameter values for Yearlings from Reach E (above Foster Dam) passing Foster Dam and moving downstream as Yearlings.

Reach	From	To	Curve type	Capacity & Productivity	Distr. type	Proportion of fish that survive
E	NOR Fry E FBW	NOR Sp sub-yr FD Downstream	Linear	Productivity	Constant	0.135
		NOR Fall sub-yr FD Downstream	Linear	Productivity	Constant	0.325
		NOR 2nd Sp yr FD Downstream	Linear	Productivity	Constant	0.425
	NOR Sub-yearlings E FBW	NOR Sp sub-yr FD Downstream	Linear	Productivity	Constant	0.15
		NOR Fall sub-yr FD Downstream	Linear	Productivity	Constant	0.375
		NOR 2nd Sp yr FD Downstream	Linear	Productivity	Constant	0.5
	NOR Yrling E FBW	NOR 2nd Sp yr FD Downstream	Linear	Productivity	Constant	0.5



Survival parameter values for Fry from Reach FG (above Green Peter Dam) passing Foster Dam and moving downstream as Spring Sub-yearlings, Fall Sub-yearlings, and Yearlings. Survival parameter values for Sub-yearlings from Reach FG (above Green Peter Dam) passing Foster Dam and moving downstream as Spring Sub-yearlings, Fall Sub-yearlings, and Yearlings. Survival parameter values for Yearlings from Reach FG (above Green Peter Dam) passing Foster Dam and moving downstream as Yearlings.

Reach	From	To	Curve type	Capacity & Productivity	Distr. type	Proportion of fish that survive
E	NOR Fry FG FD FBW	NOR Sp sub-yr FG FD Downstream	Linear	Productivity	Constant	0.135
		NOR Fall sub-yr FG FD Downstream	Linear	Productivity	Constant	0.325
		NOR 2nd Sp yr FG FD Downstream	Linear	Productivity	Constant	0.425
	NOR Sub-yearlings FG FD FBW	NOR Sp sub-yr FG FD Downstream	Linear	Productivity	Constant	0.15
		NOR Fall sub-yr FG FD Downstream	Linear	Productivity	Constant	0.375
		NOR 2nd Sp yr FG FD Downstream	Linear	Productivity	Constant	0.5
	NOR Yrling FG FD FBW	NOR 2nd Sp yr FD Downstream	Linear	Productivity	Constant	0.5

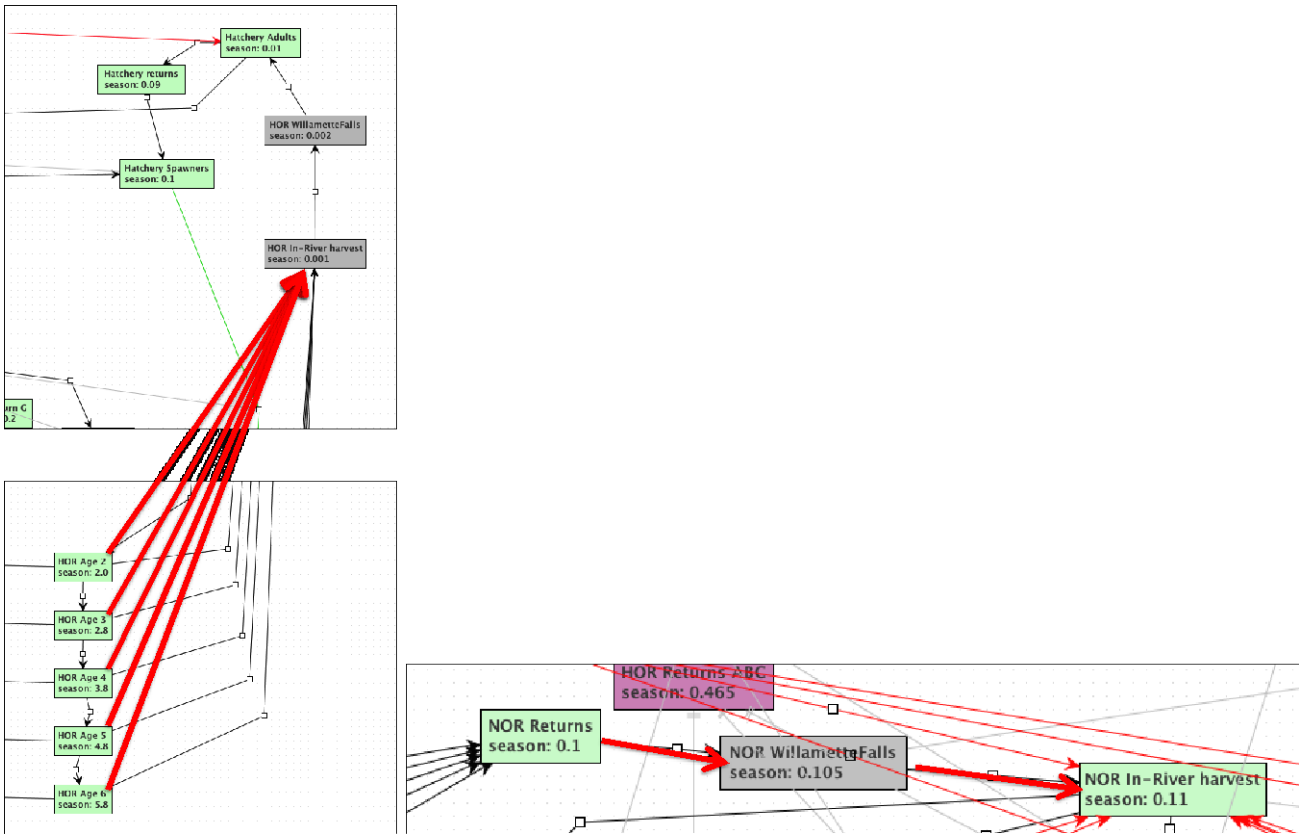


Estuary and ocean survival. Juveniles below Willamette Falls have an estuary survival time series applied, and in subsequent ocean years from, from 1, up to 4 ocean years, an ocean survival time series is applied (see Table 7.6 in Parameter variability section).

Survival parameter values associated with ocean and freshwater adult harvest and adult mainstem "loss". Hatchery origin individuals are fished. We assume that fish in South Santiam River experience the same harvest mortality as those in North Santiam. There is 45.6% mortality (average of 2006-2011) due to harvest below Willamette Falls (Fisheries Management and Evaluation for 2012 Willamette River spring Chinook 2013). This 45.6% mortality is the sum of mortality by recreational fishery at the mouth of the Columbia River to Willamette River (5.2%), lower Willamette recreational fishery (20.8%), mainstem net fishery (9%), and the recreational fishery in the South Santiam River (10.6%). This 45.6% mortality (i.e., 0.544 survival) is comparable to 30.7% and 55% mortality reported by Lindsay et al. (1998) and Ford 2011, respectively. There is also a loss of fish observed from Willamette Falls to counts within South Santiam River, which we calculated as an average of 28.4% using data from 1995-2011 (i.e., 0.716 survival).

We assume that natural origin fish in the South Santiam River experience the same harvest mortality as those from North Santiam. North Santiam fish experience an average fishing mortality of 8.7% (range of 5% - 14.2%; 2013, Fisheries Management & Evaluation) (i.e. 0.913 survival). There is also a loss of fish observed from Willamette Falls to counts within South Santiam River, which we calculated as an average of 28.4% using data from 1995-2011) (i.e., 0.716 survival) (based on Willis et al. 1996; Foster et al. 1997; Bennett 1998; Lindsay et al. 1998; Ford 2011; Foster & Boatner 2002).

Reach	From	To	Curve type	Capacity & Productivity	Dist. type	Proportion of fish that survive
Hatchery	HOR Parr	HOR River Migrants	Linear	Productivity	Constant	0.55
	HOR Age 2	HOR In-River harvest	Linear	Productivity	Constant	0.524
	HOR Age 3	HOR In-River harvest	Linear	Productivity	Constant	0.524
	HOR Age 4	HOR In-River harvest	Linear	Productivity	Constant	0.524
	HOR Age 5	HOR In-River harvest	Linear	Productivity	Constant	0.524
	HOR Age 6	HOR In-River harvest	Linear	Productivity	Constant	0.524
	HOR In-River harvest	HOR WillametteFalls	Linear	Productivity	Constant	0.716
NORs	NOR Returns	NOR WillametteFalls	Linear	Productivity	Constant	0.716
	NOR WillametteFalls	In-River harvest	Linear	Productivity	Constant	0.903



7.2. Splits

This section describes the proportion of fish directed from an individual life-stage to two or more subsequent life-stages via different pathways (splits).

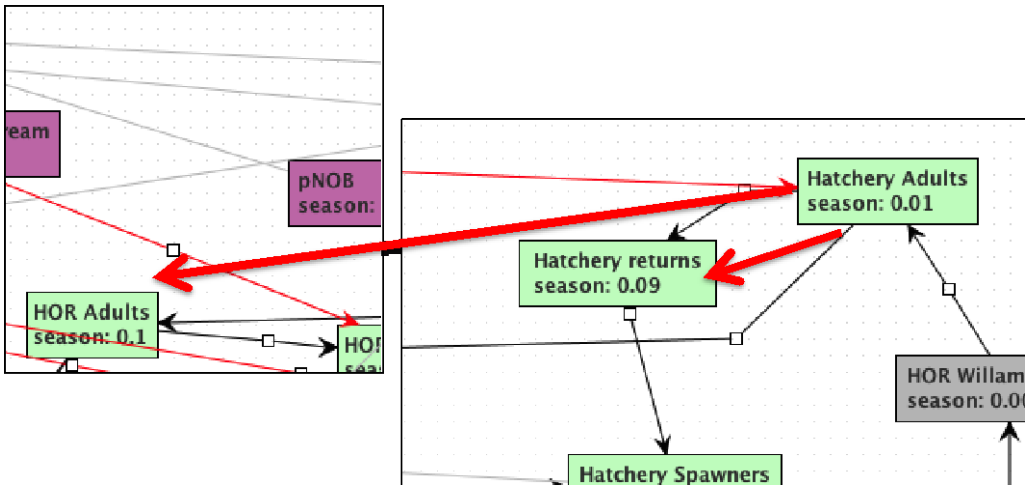
Proportion of hatchery origin adults (Hatchery Adults) that return to the hatchery (Hatchery Returns) or return to a Reach and attempt to spawn (HOR Adults). These proportions are based on abundance of South Santiam River natural origin fish (NORs) at Willamette Falls. Specifically, as more NORs pass above Willamette Falls then more HORs will return to the hatchery, thus effectively reducing hatchery contribution to wild production. When fewer than 2,501 South

Santiam River NORs are counted at Willamette Falls, 43.6% of hatchery fish that are returning to the South Santiam River will return to the hatchery rack (Hatchery returns), while the remaining 56.4% do not return to the hatchery and are allowed to spawn in the wild. When greater than 7,500 natural origin South Santiam River fish are counted at Willamette Falls then 95% of hatchery fish that are returning to the South Santiam River will return to the hatchery rack (Hatchery returns), while the remaining 5% will attempt to spawn In the wild (HOR Adults). When the number of natural origin South Santiam River fish counted at Willamette Falls is between 2,501 and 7,500 individuals, then a linear relationship (below) sets the rate of return to the rack between 82 – 95%:

$$Proportion\ of\ hatchery\ fish\ that\ return\ to\ rack\ = 0.436\ + (0.564 \times (\frac{NORs\ at\ Willamette\ Falls - 2500}{5500}).$$

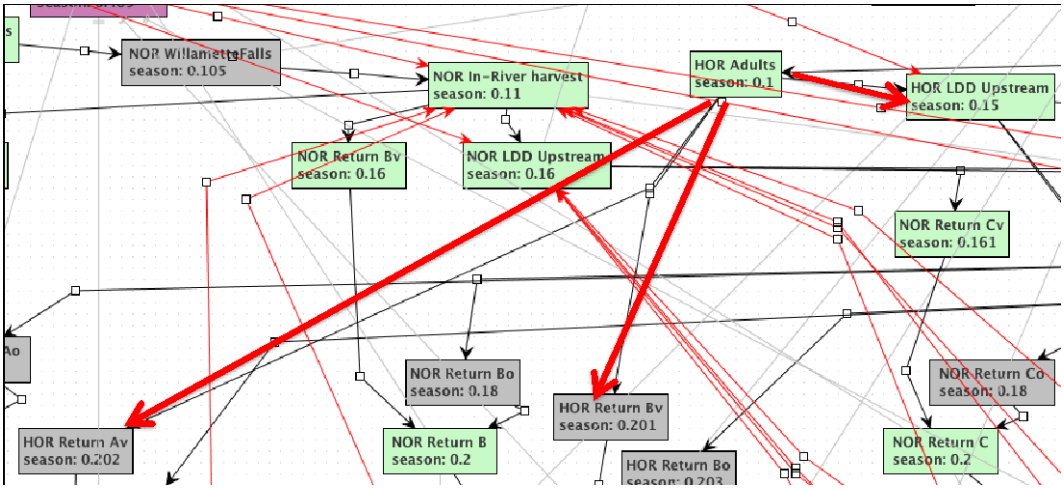
From	To	Proportion
Hatchery Adults	Hatchery returns	Split influencer (otherwise use 0.436)
	HOR Adults	Split influencer (otherwise use 0.564)

These proportions were based on observations of straying rates from 2001-2011 (Table 1 in DRAFT - Assessment of specific actions to reduce the natural spawning of hatchery Chinook in the McKenzie River (by McKenzie Hatchery Technical Workgroup, March 28, 2012).



Proportion of hatchery origin adults (HOR Adults) that volitionally return to Reach A (HOR Return A), Reach B (HOR Return B), or Upstream of Lebanon Dam (HOR LDD Upstream). Of the hatchery origin adults that do not return to the hatchery, 2.5% of returning fish go to Reach A, 7.4% to Reach B, and 90.1% to Reach HOR LDD Upstream.

From	To	Proportion
HOR Adults	HOR Return Av	0.025
	HOR Return Bv	0.074
	HOR LDD Upstream	0.901

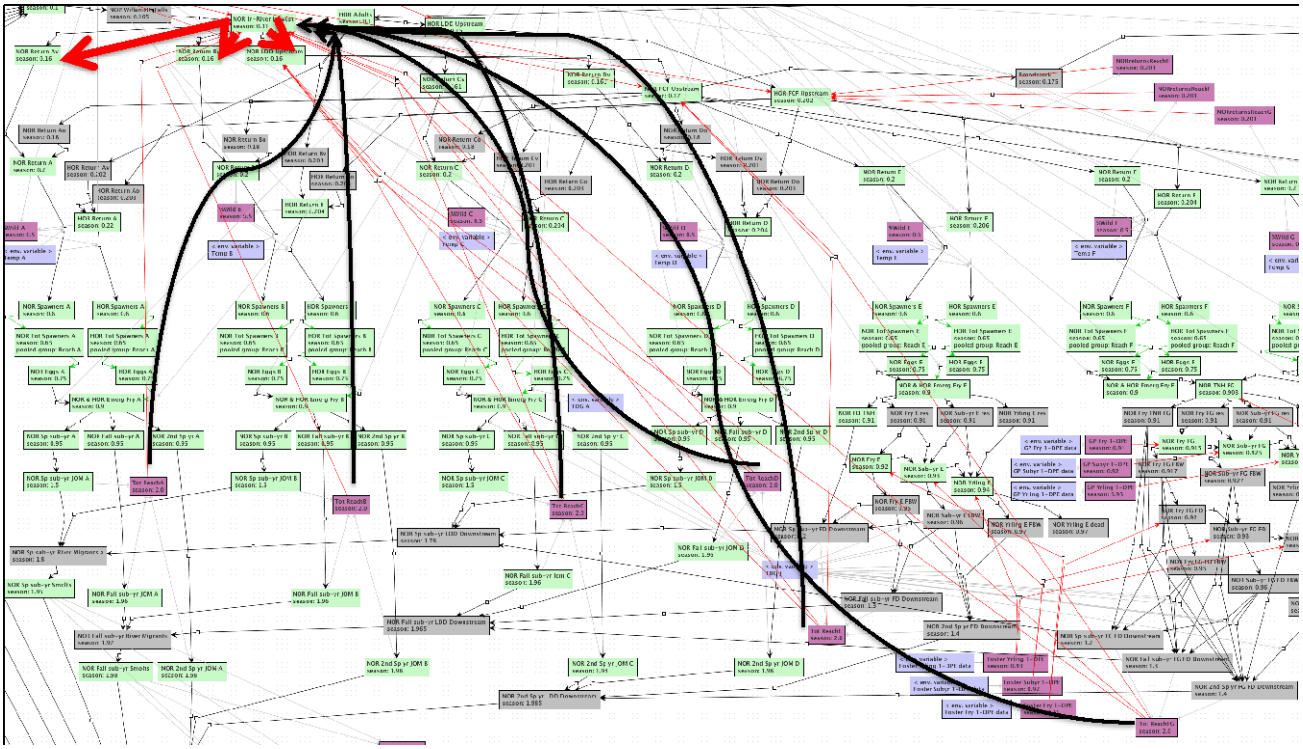


Proportion of Returning Adults that survived freshwater harvest (NOR In-River harvest) to volitionally return to Reach A (NOR Returns Av), Reach B (NOR Returns Bv), or upstream of Lebanon Dam (NOR LDD Upstream). In the process of simplifying the SLAM model structure, we pooled together juveniles from all reaches starting at the estuary stage since estuary/ocean survivals and ocean and mainstem harvest were applied equally to fish from all reaches. Because of homing of adult Chinook salmon to their natal reaches, we reapportioned returning adults in year *t* back to their natal reaches according to the numbers of juveniles produced in year *t* - 4. Specifically, for each simulated year we quantified the proportion of juveniles that exited each reach by first determining the total number of juveniles that exited each reach, the latter of which are represented as boxes named Tot ReachA, Tot ReachB, Tot ReachC, Tot ReachD, Tot ReachE, and Tot ReachFG. These proportions were then used to split returning adults (four simulated years later) that survived freshwater harvest (NOR In-River harvest) to those that volitionally return to Reach A (NOR Returns Av), Reach B (NOR Returns Bv), and upstream of Lebanon Dam (NOR LDD Upstream). To achieve this in SLAM we used a tool called a Split Influence, which is defined as a box that influences the abundance ratios of a split (McElhany et al. 2012). This means that the abundance of the influencing box (in our case, reach-specific proportion of juvenile outmigrants) will be available as an input parameter to the scripts that calculate split ratios (in our case, the proportion of adults that return to Reach A, B, and upstream of Lebanon Dam) during the simulation run. After the model was initialized with a fixed set of ratios for a split, the Split Influence determined the split from the juvenile counts four years previously:

$$Proportion\ of\ fish\ returning\ to\ NOR\ Returns\ A = \left(\frac{Tot\ ReachA}{Tot\ ReachA+Tot\ ReachB+Tot\ ReachC+Tot\ ReachD+Tot\ ReachE+Tot\ ReachFG}\right)$$

Tot ReachA, B, C, D, E, and FG correspond to the abundance of juvenile outmigrants, when pooling life history strategies, for each reach. This equation was applied for model years 4 and onward. For the first 3 years of model runs we apportioned fish to reaches according to a fixed proportion.

From	To	Proportion
NOR In-River harvest	NOR Return Av	Split influence (otherwise 0.017)
	NOR Return Bv	Split influence (otherwise 0.074)
	NOR LDD Upstream	Split influence (otherwise 0.909)



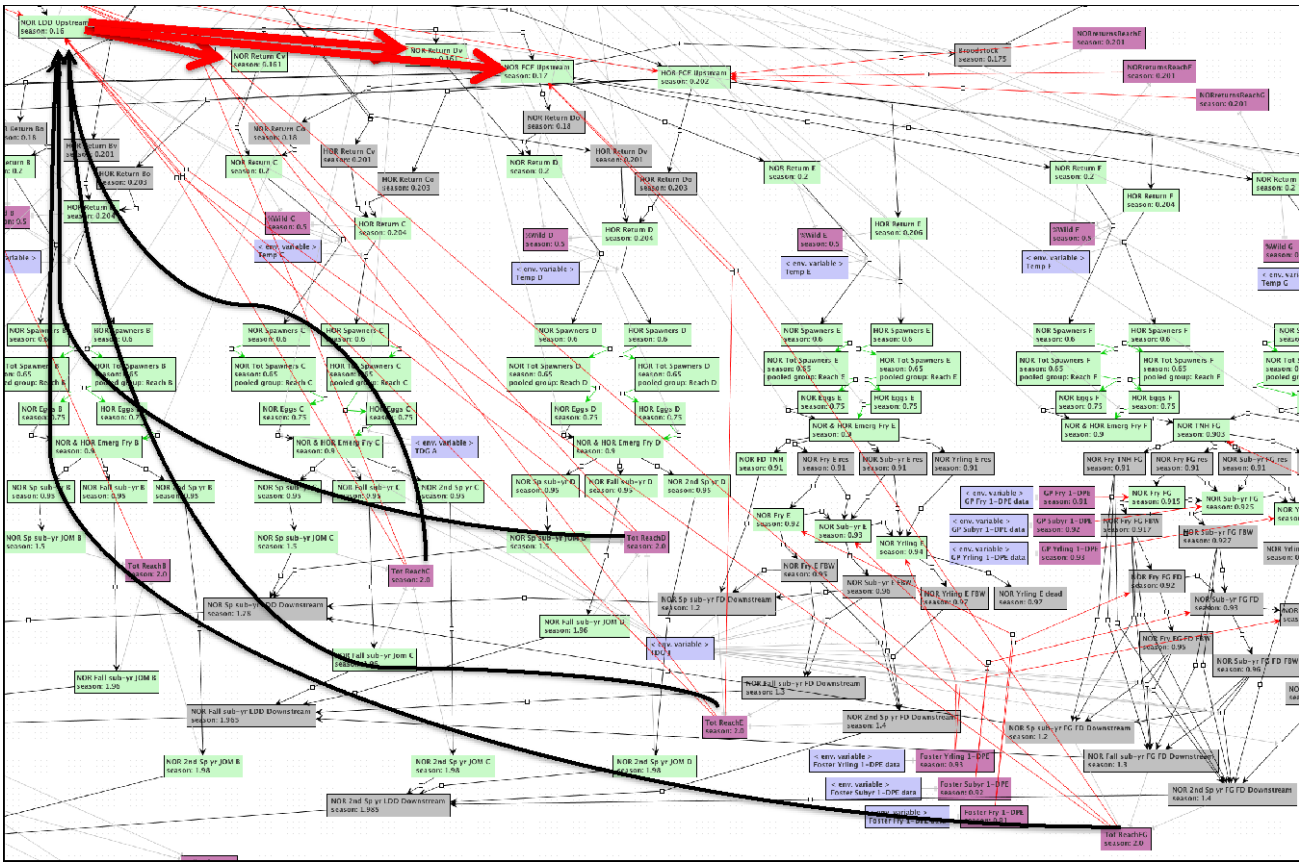
Black lines show that six (Tot ReachA, Tot ReachB, Tot ReachC, Tot ReachD, and Tot ReachE, and Tot ReachFG) are used to influence the split of fish from NOR In-River harvest to either NOR Returns Av, NOR Returns Bv, and NOR LDD Upstream.

Proportion of NORs and HORs upstream of Lebanon Dam (NOR LDD Upstream and HOR LDD Upstream, respectively) that go to Reach C, Reach D, (NOR Return C, NOR Return D, HOR Return C, and HOR Return D), or upstream of Foster Collection Facility (NOR and HOR FCF Upstream). Hatchery origin fish (HORs) are split among Reach C, D, and HOR FCF Upstream using constant proportions. For each simulated year we quantified the proportion of natural origin juveniles (NORs) that exited each reach by first determining the total number of juveniles that exited each reach, the latter of which are represented as boxes named Tot ReachC, Tot ReachD, Tot ReachE, Tot ReachFG. These proportions were then used to split returning adults at NOR LDD Upstream to those returning to Reach C (NOR Return Cv), Reach D (NOR Return Dv), and upstream of Foster Collection Facility (NOR FCF Upstream). To achieve this in SLAM we used a Split Influence. The Split Influence determined the split from the juvenile counts:

$$Proportion\ of\ fish\ returning\ to\ NOR\ Returns\ C = \left(\frac{Tot\ ReachC}{Tot\ ReachC + Tot\ ReachD + Tot\ ReachE + Tot\ ReachFG}\right)$$

Tot ReachC, Tot ReachD, Tot ReachE, and Tot ReachFG correspond to the abundance of juvenile outmigrants, when pooling life history strategies, for each reach.

From	To	Proportion
HOR LDD Upstream	HOR Return Dv	0.05
	HOR FCF Upstream	0.475
	HOR Return Cv	0.475
NOR LDD Upstream	NOR Return Cv	Split influencer (otherwise use 0.528)
	NOR Return Dv	Split influencer (otherwise use 0)
	NOR FCF Upstream	Split influencer (otherwise use 0.472)



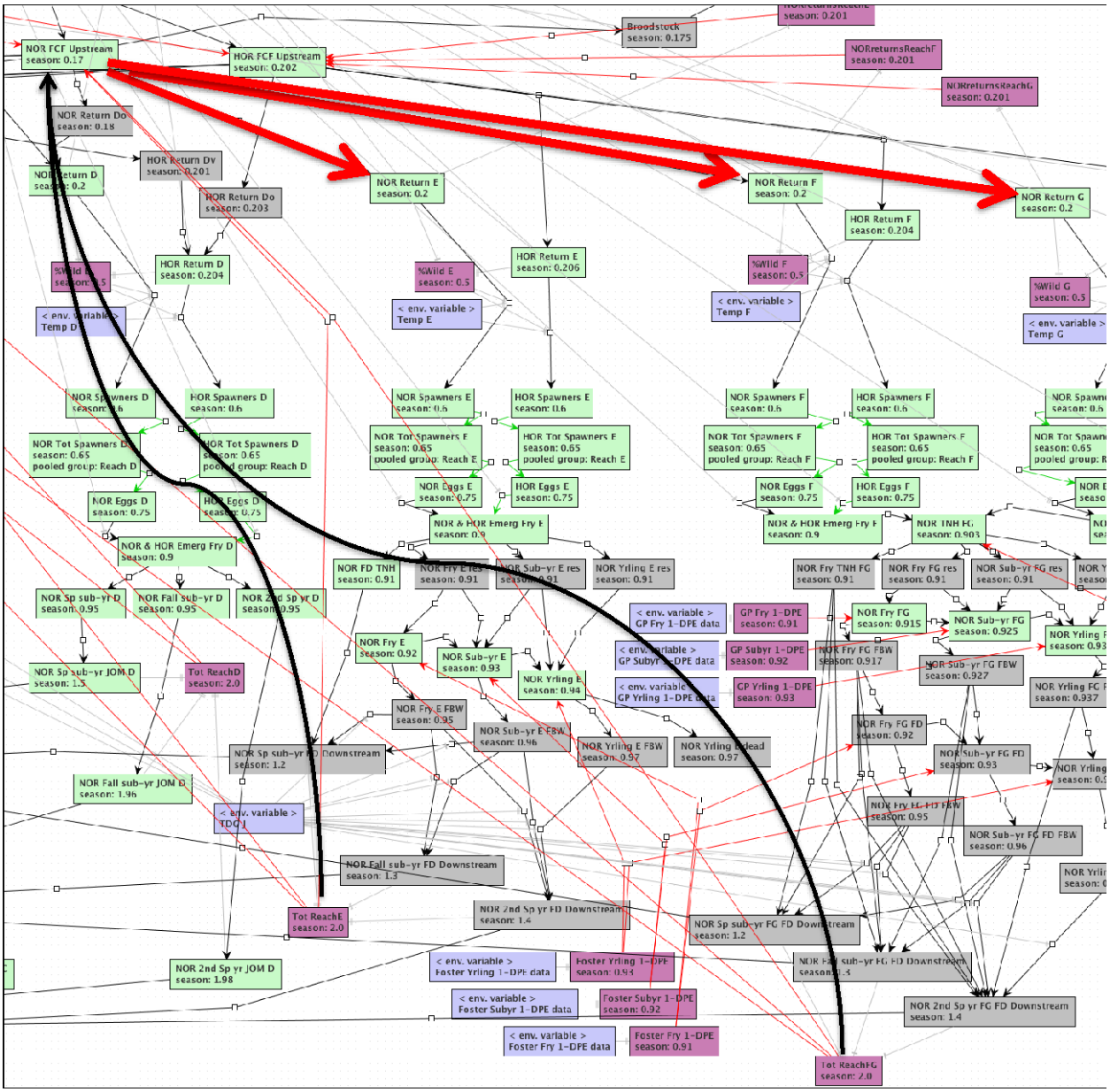
Black lines show that four boxes, of six (Tot ReachC, Tot ReachD, Tot ReachE, and Tot ReachFG) are used to influence the split of fish from NOR LDD Upstream to NOR Returns Cv, NOR Returns Dv, and NOR FCF Upstream.

Proportion of NORs upstream of Foster Collection Facility (NOR FCF Upstream) that go to Broodstock, outplants to Reach A, B, C, D (NOR Return Ao, NOR Return Bo, NOR Return Co, NOR Return Do, respectively), or continue to Reach E, Reach F, or Reach G (NOR Return E, F, G, respectively). A constant proportion of natural origin fish (NORs) are used in hatchery broodstock (Broodstock). For each simulated year we quantified the proportion of natural origin juveniles (NORs) that exited each reach by first determining the total number of juveniles that exited each reach, the latter of which are represented as boxes named Tot ReachE and Tot ReachFG. These proportions were then used to split returning adults at NOR FCF Upstream. To achieve this in SLAM we used a Split Influence. The Split Influence determined the split from the juvenile counts:

$$Proportion\ of\ fish\ returning\ to\ NOR\ Returns\ E = \left(\frac{Tot\ ReachE}{Tot\ ReachE + Tot\ ReachFG}\right)$$

Tot ReachE and Tot ReachFG correspond to the abundance of juvenile outmigrants, when pooling life history strategies, for each reach.

From	To	Proportion
NOR FCF Upstream	Broodstock	Split influencer set to 0.075
	NOR Return Ao	Split influencer set to 0
	NOR Return Bo	Split influencer set to 0
	NOR Return Co	Split influencer set to 0
	NOR Return Do	Split influencer set to 0
	NOR Return E	Split influencer (otherwise use 0.925)
	NOR Return F	Split influencer (otherwise use 0)
	NOR Return G	Split influencer (otherwise use 0)

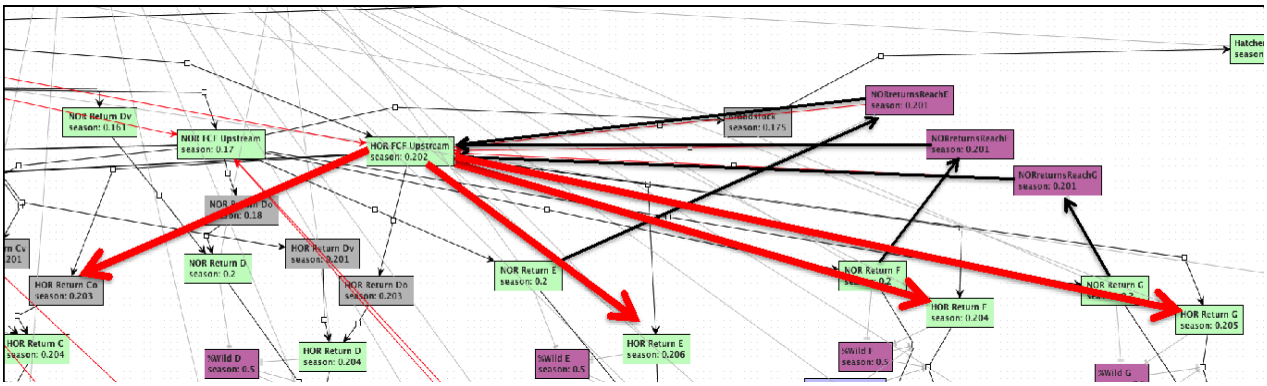


Black lines show that two boxes (Tot ReachE, and Tot ReachFG) are used to influence the split of fish from NOR FCF Upstream to NOR Return E, NOR Return F, and NOR Return G.

Proportion of HORs upstream of Foster Collection Facility (HOR FCF Upstream) that go as outplants to Reach A, B, C, D (HOR Return Ao, HOR Return Bo, HOR Return Co, HOR Return Do, respectively), or continue to Reach E, Reach F, or Reach G (HOR Return E, F, G, respectively). No adult hatchery origin fish (HORs) are outplanted to Reach A, B, & D, some are outplanted into reaches E, F, and G. For each simulated year we quantified the abundance of natural origin juveniles (NORs) that return to each reach upstream of Foster Collection Facility (i.e., Reach E, F & G); NORreturnsReachE, NORreturnsReachF, and NORreturnsReachG. When less than 401 NORs are in each of Reach E, F, & G, then 100% of HORs at Foster Collection Facility are distributed to Reach E, F, and G (33.4%, 33.3%, and 33.3%, respectively). When greater than 800 NORs are in each of Reach E, F, & G, then 0% of HORs at Foster Collection Facility are distributed to Reach E, F, and G, and 100% are outplanted to Reach C (HOR Return Co). When the number of NORs is between 401 and 800 individuals within each of Reach E, F, and G, then a linear relationship (below) determines the percent of HORs returning to Reach E, F, and G. HORs not allocated to Reach E, F, and G, are outplanted to Reach C.

$$Proportion\ of\ fish\ returning\ to\ HOR\ Return\ E = (0.334 - (0.334 * \left(\frac{NORreturnsE-400}{400}\right)$$

From	To	Proportion
HOR FCF Upstream	HOR Return Ao	Split influencer set to 0
	HOR Return Bo	Split influencer set to 0
	HOR Return Co	Split influencer set to 1- (Prop of E+F+G)
	HOR Return Do	Split influencer set to 0
	HOR Return E	Split influencer (otherwise use 0.334)
	HOR Return F	Split influencer (otherwise use 0.333)
	HOR Return G	Split influencer (otherwise use 0.333)

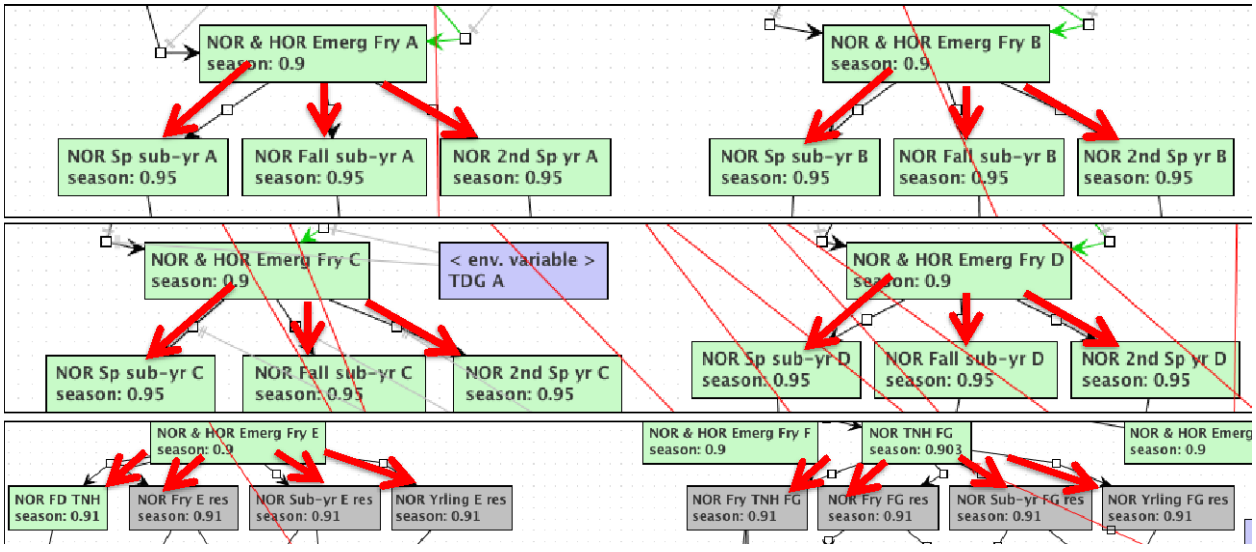


Black lines show that three NOR boxes (NORreturnsReachE, NORreturnsReachF, and NORreturnsReachG) are used to influence the split of HORs from HOR FCF Upstream to HOR Return Ao (not shown), HOR Return Bo (not shown), HOR Return Co, HOR Return Do, HOR Return E, HOR Return F, and HOR Return G.

Proportion of emergent fry (NOR & HOR Emerg Fry) in Reach A, B, C, and D, that become spring sub-yearling (NOR Sp sub-yr), fall sub-yearling (NOR Fall sub-yr), and second spring yearling (NOR 2nd Sp yr). The proportions of emergent fry in reaches A, B, C, and D that followed particular life history trajectories were determined based on Mattson (1962). Proportion of emergent fry within Reach E (above Foster Dam) that become Fry, Sub-yearling, or Yearling in Foster reservoir. Lastly, the proportion of emergent fry within Reach F & G (above Green Peter Dam) that that become Fry, Sub-yearling, or Yearling in Green Peter reservoir.

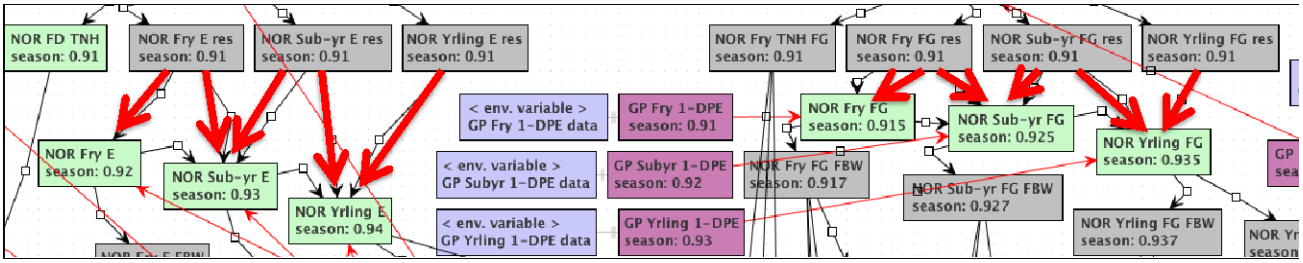
From	To	Proportion
NOR & HOR Emerg Fry A, B, C, & D	NOR Sp sub-yr	0.41
	NOR Fall sub-yr	0.304
	NOR 2nd Sp yr	0.286
NOR & HOR Emerg Fry E	NOR FD TNH	0
	NOR Fry E res	0.85
	NOR Sub-yr E res	0.1
	NOR Yrling E res	0.05
NOR TNH FG	NOR Fry FG res	0.85^
	NOR Sub-yr FG res	0.1^
	NOR Yrling FG res	0.05^
	NOR Fry TNH FG	0*

*For alternatives that include a Head of Reservoir (HoR) trap and haul option for downstream passage, USACE provides the proportion of fish collected and transported (i.e., dam passage efficiency, DPE). This trap and haul is located at head of Green Peter reservoir (Reach FG).
^For HoR trap and haul alternatives, values for NOR Fry FG res, NOR Sub-yr FG res, and NOR Yrling FG res are determined by multiplying their corresponding proportion by the proportion that were not transported via the HoR. For example, NOR Fry FG res= (0.85 x (1-NOR Fry TNH FG)).



Proportion of Fry in Foster reservoir (NOR Fry E res) that remain as Fry (NOR Fry E) or become Sub-yearlings (NOR Sub-yr E) and the proportion of Sub-yearlings in Foster reservoir (NOR Sub-yr E res) that remain as Sub-yearlings (NOR Sub-yr E) or become Yearlings (NOR Yrling E). Proportion of Fry in Green Peter reservoir (NOR Fry FG res) that remain as Fry (NOR Fry FG) or become Sub-yearlings (NOR Sub-yr FG) and the proportion of Sub-yearlings in Green Peter reservoir (NOR Sub-yr FG res) that remain as Sub-yearlings (NOR Sub-yr FG) or become Yearlings (NOR Yrling FG). These values are from parameter workshops (see Chapter 3, appendix 3.6).

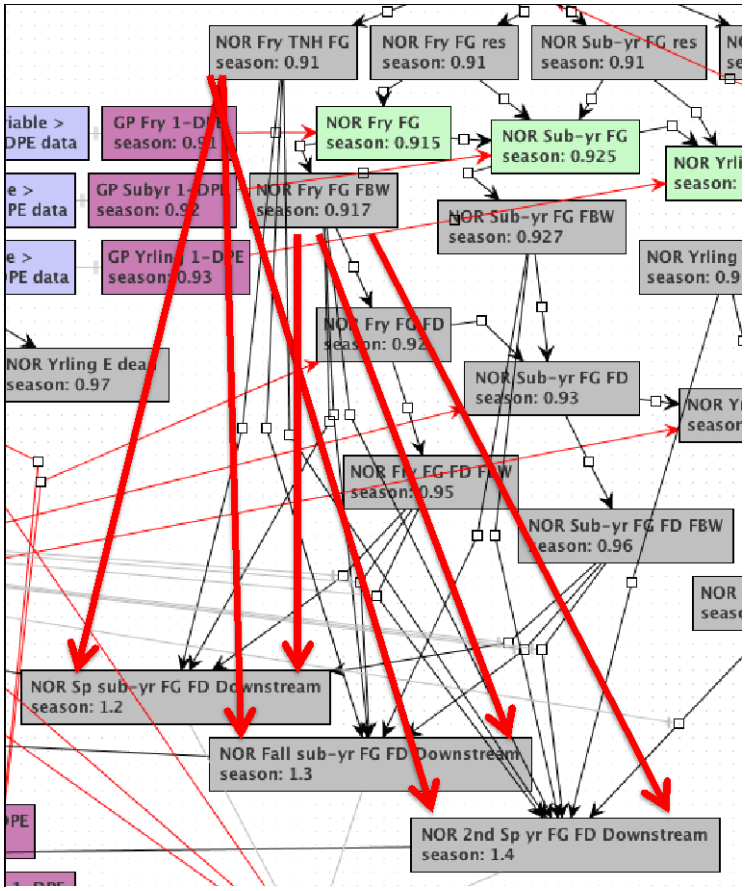
From	To	Proportion
NOR Fry E res	NOR Fry E	0.6-0.9
	NOR Sub-yr E	0.1-0.4
NOR Sub-yr E res	NOR Sub-yr E	0.8-1.0
	NOR Yrling E	0-0.2
NOR Fry FG res	NOR Fry FG	0.01-0.05
	NOR Sub-yr FG	0.95-0.99
NOR Sub-yr FG res	NOR Sub-yr FG	0.75-0.9
	NOR Yrling FG	0.1-0.25



Proportion of Fry collected at head of Green Peter reservoir (NOR Fry TNH FG) and transported downstream of Foster Dam to become spring sub-yearlings (NOR Sp sub-yr FG FD Downstream), fall sub-yearlings (NOR Fall sub-yr FG FD Downstream), or second spring yearlings (NOR 2nd Sp yr FG FD Downstream). Proportion of Fry in Foster reservoir (NOR Fry FG FBW) that remain in the reservoir or are transported downstream of Foster Dam to become spring sub-yearlings (NOR Sp sub-yr FG FD Downstream), fall sub-yearlings (NOR Fall sub-yr FG FD Downstream), or second spring yearlings (NOR 2nd Sp yr FG FD Downstream).

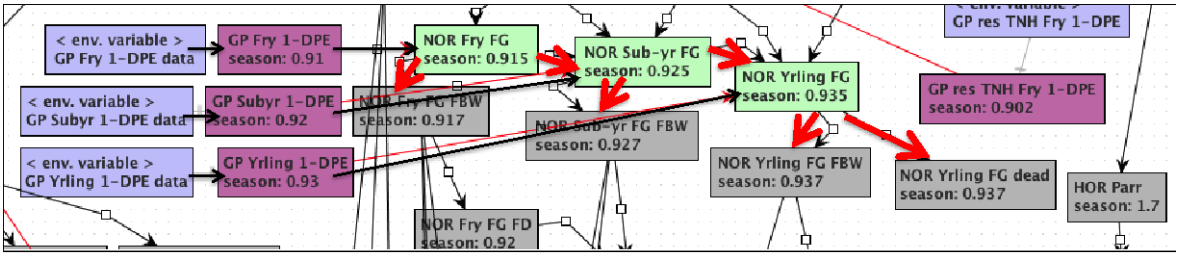
From	To	Proportion
NOR Fry TNH FG	NOR Sp sub-yr FG FD Downstream	0.4
	NOR Fall sub-yr FG FD Downstream	0.3
	NOR 2nd Sp yr FG FD Downstream	0.3
NOR Fry FG FBW	NOR Fry FG FD	1*
	NOR Sp sub-yr FG FD Downstream	0^
	NOR Fall sub-yr FG FD Downstream	0^
	NOR 2nd Sp yr FG FD Downstream	0^

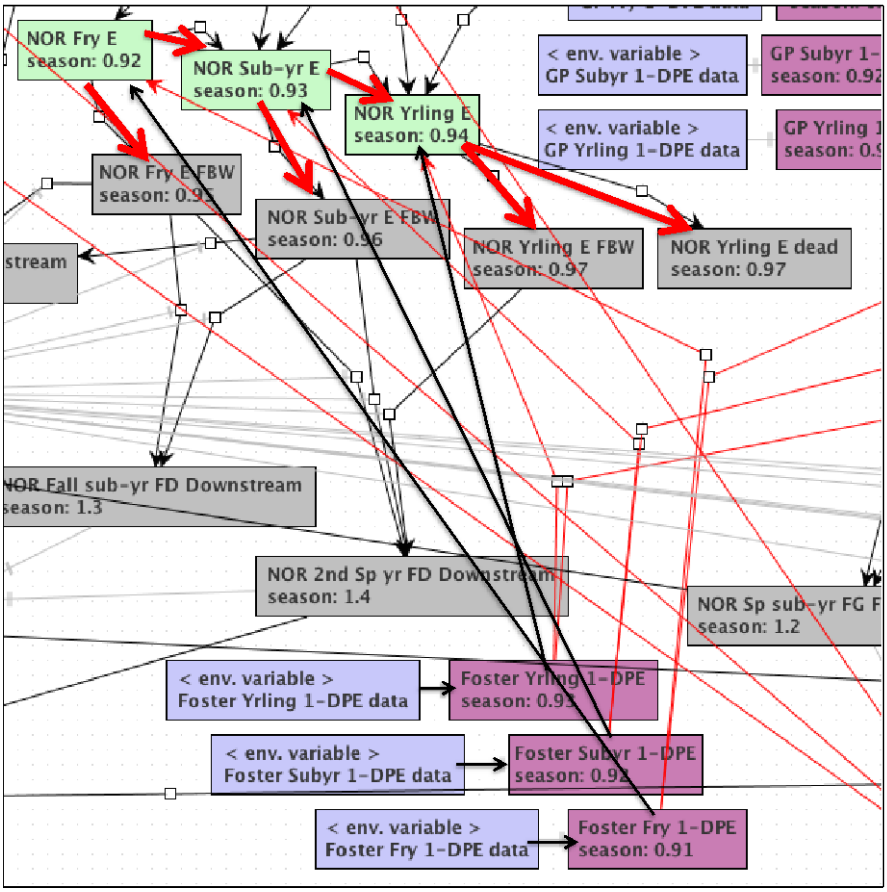
* Use 0 in alternatives where fish Bypass Foster.
^ Use 0.2-0.5, 0.2-0.6, and 0.1-0.2 for Spring Sub-yearlings, Fall Sub-yearlings, and Yearlings, respectively, in alternatives where fish Bypass Foster.



Proportion of individuals in Green Peter reservoir available to pass Green Peter Dam (DD) or unavailable to pass and thus remain in the reservoir and become the next life history strategy. Fry in Green Peter reservoir (NOR Fry FG) that are available to pass Green Peter Dam (NOR Fry FG FBW) or unavailable to pass and thus remain in the reservoir and become sub-yearlings (NOR Sub-yr FG) (Chapter 3, appendix 3.6). Proportion of sub-yearlings in Green Peter reservoir (NOR Sub-yr FG) that are available to pass Green Peter Dam (NOR Sub-yr FG FBW) or unavailable to pass and thus remain in the reservoir and become yearlings (NOR Yrling FG). Proportion of yearlings in Green Peter reservoir (NOR Yrling FG) that are available to pass Green Peter Dam (NOR Yrling FG FBW) or unavailable to pass, and are removed from the simulation (NOR Yrling FG dead). Fry in Foster reservoir (NOR Fry E) that are available to pass Foster Dam (NOR Fry E FBW) or unavailable to pass and thus remain in the reservoir and become sub-yearlings (NOR Sub-yr E) (Chapter 3, appendix 3.6). Proportion of sub-yearlings in Foster reservoir (NOR Sub-yr E) that are available to pass Foster Dam (NOR Sub-yr E FBW) or unavailable to pass and thus remain in the reservoir and become yearlings (NOR Yrling E). Proportion of yearlings in Foster reservoir (NOR Yrling E) that are available to pass Foster Dam (NOR Yrling E FBW) or unavailable to pass, and are removed from the simulation (NOR Yrling E dead). These proportions use dam passage efficiency (DPE) data that were specific to particular dam project alternatives and were provided by USACE (Fish Benefit Workbook).

From	To	Proportion
NOR Fry FG	NOR Fry FG FBW	Split influencer determined by DPE file
	NOR Sub-yr FG	Split influencer determined by DPE file
NOR Sub-yr FG	NOR Sub-yr FG FBW	Split influencer determined by DPE file
	NOR Yrling FG	Split influencer determined by DPE file
NOR Yrling FG	NOR Yrling FG FBW	Split influencer determined by DPE file
	NOR Yrling FG dead	Split influencer determined by DPE file
NOR Fry E	NOR Fry E FBW	Split influencer determined by DPE file
	NOR Sub-yr E	Split influencer determined by DPE file
NOR Sub-yr E	NOR Sub-yr E FBW	Split influencer determined by DPE file
	NOR Yrling E	Split influencer determined by DPE file
NOR Yrling E	NOR Yrling E FBW	Split influencer determined by DPE file
	NOR Yrling E dead	Split influencer determined by DPE file

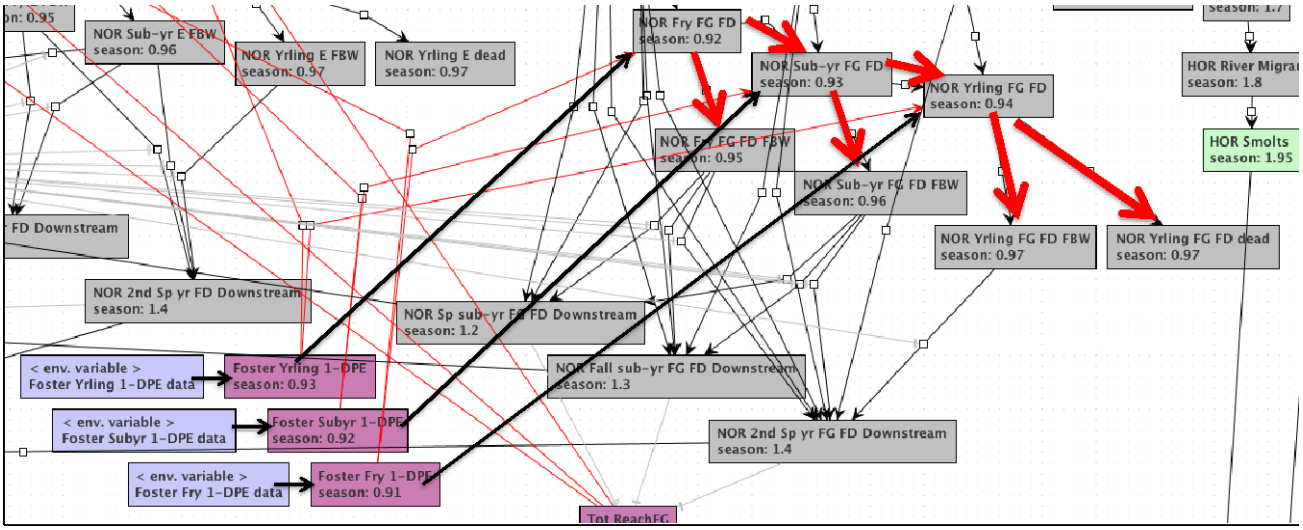




Black arrows represent the split influence from dam passage efficiency data.

Proportion of individuals from above Green Peter Dam (Reach FG) that are in Foster reservoir and available to pass Foster Dam (FD) or unavailable to pass and thus remain in the reservoir and become the next life history strategy. Fry from above Green Peter Dam that are in Foster reservoir (NOR Fry FG FD) are either available to pass Foster Dam (NOR Fry FG FD FBW) or unavailable to pass and thus remain in the reservoir and become sub-yearlings (NOR Sub-yr FG FD). Proportion of sub-yearlings from above Green Peter Dam that are in Foster reservoir (NOR Sub-yr FG FD) are either available to pass Foster Dam (NOR Sub-yr FG FD FBW) or unavailable to pass and thus remain in the reservoir and become yearlings (NOR Yrling FG FD). And, proportion of yearlings from above Green Peter Dam that are in Foster reservoir (NOR Yrling FG FD) are either available to pass Foster Dam (NOR Yrling FG FD FBW) or unavailable to pass, and are removed from the simulation (NOR Yrling FG FD dead). These proportions use dam passage efficiency (DPE) data that were specific to particular dam project alternatives and were provided by USACE (Fish Benefit Workbook).

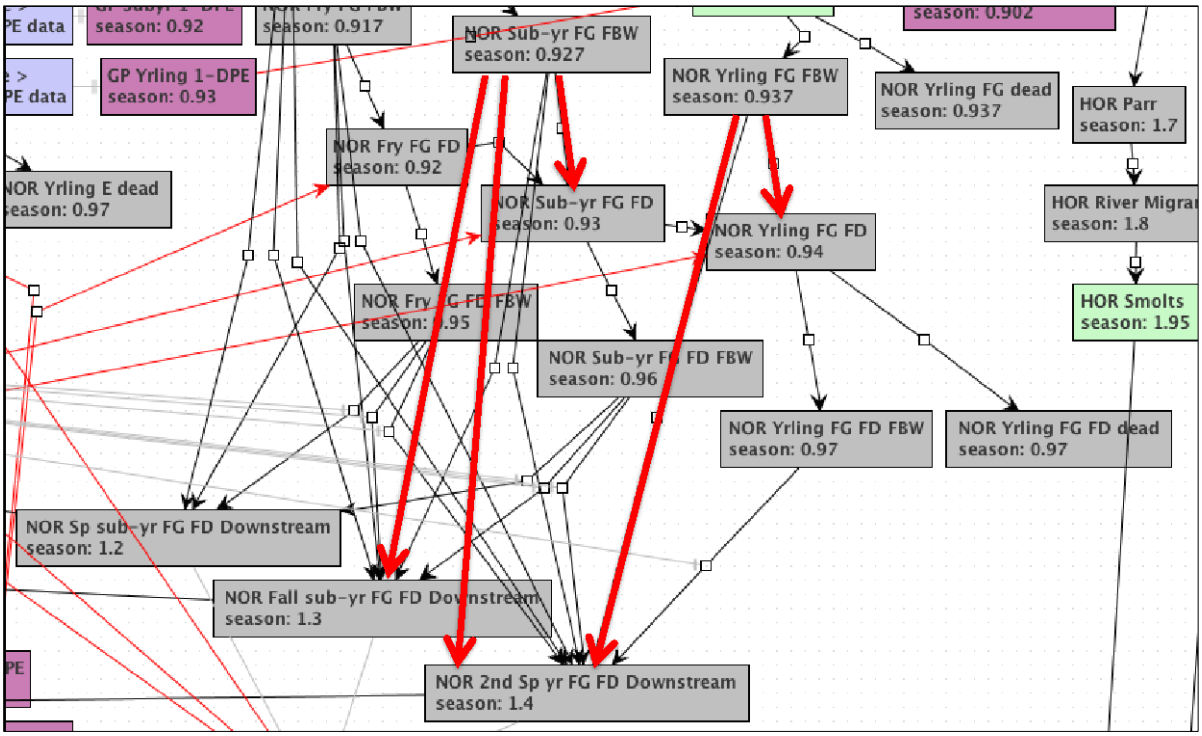
From	To	Proportion
NOR Fry FG FD	NOR Fry FG FD FBW	Split influencer determined by DPE file
	NOR Sub-yr FG FD	Split influencer determined by DPE file
NOR Sub-yr FG FD	NOR Sub-yr FG FD FBW	Split influencer determined by DPE file
	NOR Yrling FG FD	Split influencer determined by DPE file
NOR Yrling FG FD	NOR Yrling FG FD FBW	Split influencer determined by DPE file
	NOR Yrling FG FD dead	Split influencer determined by DPE file



Proportion of Sub-yearlings in Foster reservoir (NOR Sub-yr FG FBW) that remain in reservoir (NOR Sub-yr FG FD) or are transported downstream of Foster Dam to become fall sub-yearlings (NOR Fall sub-yr FG FD Downstream) or second spring yearlings (NOR 2nd Sp yr FG FD Downstream).

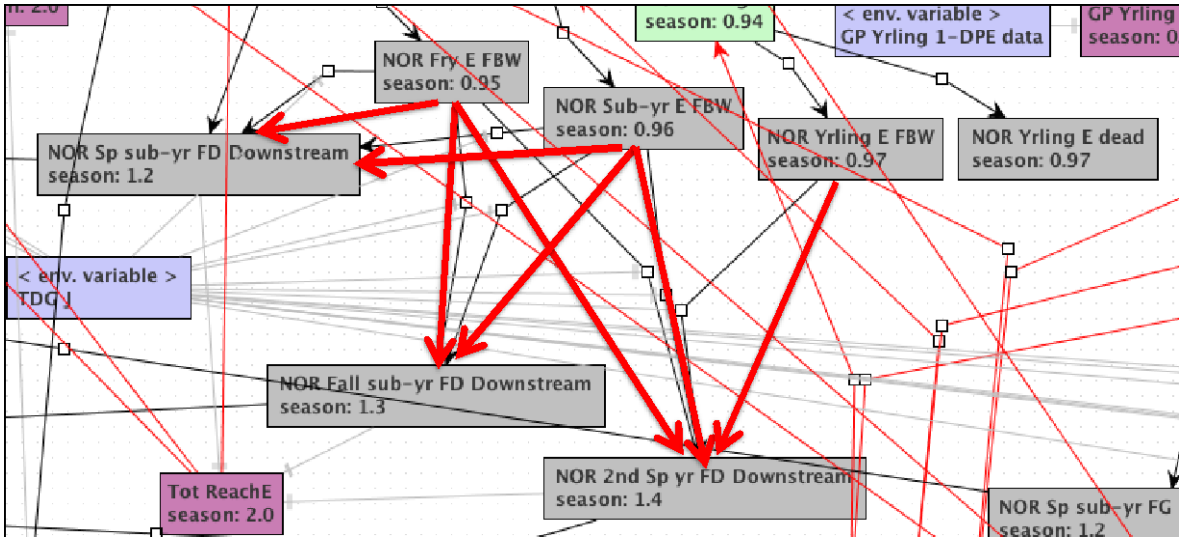
From	To	Proportion
NOR Sub-yr FG FBW	NOR Sub-yr FG FD	1*
	NOR Fall sub-yr FG FD Downstream	0^
	NOR 2nd Sp yr FG FD Downstream	0^
NOR Yrling Fg FBW	NOR Yrling FG FD	1*
	NOR 2nd Sp yr FG FD Downstream	0~

* Use 0 in alternatives where fish Bypass Foster.
^ Use 0.7-0.8 and 0.2-0.3 for Fall Sub-yearlings and Yearlings, respectively, in alternatives where fish Bypass Foster.
~ Use 1 in alternatives where fish Bypass Foster.



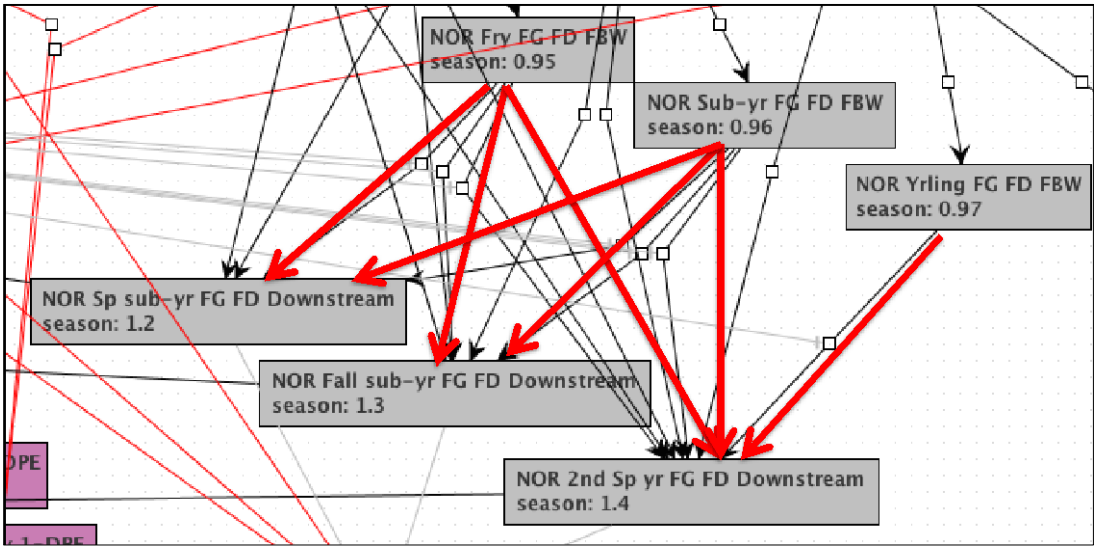
Proportion of Fry from Reach E (above Foster Dam) that passed Foster Dam and are in Reach C (below Foster Dam) as Spring sub-yearlings (NOR Sp sub-yr FD Downstream), Fall sub-yearlings (NOR Fall sub-yr FD Downstream), or Yearlings (NOR 2nd Sp yr FD Downstream).
These are the proportion of Sub-yearlings from Reach E (above Foster Dam) that passed Foster Dam and are in Reach C (below Foster Dam) as Spring sub-yearlings (NOR Sp sub-yr FD Downstream), Fall sub-yearlings (NOR Fall sub-yr FD Downstream), or Yearlings (NOR 2nd Sp yr FD Downstream). Values are from parameter workshops (see Chapter 3, appendix 3.6).

From	To	Proportion
NOR Fry E FBW	NOR Sp sub-yr FD Downstream	0.2-0.5
	NOR Fall sub-yr FD Downstream	0.2-0.6
	NOR 2nd Sp yr FD Downstream	0.1-0.2
NOR Sub-yr E FBW	NOR Sp sub-yr FD Downstream	0
	NOR Fall sub-yr FD Downstream	0.7-0.8
	NOR 2nd Sp yr FD Downstream	0.2-0.3
NOR Yrling E FBW	NOR 2nd Sp yr FD Downstream	1



Proportion of Fry from Reach FG (above Green Peter Dam) that passed Green Peter and Foster dams and are in Reach C (below Foster Dam) as Spring sub-yearlings (NOR Sp sub-yr FG FD Downstream), Fall sub-yearlings (NOR Fall sub-yr FG FD Downstream), or Yearlings (NOR 2nd Sp yr FG FD Downstream). These are the proportion of Sub-yearlings from Reach FG (above Green Peter Dam) that passed Green Peter and Foster dams and are in Reach C (below Foster Dam) as Spring sub-yearlings (NOR Sp sub-yr FG FD Downstream), Fall sub-yearlings (NOR Fall sub-yr FG FD Downstream), or Yearlings (NOR 2nd Sp yr FG FD Downstream). Values are from parameter workshops (see Chapter 3, appendix 3.6).

From	To	Proportion
NOR Fry FG FD FBW	NOR Sp sub-yr FG FD Downstream	0.2-0.5
	NOR Fall sub-yr FG FD Downstream	0.2-0.6
	NOR 2nd Sp yr FG FD Downstream	0.1-0.2
NOR Sub-yr FG FD FBW	NOR Sp sub-yr FD Downstream	0
	NOR Fall sub-yr FD Downstream	0.7-0.8
	NOR 2nd Sp yr FD Downstream	0.2-0.3
NOR Yrling FG FD FBW	NOR 2nd Sp yr FD Downstream	1



Proportional splits of ocean adults (NOR/HOR Age 2, 3, 4, 5, & 6) that stay in the ocean for another year, are harvested in the ocean, or return to freshwater.

From	To	Proportion
NOR Age 2	NOR Age 3	1
	Harvest N2	0
	NOR Returns	0
HOR Age 2	HOR Age 3	1
	Harvest N2	0
	HOR In-River harvest	0
NOR Age 3	NOR Age 4	0.996
	Harvest N3	0.002
	NOR Returns	0.002
HOR Age 3	HOR Age 4	0.996
	Harvest N3	0.002
	HOR In-River harvest	0.002
NOR Age 4	NOR Age 5	0.58
	Harvest N4	0.065
	NOR Returns	0.355
HOR Age 4	HOR Age 5	0.58
	Harvest N4	0.065
	HOR In-River harvest	0.355
NOR Age 5	NOR Age 6	0.018
	Harvest N5	0.165
	NOR Returns	0.817
HOR Age 5	HOR Age 6	0.018
	Harvest N5	0.165
	HOR In-River harvest	0.817
NOR Age 6	Harvest N6	0
	NOR Returns	1
HOR Age 6	Harvest N6	0
	HOR In-River harvest	1

Values taken from Hendrix and Shi (2012) (page 22-31), which are based on ODFW SLAM parameter values and adjusted to fit age composition from ODFW.

7.3. Datafiles

Most parameter values are scalars or drawn from distributions according to parameters within SLAM, however there are stage transitions within the life-cycle model where survivals or life history splits come from datafiles. For example, dam passage survival and efficiency, and environmental variables like temperature, enter into SLAM as a datafile. The following are the stages or stage transitions that call a datafile with survivals or splits.

7.3.1. Survivals

Stage at which datafile is used	Name of datafile	Name of series
NOR Fry FG FBW	GreenPeter_FBW_Alternatives_toSLAM.csv	GPD-Baseline-Fry-146yr
NOR Fry E FBW	Foster_FBW_Alternatives_toSLAM.csv	FD-Baseline FBW-Fry-146yr
NOR Fry FG FD FBW	Foster_FBW_Alternatives_toSLAM.csv	FD-Baseline FBW-Fry-146yr
NOR Sub-yr FG FBW	GreenPeter_FBW_Alternatives_toSLAM.csv	GPD-Baseline FBW-Subyr-146yr
NOR Sub-yr E FBW	Foster_FBW_Alternatives_toSLAM.csv	FD-Baseline FBW-Subyr-146yr
NOR Sub-yr FG FD FBW	Foster_FBW_Alternatives_toSLAM.csv	FD-Baseline FBW-Subyr-146yr
NOR Yrling FG FBW	GreenPeter_FBW_Alternatives_toSLAM.csv	GPD-Baseline FBW-Yrling-146yr
NOR Yrling E FBW	Foster_FBW_Alternatives_toSLAM.csv	FD-Baseline FBW-Yrling-146yr
NOR Yrling FG FD FBW	Foster_FBW_Alternatives_toSLAM.csv	FD-Baseline FBW-Yrling-146yr
NOR Sp sub-yr Smolts	EstuaryCurrent_modified_1_2013.csv	EstuaryCurrent x 2 (200yrs)
HOR Smolts	EstuaryCurrent_modified_1_2013.csv	EstuaryHatOr x 2 (200yrs)
NOR Fall sub-yr Smolts	EstuaryCurrent_modified_1_2013.csv	EstuaryCurrent x 2 (200yrs)
NOR 2nd Sp yr Smolts	EstuaryCurrent_modified_1_2013.csv	EstuaryCurrent x 2 (200yrs)
NOR HOR Age 2	ChSOcean4thRt_modified_1_2013.csv	ChSAge2 10% down x 2 (200yrs)
NOR HOR Age 3	ChSOcean4thRt_modified_1_2013.csv	ChSAge3 10% down x 2 (200yrs)
NOR HOR Age 4	ChSOcean4thRt_modified_1_2013.csv	ChSAge4 10% down x 2 (200yrs)
NOR HOR Age 5	ChSOcean4thRt_modified_1_2013.csv	ChSAge 5 x 2 (200yrs)
NOR HOR Age 6	ChSOcean4thRt_modified_1_2013.csv	ChSAge 6 x 2 (200yrs)
Temp A	SSantiam_Temp_Max7-DADM.csv	Reach A 200yr max7DADM (based on 11yrs of USGS data)
Temp B	SSantiam_Temp_Max7-DADM.csv	Reach A 200yr max7DADM (based on 11yrs of USGS data)
Temp C	SSantiam_Temp_Max7-DADM.csv	Reach C 200yr max7DADM (based on 11yrs of USGS data)
Temp D	SSantiam_Temp_Max7-DADM.csv	Reach C 200yr max7DADM (based on 11yrs of USGS data)
Temp E	SSantiam_Temp_Max7-DADM.csv	Reach E 200yr max7DADM (based on 5yrs of USGS data)
Temp F	SSantiam_Temp_Max7-DADM.csv	Reach F 200yr max7DADM (based on 5yrs of USGS data)
Temp G	SSantiam_Temp_Max7-DADM.csv	Reach F 200yr max7DADM (based on 5yrs of USGS data)
TDG A	SSantiam_TDG_012413_modified 2014.csv	Bseline TDG-Foster-Alevin (yolk sac fry) (148yrs)
TDG J	SSantiam_TDG_012413_modified 2014.csv	Baseline TDG-Foster-Juvenile (148yrs)
GP Fry 1-DPE data	GreenPeter_1-DPE_Alternatives_toSLAM.csv	GPD-Baseline 1-DPE-Fry-146yr
GP Sub-yr 1-DPE data	GreenPeter_1-DPE_Alternatives_toSLAM.csv	GPD-Baseline 1-DPE-Subyr-146yr
GP Yrling 1-DPE data	GreenPeter_1-DPE_Alternatives_toSLAM.csv	GPD-Baseline 1-DPE-Yrling-146yr
GP res TNH fry 1-DPE	Constant	0

7.3.2. Splits

Stage at which datafile is used	Name of datafile	Recruit stage datafile is applied	Name of series
NOR Fry E res	NOR Fry E res.csv	NOR Fry E	NOR Fry E
		NOR Sub-yr E	NOR Sub-yr E
NOR Sub-yr E res	NOR Sub-yr E res.csv	NOR Sub-yr E	NOR Sub-yr E
		NOR Yrling E	NOR Yrling E
NOR Fry FG res	NOR Fry FG.csv	NOR Fry FG	NOR Fry FG
		NOR Sub-yr FG	NOR Sub-yr FG
NOR Sub-yr FG res	NOR Sub-yr FG res.csv	NOR Sub-yr FG	NOR Sub-yr FG
		NOR Yrling FG	NOR Yrling FG
NOR Fry E FBW	NOR Fry E FBW.csv	NOR Sp sub-yr FD Downstream	NOR Sp sub-yr FD Downstream
		NOR Fall sub-yr FD Downstream	NOR Fall sub-yr FD Downstream
		NOR 2nd Sp yr FD Downstream	NOR 2nd Sp yr FD Downstream
NOR Sub-yr E FBW	NOR Sub-yr E FBW.csv	NOR 2nd Sp yr FD Downstream	NOR 2nd Sp yr FD Downstream
		NOR Sp sub-yr FD Downstream	NOR Sp sub-yr FD Downstream
		NOR Fall sub-yr FD Downstream	NOR Fall sub-yr FD Downstream

USACE provided R2 Consultants, who in turn provided NWFSC, with the following SLAM datafiles; EstuaryCurrent, ChSOcean4thRt, SSantiam_TDG_012413_modified 2014, and SSantiam_Temp_Max7-DADM. Each of the aforementioned files was expanded by NWFSC by repeating from the beginning, such that the files that were 74 years became 146 years, and those that were 100 years became 200 years. USACE provided Fish Benefits Workbooks datafiles that correspond to dam passage survival (e.g. Foster_FBW_Alternatives_toSLAM-June 3 2014, GreenPeter_FBW_Alternatives_toSLAM-June 3 2014) and dam passage efficiency (e.g., Foster_1-DPE_Alternatives_toSLAM-June 3 2014, GreenPeter_1-DPE_Alternatives_toSLAM-June 3 2014) (Fish Benefits Workbooks User Guide 2014).

7.4. Dynamic Drivers and Influence Scripts

In some cases we used scripts to influence life stage transitions and splits. These were written in a Java-compatible syntax and are called groovy script. These gave us the ability to dynamically influence splits such as apportioning adults to natal reaches based on juvenile outmigrants four years earlier, or for applying the dam passage efficiency (DPE) to juveniles attempting to pass the dam. Below is a list of boxes where dynamic drivers are located.

Box where dynamic driver is located	Dynamic driver file name	What does dynamic driver do?
pNOB	pNOB.groovy	Calculates proportion of natural origin broodstock.
pNI	pNI.groovy	Calculates proportion of natural influence.
NOR Adults	NORs.groovy	Calculates total number of natural adults returning to Willamette Falls.
NORcounts at LDD Upstream	NORs.groovy	Calculates total number of natural adults returning to Lebanon Diversion Dam.
NORreturnsReachE, F, & G	NORs.groovy	Calculates total number of natural origin adults returning to Reach E, F, & G.
ctr incr	ctr_incr.groovy	A counter to keep track of the year number being simulated.
NOR & HOR Returns DEFG	NOR HOR Returns DEFG.groovy	Calculates total number of natural or hatchery origin adults that returned to Reach D,E,F, & G.
NOR & HOR Returns ABC	NOR HOR Returns ABC.groovy	Calculates total number of natural or hatchery origin adults that returned to Reach A, B, & C.
%Wild ABCDEFG	%Wild.groovy	Calculates percent of natural origin fish with each Reach.
GP res TNH Fry 1-DPE	1-DPE.groovy	Takes proportion from DPE datafile and calculates the proportion of fry that pass head of reservoir collection.
Foster Fry 1-DPE	1-DPE.groovy	Takes proportion from DPE datafile and calculates the proportion of fry that pass dam.
GP Fry 1-DPE	1-DPE.groovy	Takes proportion from DPE datafile and calculates the proportion of fry that pass dam.
Foster Sub-yr1-DPE	1-DPE.groovy	Takes proportion from DPE datafile and calculates the proportion of sub-yearlings that pass dam.
GP Sub-yr 1-DPE	1-DPE.groovy	Takes proportion from DPE datafile and calculates the proportion of sub-yearlings that pass dam.
Foster Yrling 1-DPE	1-DPE.groovy	Takes proportion from DPE datafile and calculates the proportion of yearlings that pass dam.
GP Yrling 1-DPE	1-DPE.groovy	Takes proportion from DPE datafile and calculates the proportion of yearlings that pass dam.
Fall sub-yr	Prop per Strategy-at Smolt.groovy	Calculates proportion of smolts that are fall sub-yearlings.
Sp sub-yr	Prop per Strategy-at Smolt.groovy	Calculates proportion of smolts that are spring sub-yearlings.
2nd Sp yr	Prop per Strategy-at Smolt.groovy	Calculates proportion of smolts that are second spring yearlings.
Tot Reach A, B, C, D, E, & FG	Tot Reach.groovy	Calculates total number of juveniles that exit each Reach (A, B, C, D, E, & FG) separately, and these values are then used to calculate proportion of adults that enter each reach (see Split Influencer below).

Stage where influence script is located	Groovy script file name	What does script do?
NOR or HOR Spawners ABCDE	PSM.groovy	Calculates prespawn survival by using reach specific temperature and % wild as inputs PSM=((-9.5789)+(%wild * -2.39)+(Temp * 0.5492)); modified from Roumasset (2012) equation.
pHOS ABCDEF 2	pHOS ABCDEF 2.groovy	Calculates proportion of hatchery origin spawners.
pNI counter	PNI counter.groovy	A counter to keep track of the year number being simulated.
pHOS ABCDEF 3	pHOS ABCDEF 3.groovy	Calculates proportion of hatchery origin spawners.
NOR Emerg Fry A,B,D,E,F, & G	pNI_NORs Eggs to Emerg Fry.groovy	Calculates proportion of eggs that survive.
HOR Emerg Fry A,B,D,E,F, & G	pNI_HORs Eggs to Emerg Fry.groovy	Calculates proportion of eggs that survive.
NOR Emerg Fry C	pNI_NORs Eggs To Emerg Fry w TDG.groovy	Calculates proportion of eggs that survive w TDG influence.
HOR Emerg Fry C	pNI_HORs Eggs To Emerg Fry w TDG.groovy	Calculates proportion of eggs that survive w TDG influence.
NOR Sp sub-yr C	TDGJ.groovy	Calculates proportion of juveniles that survive the total dissolved gas.
NOR Fall sub-yr C	TDGJ.groovy	Calculates proportion of juveniles that survive the total dissolved gas.
NOR 2nd Sp yr C	TDGJ.groovy	Calculates proportion of juveniles that survive the total dissolved gas.
NOR Sp sub-yr FD Downstream	TDGJ.groovy	Calculates proportion of juveniles that survive the total dissolved gas.
NOR Fall sub-yr FD Downstream	TDGJ.groovy	Calculates proportion of juveniles that survive the total dissolved gas.
NOR 2nd Sp yr FD Downstream	TDGJ.groovy	Calculates proportion of juveniles that survive the total dissolved gas.
Harvest_N2	Harvest_N2s.groovy	

Split where split influencer is located	Stage where groovy script is located	Groovy script file name	What does script do?
Hatchery Adults	HOR Adults	HOR Adults.groovy	Calculates the proportion of Hatchery Adults that stay in river.
	Hatchery returns	Hatchery returns.groovy	Calculates the proportion of Hatchery Adults that return to hatchery.
NOR In-River harvest	NOR Return Av	NOR Return Av.groovy	Calculates the proportion of returning NOR Adults that volitionally go to Reach A.
	NOR Return Bv	NOR Return Bv.groovy	Calculates the proportion of returning NOR Adults that volitionally go to Reach B.
	NOR LDD Upstream	NOR LDD Upstream.groovy	Calculates the proportion of returning NOR Adults that volitionally go to NOR LDD Upstream.
HOR LDD Upstream	HOR Return Dv	HOR Return Dv.groovy	Calculates the proportion of HORs at Lebanon Dam that go to Reach D.
	HOR FCF Upstream	HOR FCF Upstream.groovy	Calculates the proportion of HORs at Lebanon Dam that go to Foster Collection Facility.
	HOR Return Cv	HOR Return Cv.groovy	Calculates the proportion of HORs at Lebanon Dam that go to Reach C.
NOR FCF Upstream	Broodstock	Broodstock.groovy	Calculates the proportion of NORs that go to hatchery broodstock.

Split where split influencer is located	Stage where groovy script is located	Groovy script file name	What does script do?
	NOR Return Ao	NOR Return Ao.groovy	Calculates the proportion of NORs that go to Reach A.
	NOR Return Bo	NOR Return Bo.groovy	Calculates the proportion of NORs that go to Reach B.
	NOR Return Co	NOR Return Co.groovy	Calculates the proportion of NORs that go to Reach C.
	NOR Return Do	NOR Return Do.groovy	Calculates the proportion of NORs that go to Reach D.
	NOR Return E	NOR Return E.groovy	Calculates the proportion of NORs that go to Reach E.
	NOR Return F	NOR Return F.groovy	Calculates the proportion of NORs that go to Reach F.
	NOR Return G	NOR Return G.groovy	Calculates the proportion of NORs that go to Reach G.
HOR FCF Upstream	HOR Return Ao	HOR Return Ao.groovy	Calculates the proportion of HORs that go to Reach A.
	HOR Return Bo	HOR Return Bo.groovy	Calculates the proportion of HORs that go to Reach B.
	HOR Return Co	HOR Return Co.groovy	Calculates the proportion of HORs that go to Reach C.
	HOR Return Do	HOR Return Do.groovy	Calculates the proportion of HORs that go to Reach D.
	HOR Return E	HOR Return E.groovy	Calculates the proportion of HORs that go to Reach E.
	HOR Return F	HOR Return F.groovy	Calculates the proportion of HORs that go to Reach F.
	HOR Return G	HOR Return G.groovy	Calculates the proportion of HORs that go to Reach G.
NOR TNH FG	NOR Fry FG res	NOR Fry FG res.groovy	Calculates the proportion of NORs that go to Green Peter reservoir and depends on DPE.
	NOR Sub-yr FG res	NOR Sub-yr FG res.groovy	Calculates the proportion of NORs that go to Green Peter reservoir and depends on DPE.
	NOR Yrling FG res	NOR Yrling FG res.groovy	Calculates the proportion of NORs that go to Green Peter reservoir and depends on DPE.
	NOR Fry TNG FG	NOR Fry TNG FG.groovy	Calculates the proportion of NORs that go to Green Peter trap and haul and depends on DPE.
NOR Fry FG	NOR Sub-yr FG	NOR Sub-yr FG.groovy	Calculates the proportion of NORs that go to Green Peter Dam and depends on DPE.
	NOR Fry FG FBW	NOR Fry FG FBW.groovy	Calculates the proportion of NORs that go to Green Peter Dam and depends on DPE.
NOR Fry E	NOR Sub-yr E	NOR Sub-yr E.groovy	Calculates the proportion of NORs that go to Green Peter Dam and depends on DPE.
	NOR Fry E FBW	NOR Fry E FBW.groovy	Calculates the proportion of NORs that go to Green Peter Dam and depends on DPE.
NOR Sub-yr FG	NOR Yrling FG	NOR Yrling FG.groovy	Calculates the proportion of NORs that go to Green Peter Dam and depends on DPE.
	NOR Sub-yr FG FBW	NOR Sub-yr FG FBW.groovy	Calculates the proportion of NORs that go to Green Peter Dam and depends on DPE.
NOR Yrling FG	NOR Yrling FG FBW	NOR Yrling FG FBW.groovy	Calculates the proportion of NORs that go to Green Peter Dam and depends on DPE.
	NOR Yrling FG dead	NOR Yrling FG dead.groovy	Calculates the proportion of NORs that go to Green Peter Dam and depends on DPE.
NOR Yrling E	NOR Yrling E FBW	NOR Yrling E FBW.groovy	Calculates the proportion of NORs that go to Green Peter Dam and depends on DPE.
	NOR Yrling E dead	NOR Yrling E dead.groovy	Calculates the proportion of NORs that go to Green Peter Dam and depends on DPE.

7.5. Initialization Values

When SLAM begins a simulation not all of the boxes are populated with fish. As a result, the first several simulated years can show large fluctuations in abundance and frequent extinctions. To reduce these fluctuations many of the boxes are initialized with a number of fish at the start of the model. The values used to initialize these boxes were taken from the 100th year in a previous baseline simulation.

Stage	Initialized
Hatchery Adults	2,100
Hatchery returns	400
NOR Returns	200
Hatchery Spawners	400
HOR Adults	1,500
pNOB	100
pNI	231
NOR Adults	1
NOR In-River harvest	300
NOR Foster CF	1
NORcounts at FosterCF	100
NOR Return A	1
NOR Return B	1
NOR Return C	1
NOR Return D	1
NOR Return E	1
HOR Foster CF	1
HOR Return A	1
HOR Return B	1
HOR Return C	1
HOR Return D	1
HOR Return E	1
pHOS ABCDEF 1	60
ctr incr	-
pNI counter	-
HOR Returns DE	700
NOR Returns DE	6
HOR Returns ABC	700
NOR Returns ABC	300
%Wild B	300
%Wild C	500
%Wild A	40
%Wild D	40
%Wild E	40
NOR Spawners A	1
HOR Spawners A	1
NOR Spawners B	1
HOR Spawners B	1
NOR Spawners C	1
HOR Spawners C	1
NOR Spawners D	1
HOR Spawners D	1
NOR Spawners E	1
HOR Spawners E	1
NOR Tot Spawners A	1
HOR Tot Spawners A	1
NOR Tot Spawners B	1
HOR Tot Spawners B	1
NOR Tot Spawners C	1
HOR Tot Spawners C	1
NOR Tot Spawners D	1
HOR Tot Spawners D	1
NOR Tot Spawners E	1
HOR Tot Spawners E	1
HOR Eggs D	1
NOR Eggs D	1
HOR Eggs C	1
NOR Eggs C	1
HOR Eggs B	1
NOR Eggs B	1
HOR Eggs A	1
NOR Eggs A	1
NOR Eggs E	1
HOR Eggs E	1
NOR & HOR Emerg Fry A	1
NOR & HOR Emerg Fry B	1
NOR & HOR Emerg Fry C	1
NOR & HOR Emerg Fry D	1
NOR & HOR Emerg Fry E	1
HC HoR TNH Fry 1-DPE	-
LOP Fry 1-DPE	54
HC Fry 1-DPE	92
NOR Fry C res	1
NOR Yrling C res	1
NOR Sub-yr C res	1
LOP Sub-yr 1-DPE	40
HC Sub-yr 1-DPE	79
LOP Yrling 1-DPE	49
HC Yrling 1-DPE	75

NOR Sp sub-yr A	1
NOR Fall sub-yr A	1
NOR 2nd Sp yr A	1
NOR Sp sub-yr B	1
NOR Fall sub-yr B	1
NOR 2nd Sp yr B	1
NOR Sp sub-yr JOM B	1,000
NOR Sp sub-yr JOM A	1,000
NOR Sp sub-yr Smolts	400
HOR Smolts	250,000
NOR Fall sub-yr JOM A	1
NOR Fall sub-yr JOM B	1
NOR 2nd Sp yr JOM B	1
NOR Fall sub-yr Smolts	400
NOR 2nd Sp yr JOM A	1
NOR 2nd Sp yr Smolts	400
Sp sub-yr	1,000
Fall sub-yr	1,000
2nd yr	1,000
NOR Age 2	1,000
HOR Age 2	45,000
Tot Reach A	100
Tot Reach B	250
Tot Reach C	1,000
Tot Reach DE	-
Count FryD	-
Count FryE	-
NOR Age 3	750
HOR Age 3	35,000
NOR Age 4	350
HOR Age 4	22,500
NOR Age 5	275
HOR Age 5	17,500
NOR Age 6	5
HOR Age 6	250

7.5.1. Model Demonstration & Alternative Scenarios

Here we report results from SLAM model runs that evaluated potential population responses to a set of the most recent dam project alternatives (received June 3, 2014) identified by the USACE. Below (Table 7.3) is a list of alternatives that represent various operational and structural modifications to Foster and Green Peter dams whose goal is to improve access to Reach E. F, and G (above Foster and Green Peter dams). Each alternative was run in SLAM and estimates were produced of several variables including abundance of natural origin spawners and each life history strategy, and percent wild. Each alternative was run 500 times, and each run is 100 years long. We used 500 runs because output stabilized at this level. USACE provided datafiles of dam passage survival and efficiency (Fish Benefit Workbook), which were time series of 73 years in length, and we duplicated them to produce time series that were 146 years in length. All alternatives were provided by USACE.

Table 7.3: List of alternatives run in the SLAM model of South Santiam River Chinook salmon. Alternatives vary in terms of dam passage survival, efficiency, and the influence of total dissolved gas (TDG) (it is assumed that trap and haul alternatives will release fish below any TDG influence). Abbreviations: Foster Dam (FOS), Green Peter Dam (GPD), selective withdrawal structure (SWS), floating surface collector (FSC), Floating screen structure (FSS), continuous weir (ContWeir), redesign weir 860cfs (Weir860), fish horn (FishHorn), fish friendly turbine (FriendTurb), and head of reservoir (HoR). Description of each alternative can be found in Appendix D.

	Foster Alternative Description	Green Peter Alternative Description	Alternative Description	Foster Dam hauled below Foster TDG?	Green Peter hauled below Foster TDG? (i.e., fish don't pass thru Foster)	Foster Dam Passage survival (average %)			Foster Dam 1-DPE (average %)			Green Peter Dam Passage survival (average %)			Green Peter Dam 1-DPE (average %)			Green Peter HoR	
						Fry	Sub-yr	Yrling	Fry	Sub-yr	Yrling	Fry	Sub-yr	Yrling	Fry	Sub-yr	Yrling	1-DPE (%)	Passage survival (%)
1	Baseline	Baseline	Baseline	N	N	87	81	77	20	20	20	64	32	30	33	90	60	0	0
2	Baseline	Fish Horn	FOS_Baseline-GPD_FishHorn	N	N	87	81	77	20	20	20	92	83	88	19	20	19	0	0
3	Baseline	Spillway & Powerhouse	FOS_Baseline-GPD_SpillPwr	N	N	87	81	77	20	20	20	79	40	47	33	90	60	0	0
4	Baseline	Selective Withdrawal Str, Floating Screen Str	FOS_Baseline-GPD_SWS-FSS	N	Y	87	81	77	20	20	20	96	86	91	19	20	19	0	0
5	Baseline	Selective Withdrawal Str - Only	FOS_Baseline-GPD_SWS	N	N	87	81	77	20	20	20	64	30	31	19	20	19	0	0
6	Baseline	Floating Surface Collector	FOS_Baseline-GPD_FSC	N	Y	87	81	77	20	20	20	93	86	90	19	20	19	0	0
7	Baseline	HoR Opt 1: DPE: 30%; Passage Survival: 70%	FOS_Baseline-GPD_Baseline HoR1	N	Y	87	81	77	20	20	20	64	32	30	33	90	60	70	70
8	Baseline	HoR Opt 2: DPE: 80%; Passage Survival: 90%	FOS_Baseline-GPD_Baseline HoR2	N	Y	87	81	77	20	20	20	64	32	30	33	90	60	20	90
9	Continous Weir	Baseline	FOS_ContWeir-GPD_Baseline	N	N	88	83	79	20	20	20	64	32	30	33	90	60	0	0
10	Weir 860	Baseline	FOS_Weir860-GPD_Baseline	N	N	92	91	89	20	20	20	64	32	30	33	90	60	0	0
11	Fish Friendly Turbines	Baseline	FOS_FriendTurb-GPD_Baseline	N	N	92	92	92	20	20	20	64	32	30	33	90	60	0	0
12	Baseline w spill	Baseline	FOS_Baseline wSpill-GPD_Baseline	N	N	87	81	78	20	20	20	64	32	30	33	90	60	0	0
13	Weir 860	Fish Horn	FOS_Weir860-GPD_FishHorn	N	N	92	91	89	20	20	20	92	83	88	19	20	19	0	0
14	Fish Friendly Turbines	Selective Withdrawal Str, Floating Screen Str	FOS_FriendTurb-GPD_SWS-FSS	N	Y	92	92	92	20	20	20	96	86	91	19	20	19	0	0
15	Fish Friendly Turbines	Selective Withdrawal Str - Only	FOS_FriendTurb-GPD_SWS	N	N	92	92	92	20	20	20	64	30	31	19	20	19	0	0

7.5.2. Parameter Variability

The following tables identify parameters that vary among years in each model run. In all the parameters listed below (except passage survival and estuary and ocean survival) values are randomly selected each model year from the specified distribution and these distributions and parameters defining them do not vary among alternatives (Table 7.4). For any given alternative, passage survival values vary among years of a model run, but do not vary among the 500 model runs (passage survival values are taken from a datafile). Values of passage survival vary among alternatives (Table 7.5). For any given alternative, estuary and ocean survival values vary among years of a model run, but do not vary among the 500 model runs (estuary and ocean survival values are taken from a datafile). Values of estuary and ocean survival do not vary among alternatives (Table 7.6).

Table 7.4: Capacity and survival parameters whose values vary among years in each model run and vary among model runs.

Location in Life Cycle	From	To	Curve type	Capacity & Productivity	Distribution type	Mean	SD	Min	Max
Reach A mainstem Downstream of Lebanon	NOR Tot Spawners	Eggs	Beverton-Holt	Capacity	Normal	150,000	33,000	75,000	200,000
Reach B tribs Downstream of Lebanon	NOR Tot Spawners	Eggs	Beverton-Holt	Capacity	Normal	1,000,000	200,000	500,000	2,500,000
Reach C between Lebanon & Foster dams	NOR Tot Spawners	Eggs	Beverton-Holt	Capacity	Normal	3,000,000	250,000	1,000,000	5,500,000
Reach D Wiley Creek	NOR Tot Spawners	Eggs	Beverton-Holt	Capacity	Normal	500,000	33,000	250,000	700,000
Reach E upstream of Foster reservoir	NOR Tot Spawners	Eggs	Beverton-Holt	Capacity	Normal	7,000,000	250,000	4,000,000	9,000,000
Reach F Quartzville Creek	NOR Tot Spawners	Eggs	Beverton-Holt	Capacity	Normal	2,000,000	250,000	1,000,000	12,000,000
Reach G Middle Santiam River upstream of Green Peter Reservoir	NOR Tot Spawners	Eggs	Beverton-Holt	Capacity	Normal	4,500,000	250,000	4,000,000	12,000,000
Reach A mainstem Downstream of Lebanon	HOR Tot Spawners	Eggs	Beverton-Holt	Capacity	Normal	150,000	33,000	75,000	200,000
Reach B tribs Downstream of Lebanon	HOR Tot Spawners	Eggs	Beverton-Holt	Capacity	Normal	1,000,000	200,000	500,000	2,500,000
Reach C between Lebanon & Foster dams	HOR Tot Spawners	Eggs	Beverton-Holt	Capacity	Normal	3,000,000	250,000	1,000,000	5,500,000
Reach D Wiley Creek	HOR Tot Spawners	Eggs	Beverton-Holt	Capacity	Normal	500,000	33,000	250,000	700,000
Reach E upstream of Foster reservoir	HOR Tot Spawners	Eggs	Beverton-Holt	Capacity	Normal	7,000,000	250,000	4,000,000	9,000,000
Reach F Quartzville Creek	HOR Tot Spawners	Eggs	Beverton-Holt	Capacity	Normal	2,000,000	250,000	1,000,000	12,000,000
Reach G Middle Santiam River upstream of Green Peter Reservoir	HOR Tot Spawners	Eggs	Beverton-Holt	Capacity	Normal	4,500,000	250,000	4,000,000	12,000,000
Hatchery	Hatchery returns	Hatchery Spawners	Hockey-Stick	Capacity	Normal	1,000	100	700	1,100
Hatchery	Hatchery Spawners	HOR JOM	Hockey-Stick	Capacity	Normal	1,021,000	25,000	950,000	1,100,000
Reach E	NOR Fry E res	NOR Sub-yr E	Linear	Productivity	Triangular	0.20		0.15	0.35
Reach E	NOR Sub-yr E res	NOR Yrling E	Linear	Productivity	Uniform			0.40	0.90
Reach FG	NOR Fry FG res	NOR Sub-yr FG	Linear	Productivity	Triangular	0.20		0.50	0.35
Reach FG	NOR Sub-yr FG res	NOR Yrling FG	Linear	Productivity	Triangular	0.75		0.60	0.9
Reach FG	NOR Fry FG	NOR Sub-yr FG	Linear	Productivity	Triangular	0.20		0.15	0.35
Reach E	NOR Fry E	NOR Sub-yr E	Linear	Productivity	Triangular	0.20		0.15	0.35
Reach FG	NOR Fry FG FD	NOR Sub-yr FG FD	Linear	Productivity	Triangular	0.20		0.15	0.35
Reach FG	NOR Sub-yr FG	NOR Yrling FG	Linear	Productivity	Triangular	0.75		0.60	0.9
Reach E	NOR Sub-yr E	NOR Yrling E	Linear	Productivity	Uniform			0.40	0.90
Reach FG	NOR Sub-yr FG FD	NOR Yrling FG FD	Linear	Productivity	Uniform			0.40	0.90

Table 7.5: Average, minimum, and maximum passage survival for each alternative and life history strategy. These values vary among years of a model run but do not vary among model runs.

FBW		Average Passage Survival			Min Passage Survival			Max Passage Survival		
Output File name	Alternative	Fry	Sub-yr	Yrling	Fry	Sub-yr	Yrling	Fry	Sub-yr	Yrling
Ch_FOS_1	Foster-Baseline	0.87	0.81	0.77	0.85	0.80	0.74	0.89	0.83	0.81
Ch_FOS_2	Foster-Continous Weir	0.88	0.83	0.79	0.86	0.81	0.76	0.89	0.84	0.82
Ch_FOS_3aa	Foster-Weir 860	0.92	0.91	0.89	0.89	0.82	0.82	0.94	0.92	0.91
Ch_FOS_7	Foster-Fish Friendly Turbines	0.92	0.92	0.92	0.92	0.92	0.92	0.93	0.92	0.93
Ch_FOS_8	Foster-Baseline w spill	0.87	0.81	0.78	0.86	0.80	0.76	0.89	0.83	0.81
Ch_GPR_1	Green Peter-Baseline	0.64	0.32	0.30	0.64	0.29	0.29	0.66	0.42	0.36
Ch_GPR_2	Green Peter-Fish Horn	0.92	0.83	0.88	0.91	0.47	0.72	0.93	0.88	0.91
Ch_GPR_5	Green Peter-Selective Withdrawal Str, Floating Screen Str	0.96	0.86	0.91	0.92	0.84	0.85	0.97	0.88	0.97
Ch_GPR_6	Green Peter-Selective Withdrawal Str - Only	0.64	0.30	0.31	0.64	0.29	0.29	0.66	0.31	0.36

Table 7.6: Average, minimum, and maximum survival values during estuary and ocean stages. Age-specific time series of estuary and ocean survival were generated by ODFW, and incorporated into SLAM as datafiles.

Stage	Min	Average	Max
Estuary	0.61	0.66	0.70
Ocean 2yr olds	0.22	0.35	0.51
Ocean 3yr olds	0.28	0.46	0.67
Ocean 4yr olds	0.33	0.54	0.78
Ocean 5yr olds	0.42	0.68	0.99
Ocean 6yr olds	0.47	0.76	1

7.5.3. SLAM Output and VSP Scores

For each alternative run in SLAM, four categories of model output are produced; abundance and productivity, proportion of hatchery origin spawners, life history diversity, and spatial structure (see Chapter 3, Parameterization of VSP Criteria). For each of these categories we generate VSP scores, and then use the following equation to produce a Total VSP score:

$$Total\ VSP\ score = \frac{2(Abundance) + 2(Productivity) + Diversity + Spatial\ Structure}{6}$$

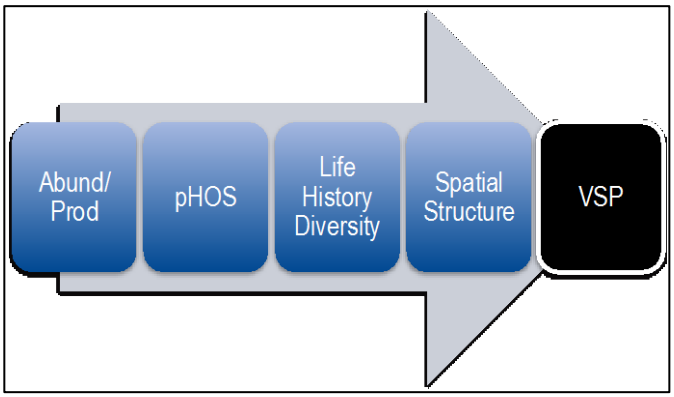


Figure 7.3: Representation of the four components (abundance and productivity, proportion of hatchery origin spawners, life history diversity, and spatial structure) that comprise VSP score.

Abundance and Productivity

Under Baseline (i.e., current) conditions a median of 776 natural origin spawners was estimated for South Santiam River, while the alternative that had a Fish Friendly Turbine (FriendTurb) at Foster Dam and Selective Withdrawal Structure and Floating Screen Structure (SWS-FSS) at Green Peter Dam (FOS_FriendTurb-GPD_SWS-FSS) was estimated to have a median of 3,208 individuals (Figure 7.4 and Table 7.3).

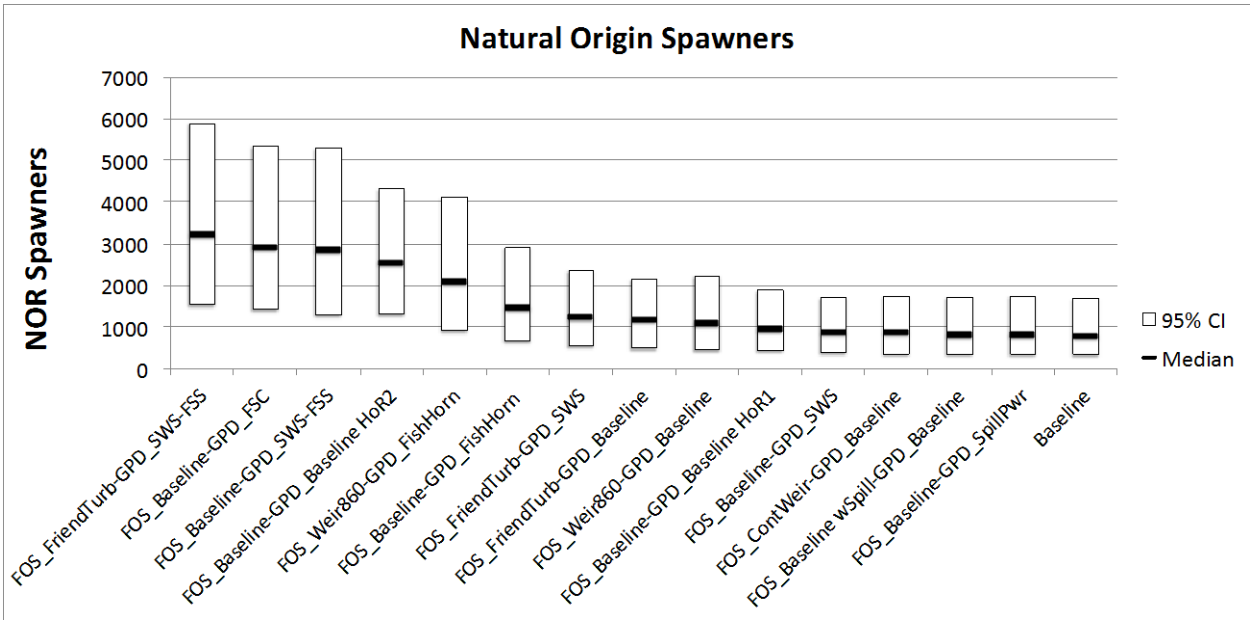


Figure 7.4: Abundance of natural origin spawners among South Santiam River alternatives (see Table 7.3). Median and 95% confidence limits (line and box, respectively) were calculated from the 500 geomeans (1 geomean per run) of abundance, each of which was for a 100-year period.

We estimated the probability quasi-extinction threshold (QET) for each alternative under the following conditions; critical abundance was set as 250 individuals (set by the Lower Columbia/Willamette TRT), a four-year moving average was used over a 100-year period (from year 6 to year 105). We started QET calculation at year 6 because the model was fully initialized beyond this point and reflected system dynamics rather than the influences of starting values. Under Baseline (i.e., current) conditions, QET was estimated as 90% for the South Santiam River, while it was 17.4% for the alternative that had a Fish Friendly Turbine (FriendTurb) at Foster Dam and Selective Withdrawal Structure and Floating Screen Structure (SWS-FSS) at Green Peter Dam (FOS_FriendTurb-GPD_SWS-FSS) (Figure 7.5).

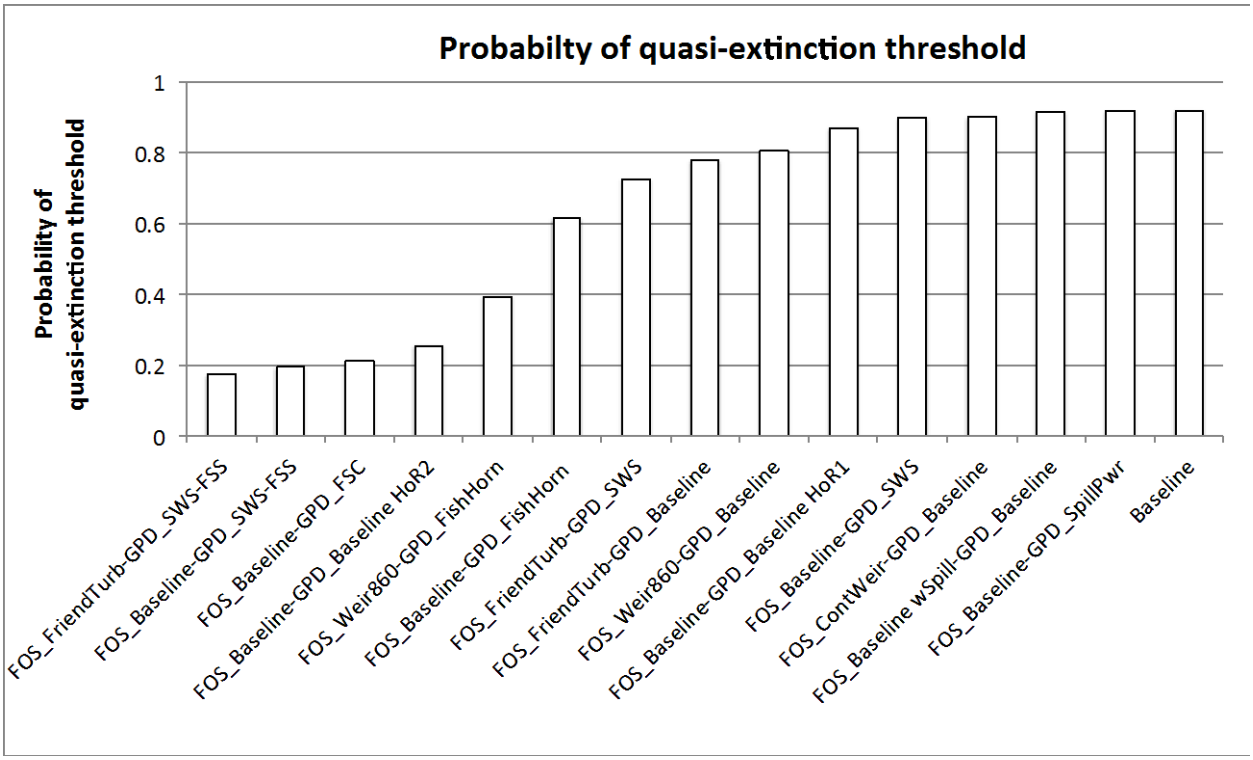


Figure 7.5: Probability of quasi-extinction among South Santiam River alternatives.

Based on a relationship between VSP score and abundance and productivity (see Chapter 3, Parameterization of VSP Criteria), the Baseline (i.e., current) conditions received a median VSP score of 0.05, while the alternative that had a Fish Friendly Turbine (FriendTurb) at Foster Dam and Selective Withdrawal Structure and Floating Screen Structure (SWS-FSS) at Green Peter Dam (FOS_FriendTurb-GPD_SWS-FSS) yielded a median VSP score of 2.9 (Figure 7.6).

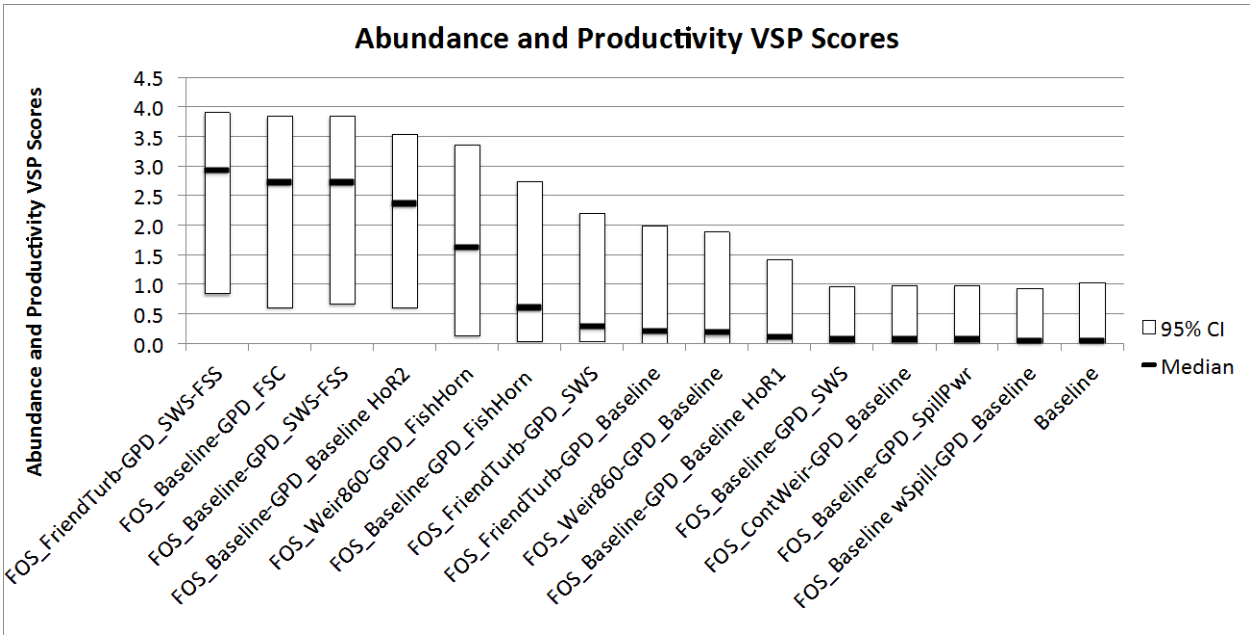


Figure 7.6: Abundance and Productivity VSP scores among South Santiam Fork River alternatives.

Proportion of Hatchery Origin Spawners

Under Baseline (i.e., current) conditions, the median proportion of hatchery origin spawners was estimated as 0.46, while the alternative that had a Fish Friendly Turbine (FriendTurb) at Foster Dam and Selective Withdrawal Structure and Floating Screen Structure (SWS-FSS) at Green Peter Dam (FOS_FriendTurb-GPD_SWS-FSS) was estimated to have a median of 0.09 (a median of 0.13 was estimated for FOS_Baseline-GPD_SWS-FSS and FOS_Baseline-GPD_FSC alternatives). This decline in the proportion of hatchery origin spawners for the FOS_FriendTurb-GPD_SWS-FSS alternative (also for FOS_Baseline-GPD_SWS-FSS and FOS_Baseline-GPD_FSC) is due to an increase in natural origin spawners that resulted from improved dam passage efficiency and survival relative to the Baseline (Figure 7.7).

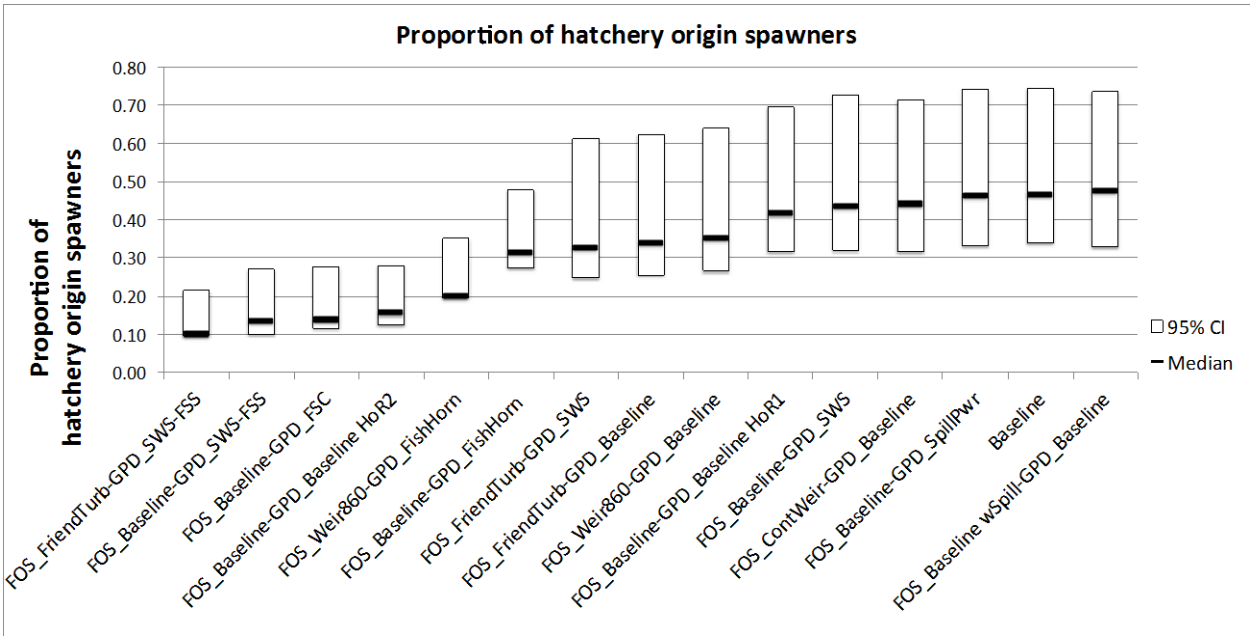


Figure 7.7: Proportion of hatchery origin spawners among South Santiam River alternatives (see Table 7.3). Median and standard deviation are shown (line and box, respectively), which were calculated at the final simulated year using all 500 SLAM trajectories.

The VSP score for proportion of hatchery origin spawners is calculated based on a combination of proportion of natural influence and proportion of hatchery origin spawners (see Chapter 3). Under Baseline (i.e., current) conditions, a median VSP score of 1.6 was estimated, while the alternative that had a Fish Friendly Turbine (FriendTurb) at Foster Dam and Selective Withdrawal Structure and Floating Screen Structure (SWS-FSS) at Green Peter Dam (FOS_FriendTurb-GPD_SWS-FSS) had a median VSP score of 3.7 (Figure 7.8).

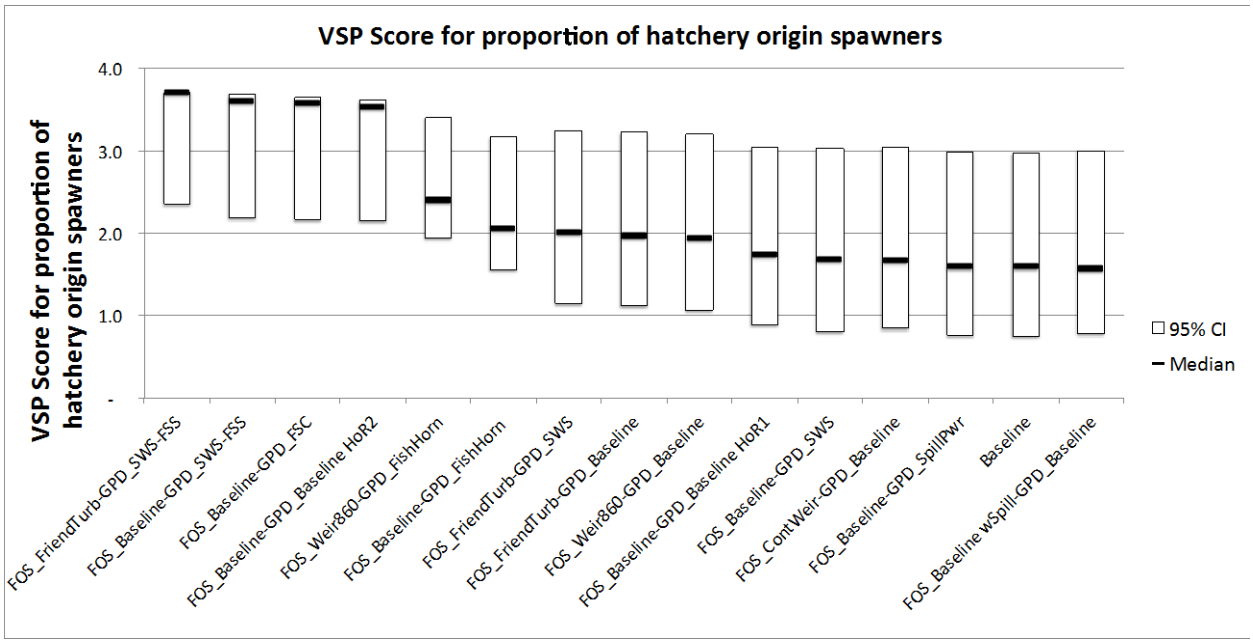


Figure 7.8: Proportion of Hatchery Origin Spawners VSP scores among South Santiam River alternatives. Median and standard deviation are shown (line and box, respectively), which were calculated using the median and standard deviation of PNI and pHOS.

Life History Diversity

Moving from baseline conditions to FOS_Baseline-GPD_Baseline-HoR2, the number of spring subyearlings increased but not as much as the numbers of fall subyearlings and spring yearlings (Fig. 7.9). The composition of each life history was the most similar to baseline conditions in five alternatives (FOS_Baseline-GPD_SpillPwr, FOS_Baseline-GPD_SWS, FOS_Baseline-GPD_Baseline HoR1, FOS_ContWeir-GPD_Baseline, and FOS_Baseline wSpill-GPD_Baseline).

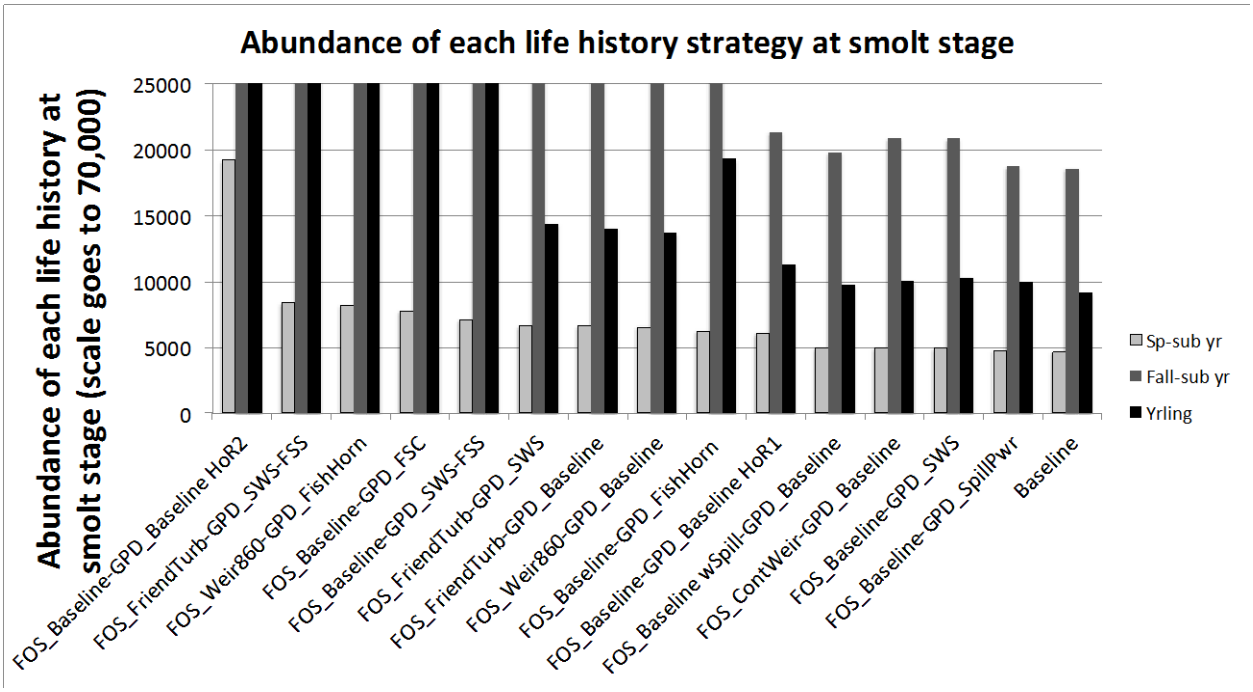


Figure 7.9: Median smolt abundance for each life history strategy among alternatives (see Table 7.3). Median was calculated at the final simulated year using all 500 SLAM trajectories. Standard deviation is excluded to improve clarity.

If number of individuals of a given life history strategy falls below 5000 then 0.5 VSP point was subtracted from an initial 4.0 VSP score for that alternative, and if the number of individuals of a given life history strategy falls below 1000 then 1.0 VSP point was subtracted from the VSP score. This is determined for each life history strategy. Under Baseline (i.e., current) conditions, SLAM estimated a median VSP score of 3.5, while the alternative that had a Fish Friendly Turbine (FriendTurb) at Foster Dam and Selective Withdrawal Structure and Floating Screen Structure (SWS-FSS) at Green Peter Dam (FOS_FriendTurb-GPD_SWS-FSS) was estimated to be 4.0 (Figure 7.10).

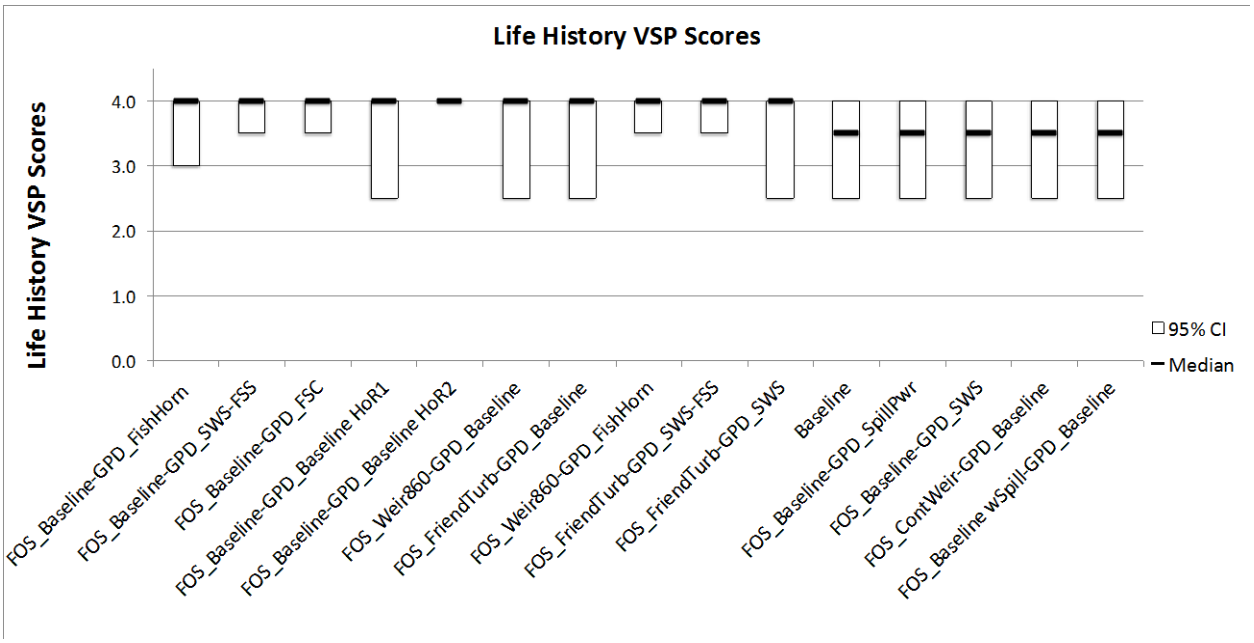


Figure 7.10: Life History Diversity VSP scores among South Santiam River alternatives. Median and standard deviation are shown (line and box, respectively), which were calculated using the median and standard deviation of abundance of smolts among life history strategies.

Spatial Structure

Spatial structure is a measure of population replacement above Foster and Green Peter dams (reaches E, F, and G). To assess replacement above dams we used recruits per spawner, measured as returning spawners referenced to the spawning brood that produced them (i.e., the spawner to spawner).

$$Spawner{:}Spawner = \frac{Natural\ origin\ spawners\ in\ Reach\ C\ at\ time\ y + 4yrs}{Hatchery\ origin\ spawners\ in\ Reach\ C\ at\ time\ y + Natural\ origin\ spawners\ in\ Reach\ C\ at\ time\ y}$$

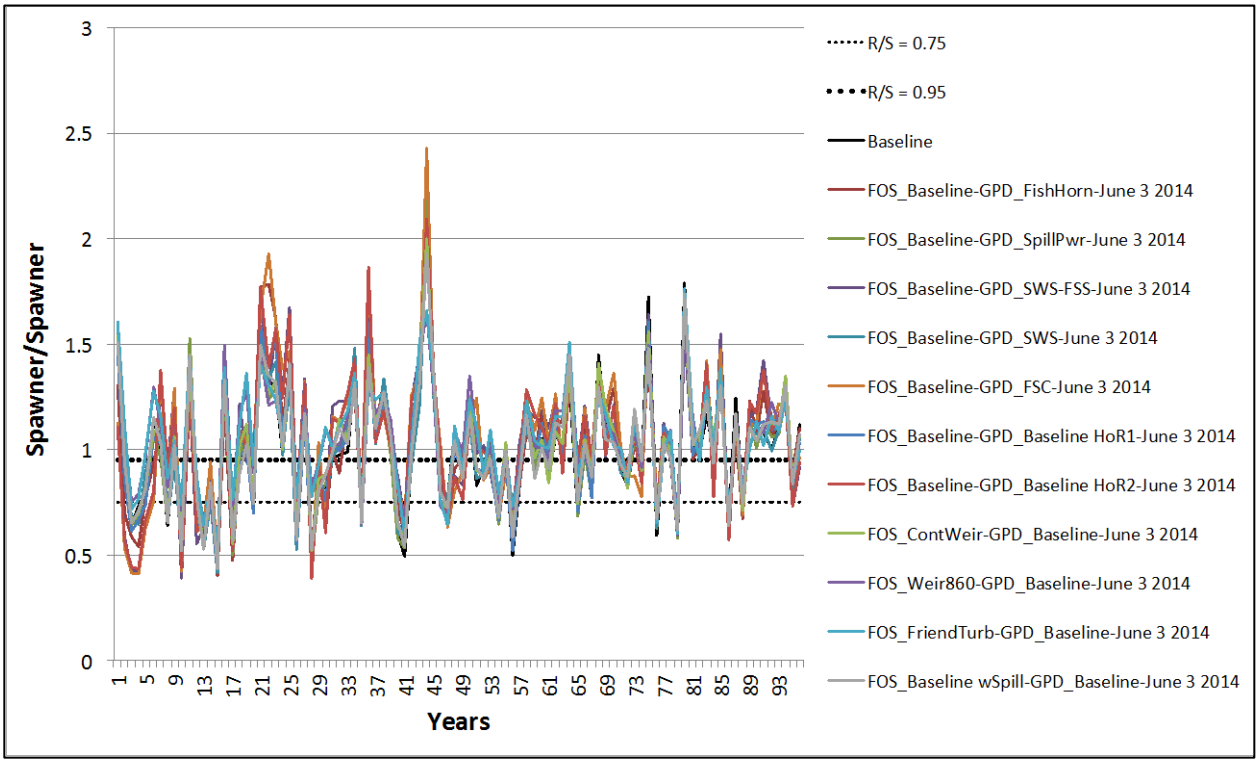


Figure 7.11: Times series of spawner-to-spawner ratio for Reach E (above Foster Dam) for each South Santiam River alternative. See text above for the equation used to calculate spawner-to-spawner ratio.

For each alternative and for each of the Reaches (E, F, and G) we calculated a median spawner-to-spawner ratio over all simulated years. The overall VSP score was determined by a combination of spawner-to-spawner ratios for all Reaches (see Table 7.4 and Chapter 3, Parameterization of VSP Criteria, for more details).

!	!	Reach!FG!(QC,MS)!		
!	!	<0.75!	0.75<x<0.95!	>0.95!
!	<0.75!	2.0!	2.33!	2.5!
Reach!E!(SSR)!	0.75<x<0.95!	2.33!	2.4!	3.17!
!	>0.95!	2.5!	3.17!	3.5!

Table 7.4: VSP scores associated with spawner-to-spawner ratios for Reach E and FG.

Under Baseline conditions, the median VSP score for Spatial Structure was 2.5, while the alternative that had a Fish Friendly Turbine (FriendTurb) at Foster Dam and Selective Withdrawal Structure and Floating Screen Structure (SWS-FSS) at Green Peter Dam (FOS_FriendTurb-GPD_SWS-FSS) was estimated as 3.5 (Figure 7.12).

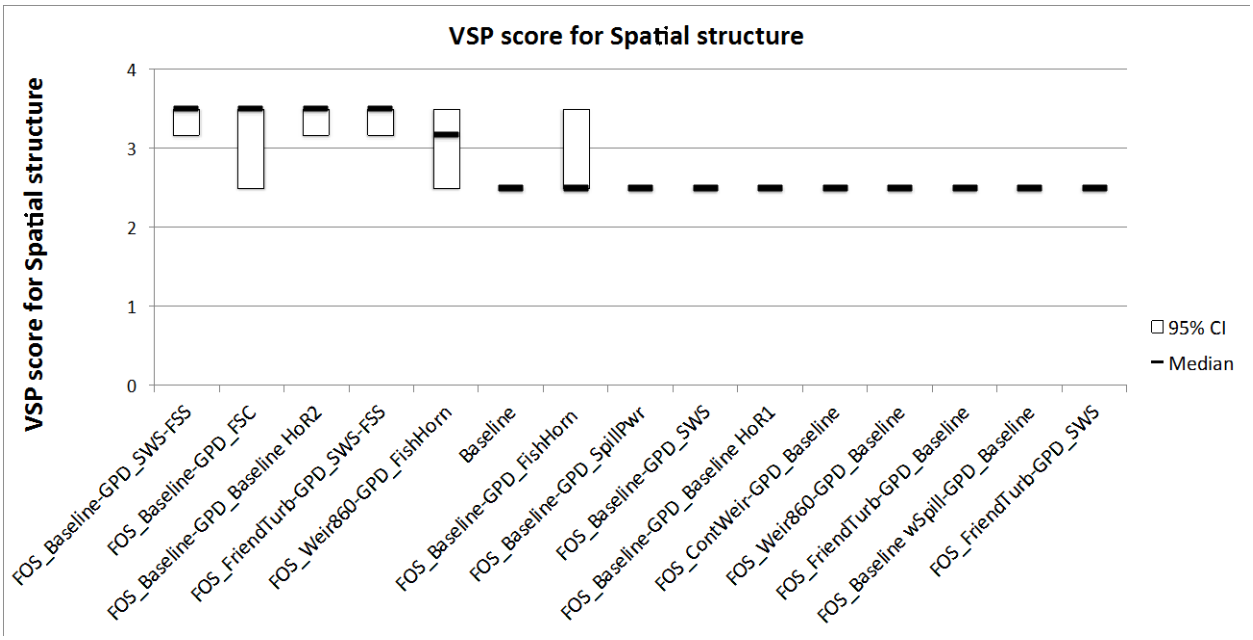


Figure 7.12: Spatial Structure VSP scores among South Santiam River alternatives. Median and standard deviation are shown (line and box, respectively), which were calculated using the median and standard deviation of spawner-to-spawner ratio.

Total VSP Score

To estimate the Total VSP score, we combined all the component VSP scores according to the following equation:

$$Total\ VSP\ score = \frac{2(Abundance) + 2(Productivity) + Diversity + Spatial\ Structure}{6}$$

Of the South Santiam River alternatives, the greatest Total VSP Score of 3.2 came from the alternative that had a Fish Friendly Turbine (FriendTurb) at Foster Dam and Selective Withdrawal Structure and Floating Screen Structure (SWS-FSS) at Green Peter Dam (FOS_FriendTurb-GPD_SWS-FSS), while Baseline conditions yielded a score of 0.9 (Figure 7.13).

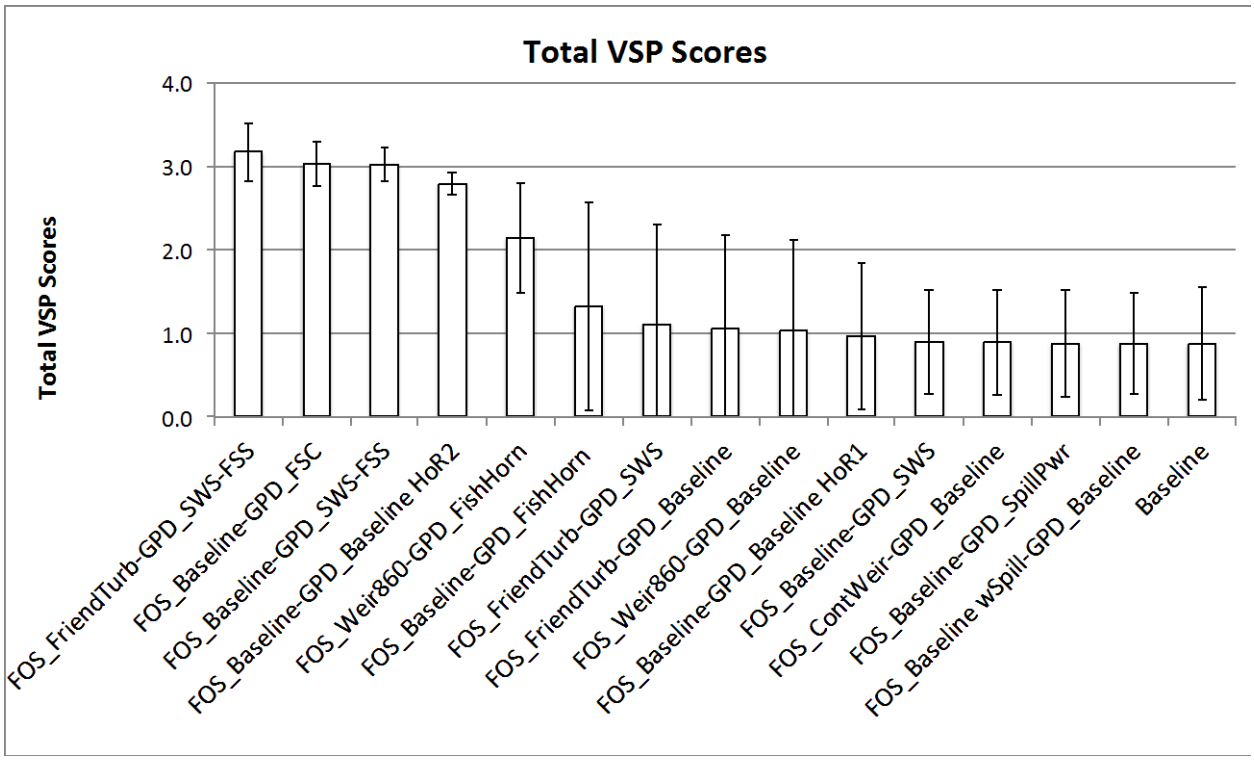


Figure 7.13: Total VSP scores among South Santiam River alternatives. Whiskers denote +/- one standard deviation.

7.6. References

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CHAPTER 8. SLAM MODEL OF NORTH SANTIAM RIVER WINTER STEELHEAD

This chapter provides a description of the parameter values used in the North Santiam River SLAM model for steelhead salmon. Below, we provide a short description of the model parameters used in each of five categories (1. Productivity, capacity, & survivals, 2. Splits, 3. Datafiles, 4. Dynamic drivers & influencers, and 5. Initialized). For reference purposes, a map of North Santiam River (Figure 8.1) is provided that highlights each reach used in SLAM. Figure 8.2 shows how the life-cycle model is modeled within SLAM. Lastly, Table 8.1 is a list of definitions corresponding to each box within the life-cycle model, while Table 8.2 is a list of abbreviations used throughout this chapter.

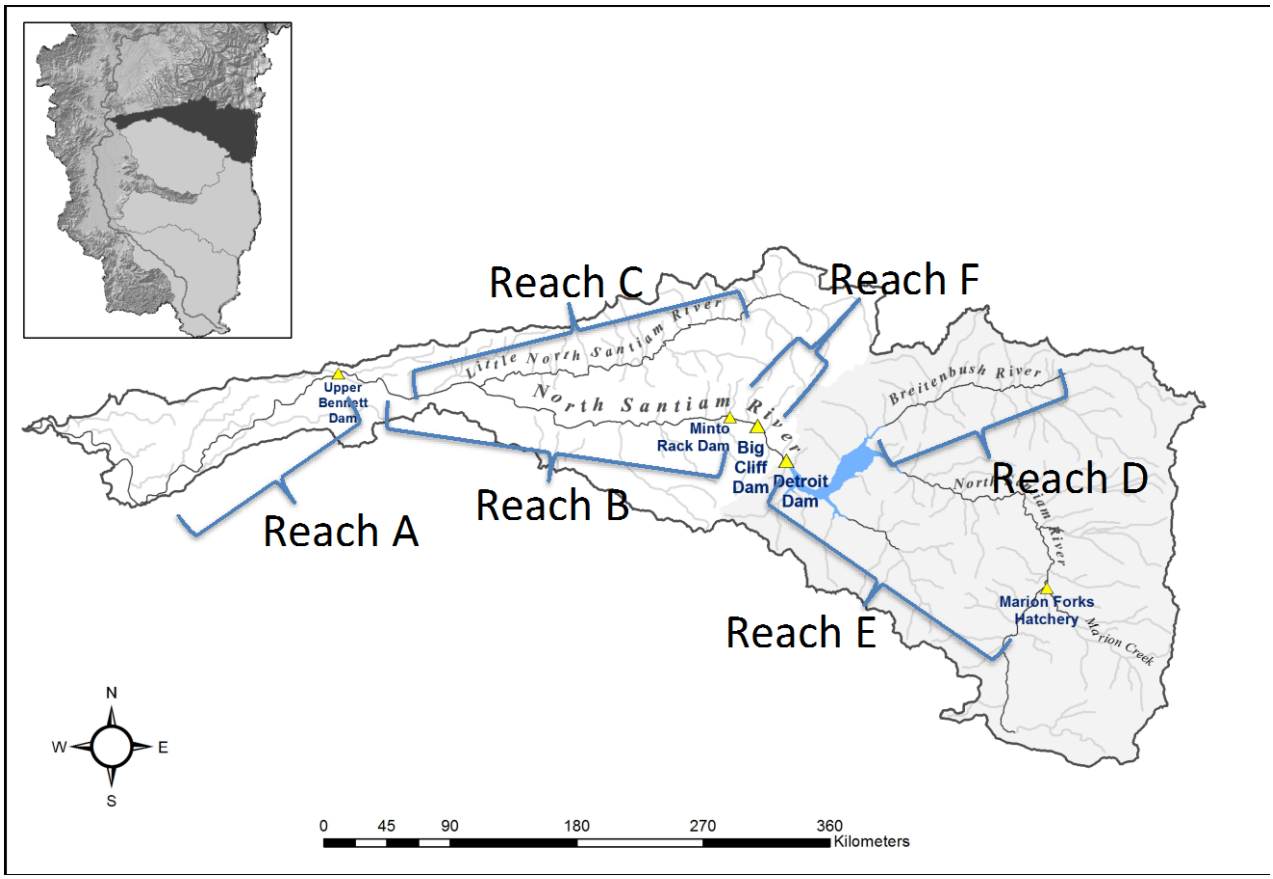


Figure 8.1: Map showing North Santiam River and the six reaches (A-F) that are modeled in SLAM; Reach A corresponds to mainstem North Santiam River downstream of Upper Bennett Dam, Reach B corresponds to mainstem North Santiam River between Upper Bennett Dam and the Minto Collection Facility, Reach C corresponds to Little North Santiam River, Reach D corresponds to Breitenbush River, Reach E corresponds to North Santiam River upstream of Detroit Dam, and Reach F corresponds to maintstem North Santiam River from Minto Collection Facility to Big Cliff Dam.

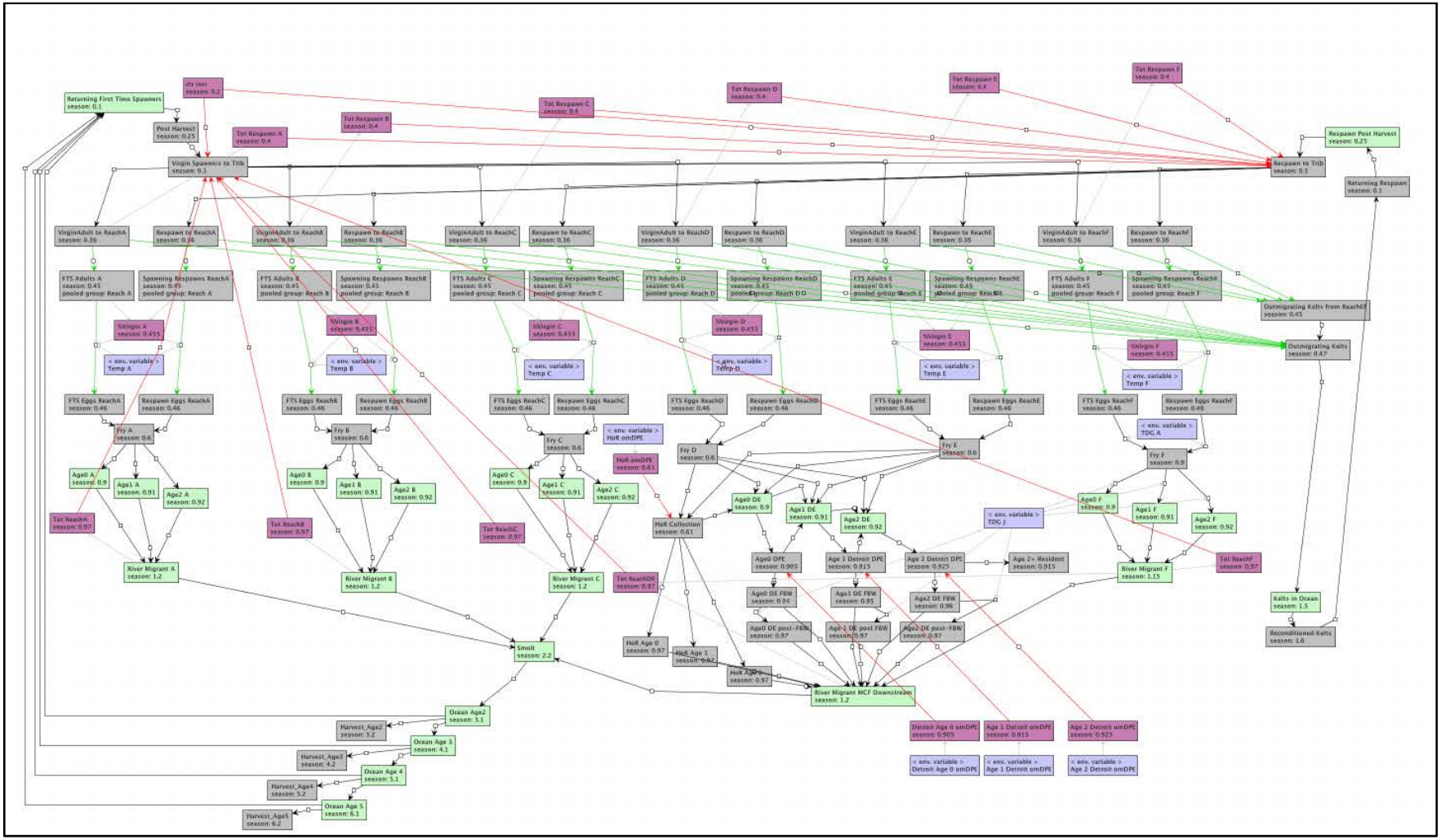


Figure 8.2: SLAM generated flow diagram of North Santiam River Steelhead salmon life cycle model. Details of this model are provided in Table 8.1 and subsequent figures in this chapter will emphasize components of this diagram..

Table 8.1: Life history stages and transitions for the North Santiam River Steelhead salmon life cycle model (Figure 8.2).

Life Stage	Definition
Returning Respawn	Kelts returning to freshwater
Returning First Time Spawners	Virgin adults returning to freshwater
Post Harvest	Freshwater harvest of returning virgin adults
Repsawn Post Harvest	Freshwater harvest of returning Kelts
Virgin Spawners to Trip	Returning virgin adults to mouth of North Santiam
Respawn to Trib	Returning Kelts to mouth of North Santiam
Respawn to Reach A	Returning Kelts to below Bennett Dam (Reach A)
Respawn to Reach B	Returning Kelts to between Bennett Dam and Minto Collection Facility (Reach B)
Respawn to Reach C	Returning Kelts to Little North Santiam (Reach C)
Respawn to Reach D	Returning Kelts to Breitenbush River (Reach D)
Respawn to Reach E	Returning Kelts to North Santiam River, upstream of Detroit Dam (Reach E)
Respawn to Reach F	Returning Kelts to between Minto Collection Facility and Detroit Dam (Reach F)
VirginAdult to ReachA	Returning virigin adults to below Bennett Dam (Reach A)
VirginAdult to ReachB	Returning virigin adults to between Bennett Dam and Minto Collection Facility (Reach B)
VirginAdult to ReachC	Returning virigin adults to Little North Santiam (Reach C)
VirginAdult to ReachD	Returning virigin adults to Breitenbush River (Reach D)
VirginAdult to ReachE	Returning virigin adults to North Santiam River, upstream of Detroit Dam (Reach E)
VirginAdult to ReachF	Returning virigin adults to between Minto Collection Facility and Detroit Dam (Reach F)
Spawning Respawns ReachA	Adults available to respawn in Reach A
Spawning Respawns ReachB	Adults available to respawn in Reach B
Spawning Respawns ReachC	Adults available to respawn in Reach C
Spawning Respawns ReachD	Adults available to respawn in Reach D
Spawning Respawns ReachE	Adults available to respawn in Reach E
Spawning Respawns ReachF	Adults available to respawn in Reach F
FTS Adults A	Adults available to spawn in Reach A
FTS Adults B	Adults available to spawn in Reach B
FTS Adults C	Adults available to spawn in Reach C
FTS Adults D	Adults available to spawn in Reach D
FTS Adults E	Adults available to spawn in Reach E
FTS Adults F	Adults available to spawn in Reach F
Outmigrating Kelts from ReachEF	Adults from Reach E and F that return to ocean as Kelts
Outmigrating Kelts	Adults from Reach A, B, C, and D that return to ocean as Kelts
Respawn Eggs ReachA	Eggs in Reach A produced by adult respawners in Reach A
Respawn Eggs ReachB	Eggs in Reach B produced by adult respawners in Reach B
Respawn Eggs ReachC	Eggs in Reach C produced by adult respawners in Reach C
Respawn Eggs ReachD	Eggs in Reach D produced by adult respawners in Reach D
Respawn Eggs ReachE	Eggs in Reach E produced by adult respawners in Reach E

Respawn Eggs ReachF	Eggs in Reach F produced by adult respawners in Reach F
FTS Eggs ReachA	Eggs in Reach A produced by adult virgins in Reach A
FTS Eggs ReachB	Eggs in Reach B produced by adult virgins in Reach B
FTS Eggs ReachC	Eggs in Reach C produced by adult virgins in Reach C
FTS Eggs ReachD	Eggs in Reach D produced by adult virgins in Reach D
FTS Eggs ReachE	Eggs in Reach E produced by adult virgins in Reach E
FTS Eggs ReachF	Eggs in Reach F produced by adult virgins in Reach F
Fry A	Fry in Reach A produced adult virgins and respawners in Reach A
Fry B	Fry in Reach B produced adult virgins and respawners in Reach B
Fry C	Fry in Reach C produced adult virgins and respawners in Reach C
Fry D	Fry in Reach D produced adult virgins and respawners in Reach D
Fry E	Fry in Reach E produced adult virgins and respawners in Reach E
Fry F	Fry in Reach F produced adult virgins and respawners in Reach F
HoR Collection	Fry from Reach E & F collected at head of Detroit reservoir
Age0 A	Fish of age class 0 in Reach A
Age0 B	Fish of age class 0 in Reach B
Age0 C	Fish of age class 0 in Reach C
Age0 DE	Fish of age class 0 in Reach DE
Age0 F	Fish of age class 0 in Reach F
Age1 A	Fish of age class 1 in Reach A
Age1 B	Fish of age class 1 in Reach B
Age1 C	Fish of age class 1 in Reach C
Age1 DE	Fish of age class 1 in Reach DE
Age1 F	Fish of age class 1 in Reach F
Age2 A	Fish of age class 2 in Reach A
Age2 B	Fish of age class 2 in Reach B
Age2 C	Fish of age class 2 in Reach C
Age2 DE	Fish of age class 2 in Reach DE
Age2 F	Fish of age class 2 in Reach F
Age0 DPE	Fish of age class 0 available to pass Detroit Dam
Age1 Detroit DPE	Fish of age class 1 available to pass Detroit Dam
Age2 Detroit DPE	Fish of age class 2 available to pass Detroit Dam
Age0 DE FBW	Fish of age class 0 that pass Detroit Dam
Age1 DE FBW	Fish of age class 1 that pass Detroit Dam
Age2 DE FBW	Fish of age class 2 that pass Detroit Dam
Age0 DE post-FBW	Fish of age class 0 that passed Detroit Dam
Age1 DE post-FBW	Fish of age class 1 that passed Detroit Dam
Age2 DE post-FBW	Fish of age class 2 that passed Detroit Dam
HoR Age 0	Fish collected in head of Detroit reservoir that are transported below Minto Collection Facility and remain age class 0
HoR Age 1	Fish collected in head of Detroit reservoir that are transported below Minto Collection Facility and become age class 1

HoR Age 2	Fish collected in head of Detroit reservoir that are transported below Minto Collection Facility and become age class 2
River Migrant A	Fish from Reach A leaving North Santiam River
River Migrant B	Fish from Reach B leaving North Santiam River
River Migrant C	Fish from Reach C leaving North Santiam River
River Migrant MCF Downstream	Fish from Reach DE leaving North Santiam River
River Migrant F	Fish from Reach F leaving North Santiam River
Kelts in Ocean	Outmigrating Kelts that enter the ocean
Reconditioned Kelts	Kelts returning to freshwater
Smolt	River Migrants from all Reaches that survive to become smolts
Ocean Age2	Smolts that survive to enter the ocean as age class 2
Ocean Age3	Fish in the ocean as age class 3
Ocean Age4	Fish in the ocean as age class 4
Ocean Age5	Fish in the ocean as age class 5
Harvest_Age2	Adults harvested at age 2
Harvest_Age3	Adults harvested at age 3
Harvest_Age4	Adults harvested at age 4
Harvest_Age5	Adults harvested at age 5

Table 8.2: List of Acronyms and Abbreviations.

Abbreviation	**Definition**
0+	Juveniles less than one year old
1+	Juveniles older than one year but less than two years old
Beverton-Holt	Beverton-Holt spawner-recruit relationship
FOS	Foster Dam
BD	Bennett Dam
MCF	Minto Collection Facilty
d/s	Downstream
Harvest_Age#	Fishery harvest of age N# fish (# = 2, 3, 4, 5, & 6 for spring Steelhead)
Hockey-Stick	Spawner-recruit relationship in the Hockey-stick shape
FTS	First Time Spawners
FBW	Fish Benefits Workbook
Res	Reservoir
HoR	Head of reservoir
ODFW	Oregon Department of Fish and Wildlife
SE	Standard Error
SLAM	Species Life-Cycle Analysis Modules
u/s	Upstream
TDG	Total Dissolved Gas
DPE	Dam Passage Efficiency
omDPE	One minus Dam Passage Efficiency

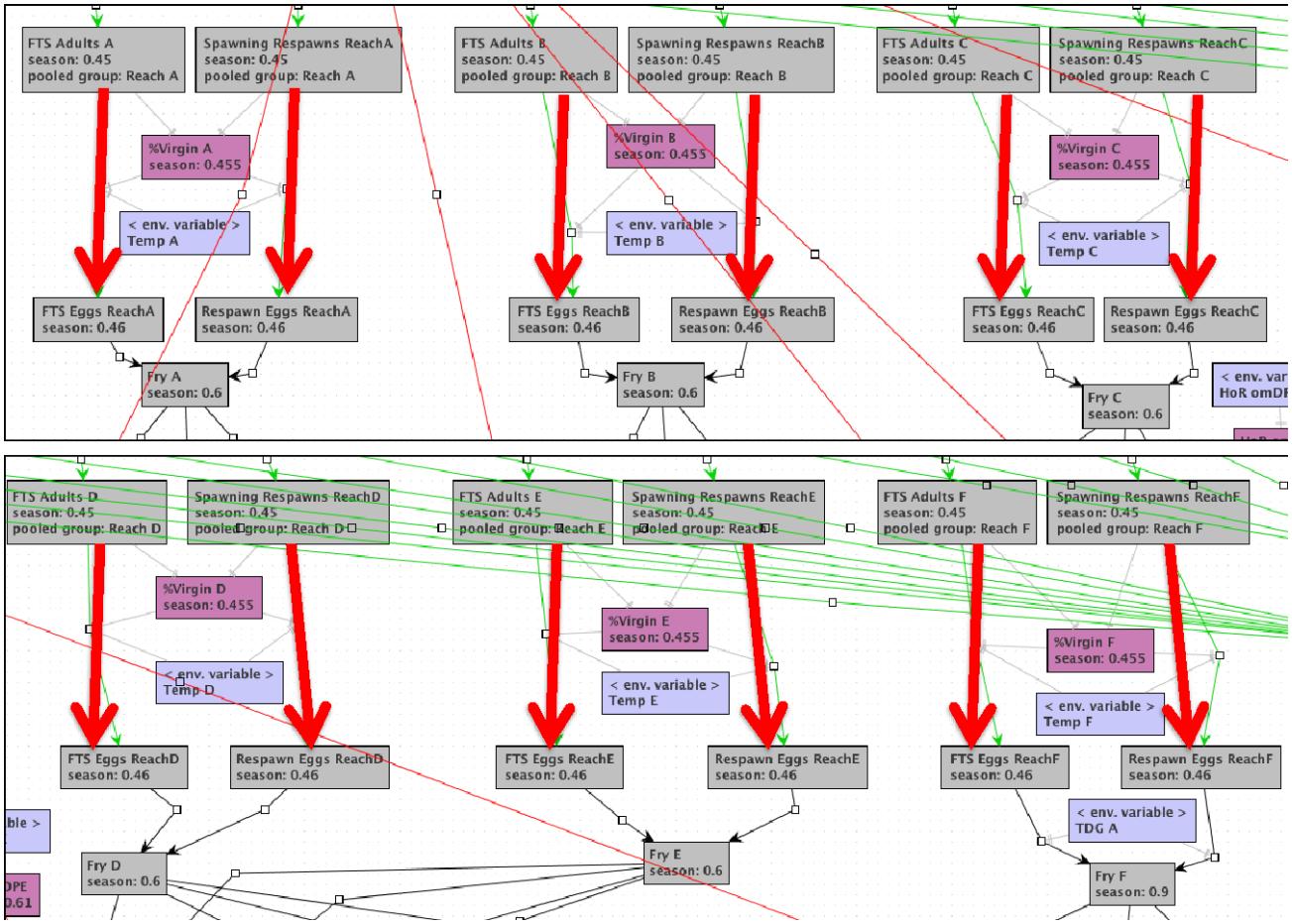
8.1. Productivity, Capacity, & Survivals

This section describes the reproductive capability of spawners within each reach, reach-specific capacity, and the proportion of individuals that survive as they move among stages in the life-cycle model (Figure 8.2, Tables 8.1 and 8.2).

Productivity and capacity parameter values of first time spawners (FTS Adults) and those adults that are spawning again (Spawning Respawns). Within each reach spawners are pooled by reach, and a reach-specific Beverton-Holt capacity function is applied to determine the number of eggs.

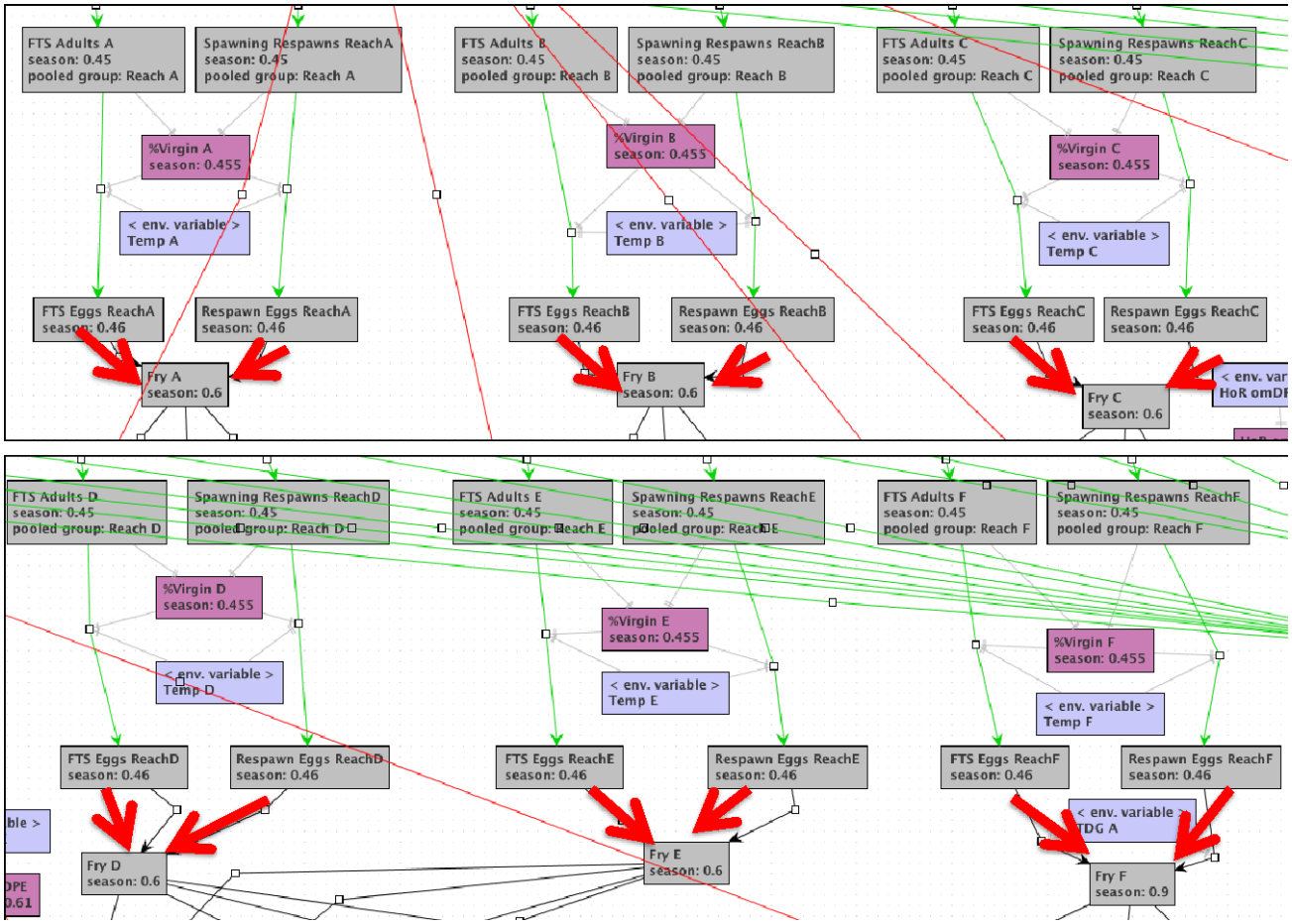
The Beverton-Holt productivity term is fixed at 0.5 times fecundity, with the assumption that the sex ratio of spawning fish is 50:50 (see Chapter 3, Steelhead, Capacity Estimates). Egg capacity is stochastic, and each year reach-specific egg capacity is drawn from a normal distribution according to the following parameters:

Reach	From	To	Capacity & Productivity	Mean	SD	Min	Max
A	FTS Adults	FTS Eggs	Capacity	50,000	10,000	25,000	250,000
			Productivity	2,000	100	1,000	2,250
B	FTS Adults	FTS Eggs	Capacity	3,000,000	100,000	1,000,000	6,000,000
			Productivity	2,000	100	1,000	2,250
C	FTS Adults	FTS Eggs	Capacity	2,500,000	100,000	500,000	4,000,000
			Productivity	2,000	100	1,000	2,250
D	FTS Adults	FTS Eggs	Capacity	4,000,000	100,000	2,000,000	7,500,000
			Productivity	2,000	100	1,000	2,250
E	FTS Adults	FTS Eggs	Capacity	10,000,000	250,000	4,000,000	12,000,000
			Productivity	2,000	100	1,000	2,250
F	FTS Adults	FTS Eggs	Capacity	250,000	50,000	100,000	600,000
			Productivity	2,000	100	1,000	2,250
A	Spawning Respawns	FTS Eggs	Capacity	50,000	10,000	25,000	250,000
			Productivity	4,160	100	2,000	5,600
B	Spawning Respawns	FTS Eggs	Capacity	3,000,000	100,000	1,000,000	6,000,000
			Productivity	4,160	100	2,000	5,600
C	Spawning Respawns	FTS Eggs	Capacity	2,500,000	100,000	500,000	4,000,000
			Productivity	4,160	100	2,000	5,600
D	Spawning Respawns	FTS Eggs	Capacity	4,000,000	100,000	2,000,000	7,500,000
			Productivity	4,160	100	2,000	5,600
E	Spawning Respawns	FTS Eggs	Capacity	10,000,000	250,000	4,000,000	12,000,000
			Productivity	4,160	100	2,000	5,600
F	Spawning Respawns	FTS Eggs	Capacity	250,000	50,000	100,000	600,000
			Productivity	4,160	100	2,000	5,600



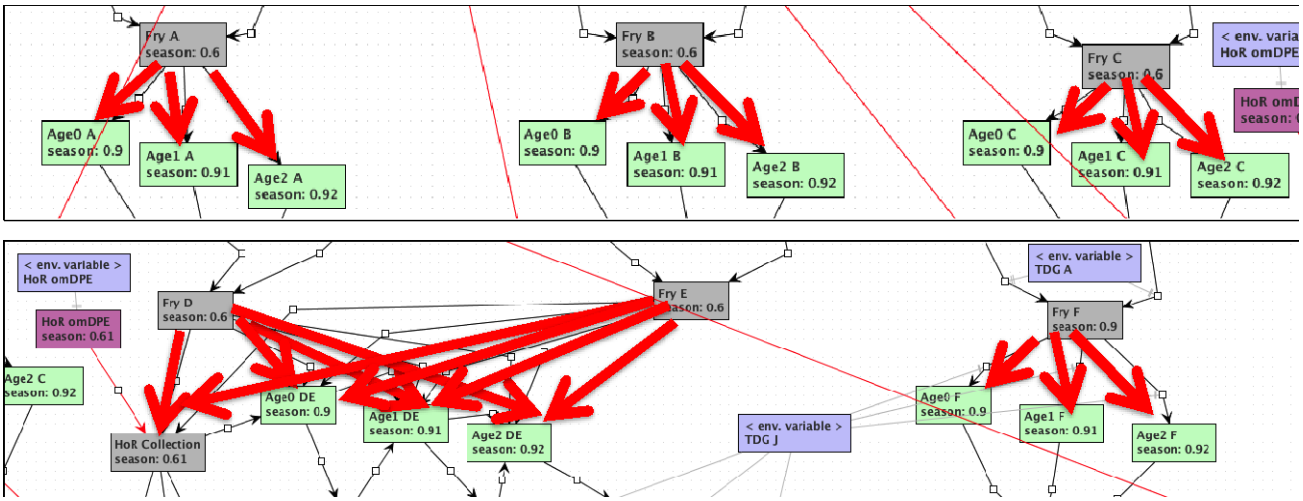
Survival parameter values from Egg to Fry stage, First Time and Respawners. The below values correspond to the reach-specific proportion of Eggs that survive to become Fry (see Chapter 3, Steelhead, Survival).

Reach	From	To	Curve type	Capacity & Productivity	Distribution type	Proportion of fish that survive
A	FTS & Respawn Eggs	Fry A	Linear	Productivity	Constant	0.3
B	FTS & Respawn Eggs	Fry B	Linear	Productivity	Constant	0.375
C	FTS & Respawn Eggs	Fry C	Linear	Productivity	Constant	0.35
D	FTS & Respawn Eggs	Fry D	Linear	Productivity	Constant	0.435
E	FTS & Respawn Eggs	Fry E	Linear	Productivity	Constant	0.435
F	FTS & Respawn Eggs	Fry F	Linear	Productivity	Constant	0.35



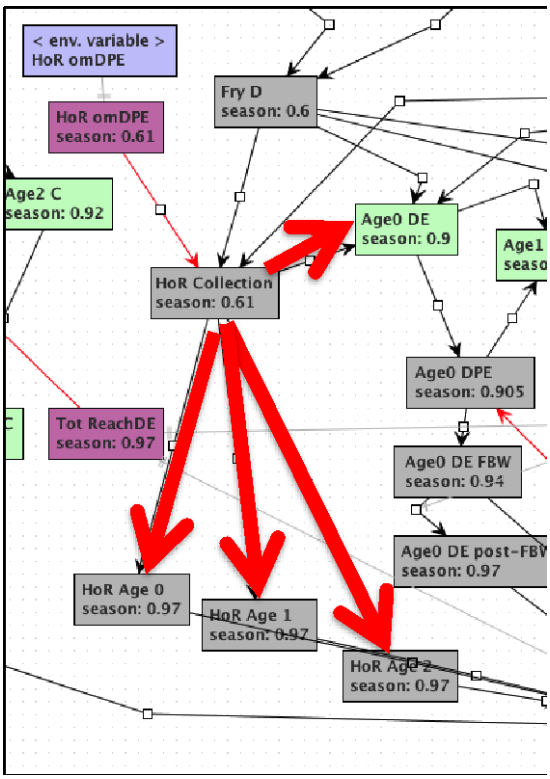
Survival parameter values from Fry to each year class. The values below correspond to the reach-specific proportion of Fry that survive to become Age 0, 1, and 2.

Reach	From	To	Curve type	Capacity & Productivity	Dist. type	Proportion of fish that survive
A	Fry A	Age0 A	Linear	Productivity	Constant	0.275
		Age1 A	Linear	Productivity	Constant	0.14
		Age2 A	Linear	Productivity	Constant	0.0725
B	Fry B	Age0 B	Linear	Productivity	Constant	0.275
		Age1 B	Linear	Productivity	Constant	0.15
		Age2 B	Linear	Productivity	Constant	0.09
C	Fry C	Age0 C	Linear	Productivity	Constant	0.275
		Age1 C	Linear	Productivity	Constant	0.17
		Age2 C	Linear	Productivity	Constant	0.09
D & E	Fry D & Fry E	Age0 DE	Linear	Productivity	Constant	0.6
		Age1 DE	Linear	Productivity	Constant	0.35
		Age2 DE	Linear	Productivity	Constant	0.275
		HoR Collection	Linear	Productivity	Constant	0.6
F	Fry F	Age0 F	Linear	Productivity	Constant	0.3
		Age1 F	Linear	Productivity	Constant	0.17
		Age2 F	Linear	Productivity	Constant	0.09



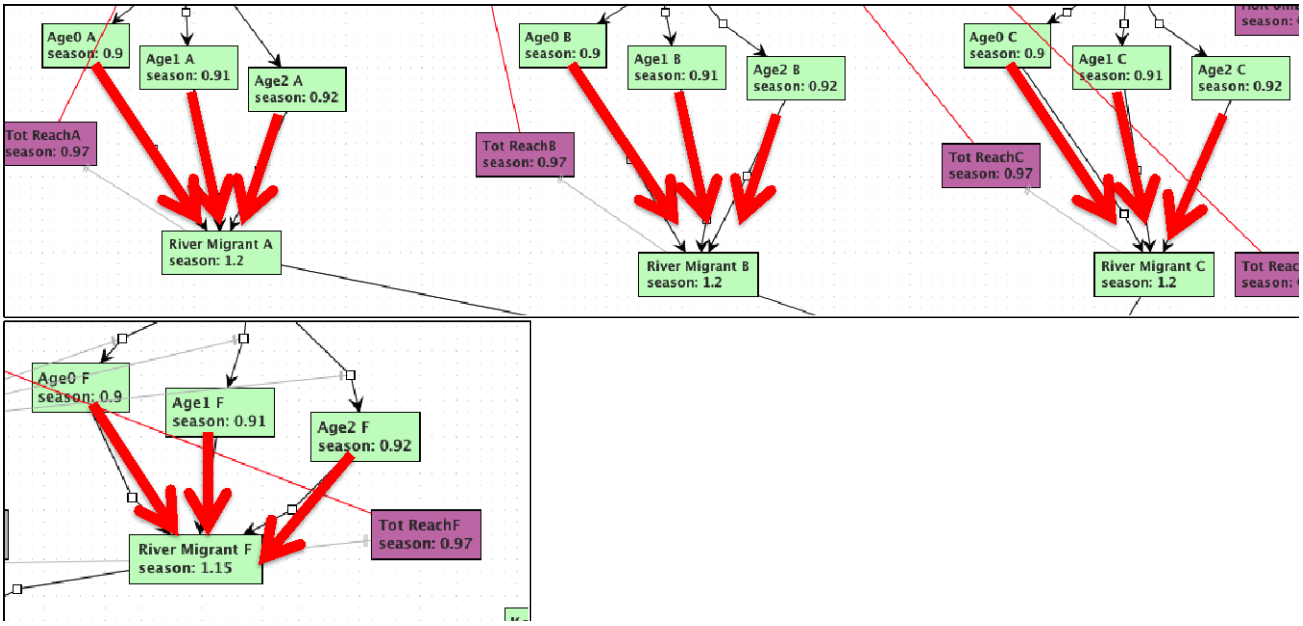
Survival parameter values of Fry collected at Head of Detroit reservoir (HoR collection) to each age class (HoR Age0, HoR Age1, and HoR Age2) and those individuals that were not collected (Age0 DE).

Reach	From	To	Curve type	Capacity & Productivity	Distribution type	Proportion of fish that survive
DE	HoR Collection	HoR Age0	Linear	Productivity	Constant	0.05
		HoR Age1	Linear	Productivity	Constant	0.065
		HoR Age2	Linear	Productivity	Constant	0.0825
		Age0 DE	Linear	Productivity	Constant	1



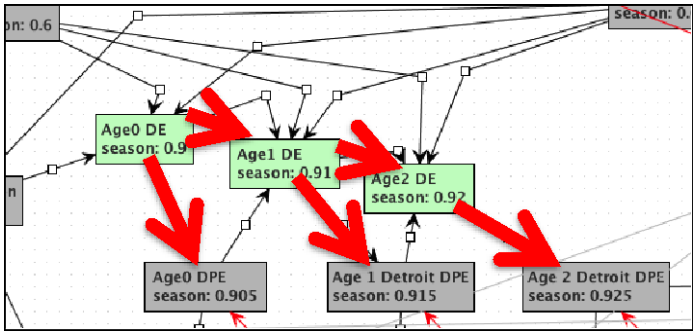
Survival parameter values of each of three age classes (Age0, Age1, and Age2) in Reach A, B, C, and F (below Bennett Dam, between Bennett Dam and Minto Collection Facility, Little North Santiam, between Minto Collection Facility and Big Cliff Dam, respectively) to the River Migrant stage downstream of North Santiam.

Reach	From	To	Curve type	Capacity & Productivity	Distribution type	Proportion of fish that survive
A	Age0 A	River Migrant A	Linear	Productivity	Constant	0.075
	Age1 A	River Migrant A	Linear	Productivity	Constant	0.175
	Age2 A	River Migrant A	Linear	Productivity	Constant	0.5
B	Age0 B	River Migrant B	Linear	Productivity	Constant	0.075
	Age1 B	River Migrant B	Linear	Productivity	Constant	0.175
	Age2 B	River Migrant B	Linear	Productivity	Constant	0.5
C	Age0 C	River Migrant C	Linear	Productivity	Constant	0.075
	Age1 C	River Migrant C	Linear	Productivity	Constant	0.175
	Age2 C	River Migrant C	Linear	Productivity	Constant	0.5
F	Age0 F	River Migrant F	Linear	Productivity	Constant	0.08
	Age1 F	River Migrant F	Linear	Productivity	Constant	0.2
	Age2 F	River Migrant F	Linear	Productivity	Constant	0.5



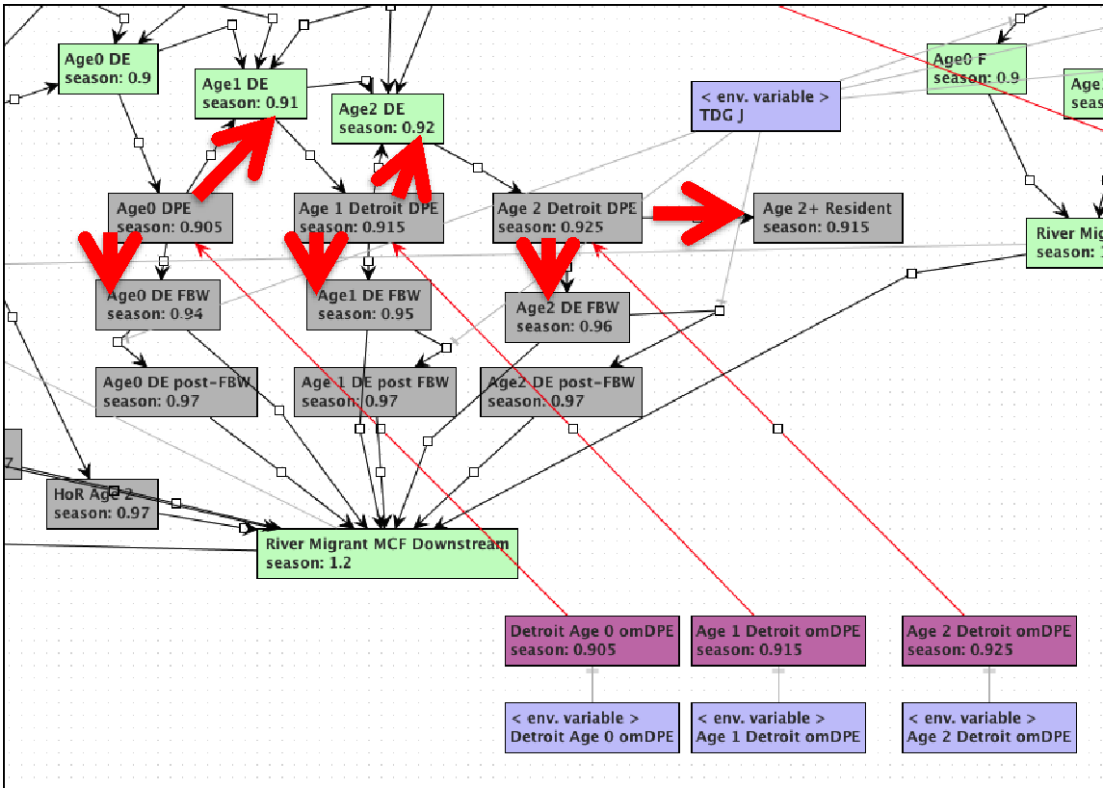
Survival parameter values of each of three age classes (Age0, Age1, and Age2) in Reach D and E (above Detroit Dam) to Detroit reservoir. These values are from parameter workshops (see Chapter 3, appendix 3.6).

Reach	From	To	Curve type	Capacity & Productivity	Dist. type	Proportion of fish that survive Max
DE	Age0 DE	Age1 DE	Linear	Productivity	Triangular	0.2 (mean), 0.1-0.3 (min & max)
		Age0 DPE	Linear	Productivity	Triangular	0.4 (mean), 0.3-0.5 (min & max)
	Age1 DE	Age2 DE	Linear	Productivity	Triangular	0.5 (mean), 0.4-0.6 (min & max)
		Age1 Detroit DPE	Linear	Productivity	Triangular	0.5 (mean), 0.4-0.6 (min & max)
	Age2 DE	Age2 Detroit DPE	Linear	Productivity	Triangular	0.85 (mean), 0.8-0.95 (min & max)



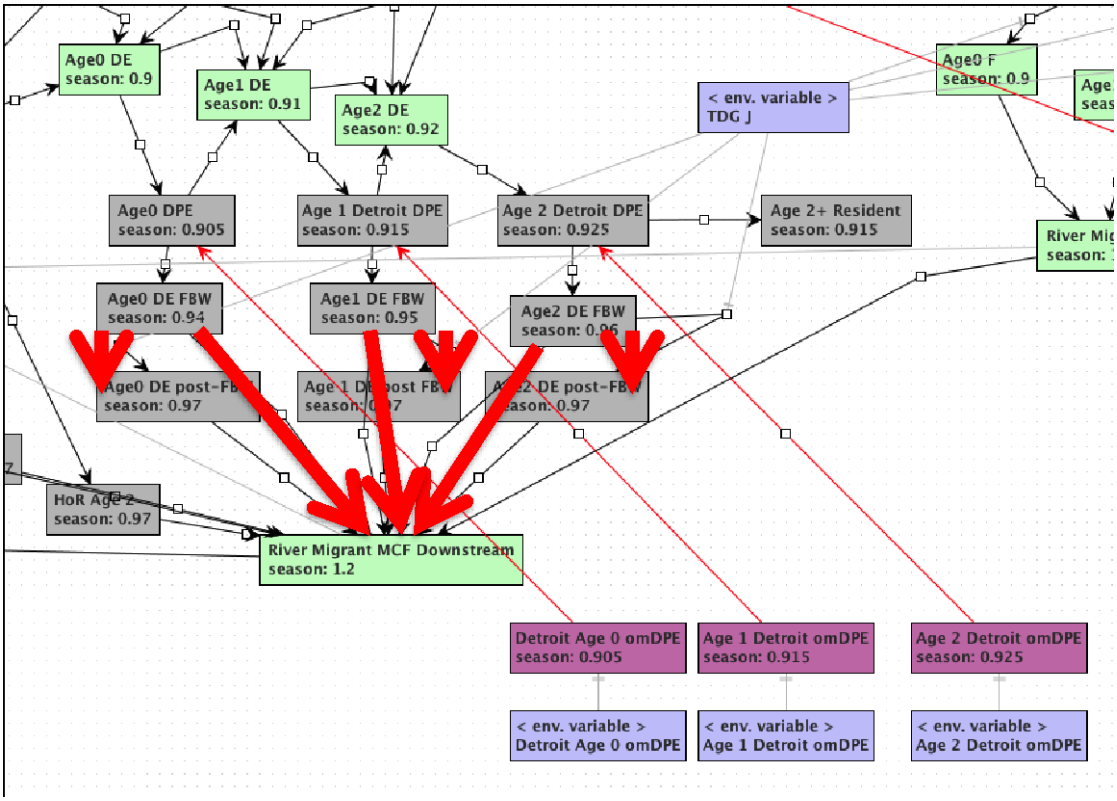
Survival parameter values of each age class in Detroit reservoir (Reach DE) that will either pass Detroit Dam or remain and rear in the reservoir and become the next age class. Dam passage survival ('Passage survival' in the below table) is one of two datafiles from the Fish Benefits Workbook, the other being dam passage efficiency (DPE) (Fish Benefits Workbooks User Guide 2014), both of which are provided by USACE. Dam passage efficiency is the fraction of fish available to pass a dam that actually pass, those that do not pass remain in the reservoir.

Reach	From	To	Curve type	Capacity & Productivity	Distr. type	Proportion of fish that survive Max
DE	Age0 DPE	Age0 DE FBW	Linear	Productivity	Datafile	Passage survival
		Age1 DE	Linear	Productivity	Constant	0.5
	Age1 Detroit DPE	Age1 DE FBW	Linear	Productivity	Datafile	Passage survival
		Age2 DE	Linear	Productivity	Constant	1
	Age2 Detroit DPE	Age2 DE FBW	Linear	Productivity	Datafile	Passage survival
		Age2+ Resident	Linear	Productivity	Constant	0



Survival parameter values of each age class from Reach DE (above Detroit Dam) that pass Detroit Dam (Age0 DE post-FBW, Age1 DE post-FBW, and Age3 DE post-FBW) or are transported downstream of Minto Collection Facility (River Migrant MCF Downstream).

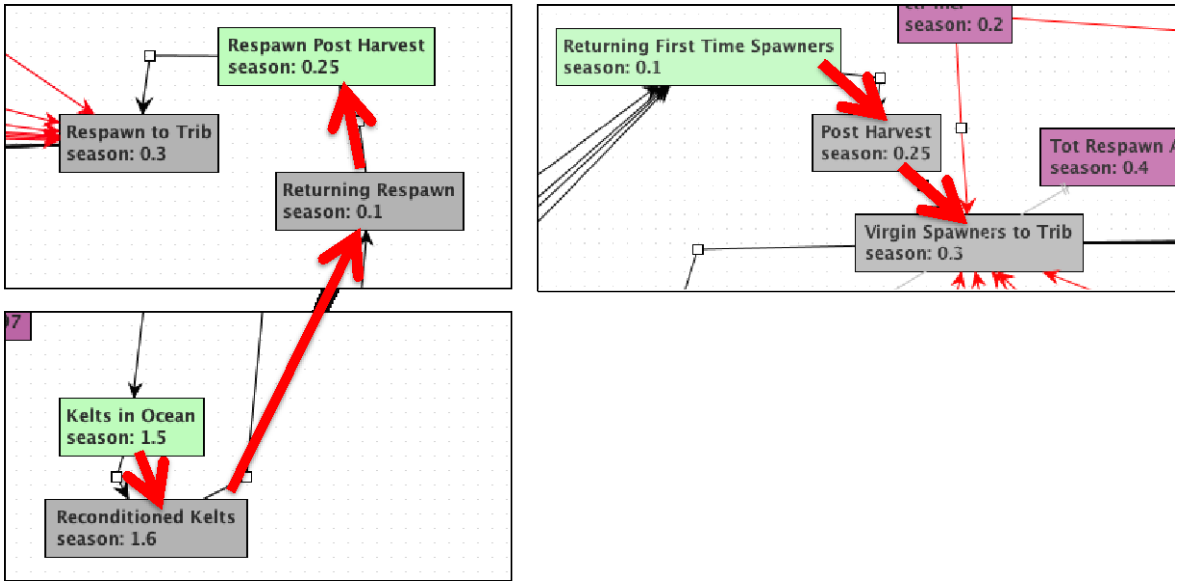
Reach	From	To	Curve type	Capacity & Productivity	Distr. type	Proportion of fish that survive
DE	Age0 DE FBW	Age0 DE post-FBW	Linear	Productivity	Constant	0.115
		River Migrant MCF Downstream	Linear	Productivity	Constant	0.115
	Age1 DE FBW	Age1 DE post-FBW	Linear	Productivity	Constant	0.4
		River Migrant MCF Downstream	Linear	Productivity	Constant	0.4
	Age2 DE FBW	Age2 DE post-FBW	Linear	Productivity	Constant	0.6
		River Migrant MCF Downstream	Linear	Productivity	Constant	0.6



Estuary and ocean survival. Juveniles below Willamette Falls have an estuary survival time series applied, and in subsequent ocean years from, from 1, up to 4 ocean years, an ocean survival time series is applied (see Table 8.6 in Parameter variability section).

Survival parameter values of Kelts (Kelts in Ocean) returning to respawn and first time spawners returning to spawn.

Reach	From	To	Curve type	Capacity & Productivity	Distr. type	Proportion of fish that survive
Kelts	Kelts in Ocean	Reconditioned Kelts	Linear	Productivity	Constant	0.575
	Reconditioned Kelts	Returning Respawn	Linear	Productivity	Constant	0.5
	Returning Respawn	Respawn Post Harvest	Linear	Productivity	Constant	0.825
	Respawn Post Harvest	Respawn to Trib	Linear	Productivity	Constant	0.9
	Respawn to Reach ABCDEF	Spawning Respawns Reach ABCDEF	Linear	Productivity	Constant	1
		Outmigrating Kelts from Reach ABCDEF	Linear	Productivity	Constant	0.8
First Time Spawners	Returning First Time Spawners	Post Harvest	Linear	Productivity	Constant	0.825
	Post Harvest	Virgin Spawners to Tribs	Linear	Productivity	Constant	0.9
	VirginAdult to Reach ABCDEF	FTS Adults A	Linear	Productivity	Constant	1
		Outmigrating Kelts from Reach ABCDEF	Linear	Productivity	Constant	0.8



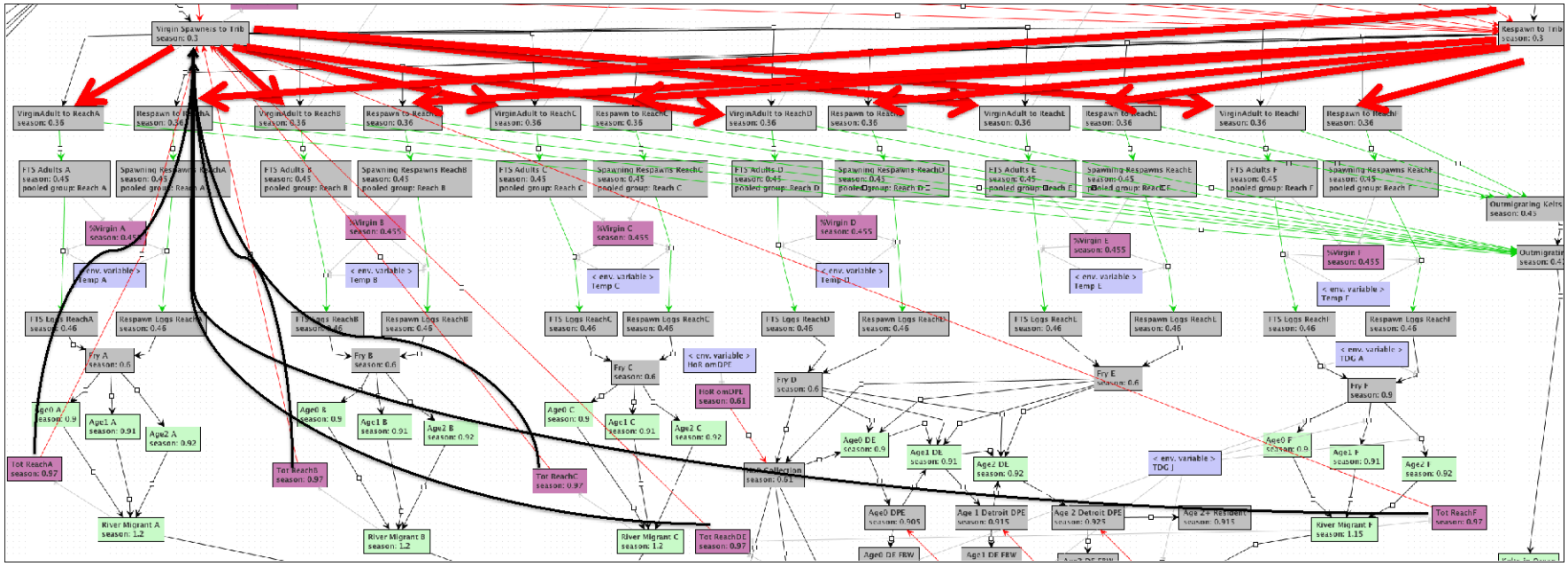
8.2. Splits

This section describes the proportion of fish directed from an individual life-stage to two or more subsequent life-stages via different pathways (splits).

Proportion of first time spawners that return to Reach A, B, C, D, E, or F. Proportion of repeat spawners that return to Reach A, B, C, DE, or F. In the process of simplifying the SLAM model structure, we pooled together juveniles from all reaches starting at the estuary stage since estuary/ocean survivals and ocean and mainstem harvest were applied equally to fish from all reaches. Because of homing of adult Steelhead salmon to their natal reaches we reapportioned returning adults in year *t* back to their natal reaches according to the numbers of juveniles produced in year *t*-4. Specifically, for each simulated year we quantified the proportion of juveniles that exited each reach. These proportions were then used to split returning adults (four simulated years later) that survived freshwater harvest (Virgin Spawners to Trib and Respawn to Trib) to those that return to Reach A (VirginAdult to ReachA and Respawn to ReachA), Reach B (VirginAdult to Reach B and Respawn to ReachB), Reach C (VirginAdult to Reach C and Respawn to ReachC), Reach DE (VirginAdult to Reach DE and Respawn to ReachDE), and Reach F (VirginAdult to Reach F and Respawn to ReachF). To achieve this in SLAM we used a tool called a Split Influence, which influences the ratios of a split (McElhany et al. 2012). After the model was initialized with a fixed set of ratios for a split, the Split Influence determined the split from the juvenile counts four years previously:

$$Proportion\ of\ fish\ returning\ to\ VirginAdult\ to\ ReachA = \left(\frac{Tot\ ReachA}{Tot\ ReachA + Tot\ ReachB + Tot\ ReachC + Tot\ ReachDE + Tot\ ReachF}\right)$$

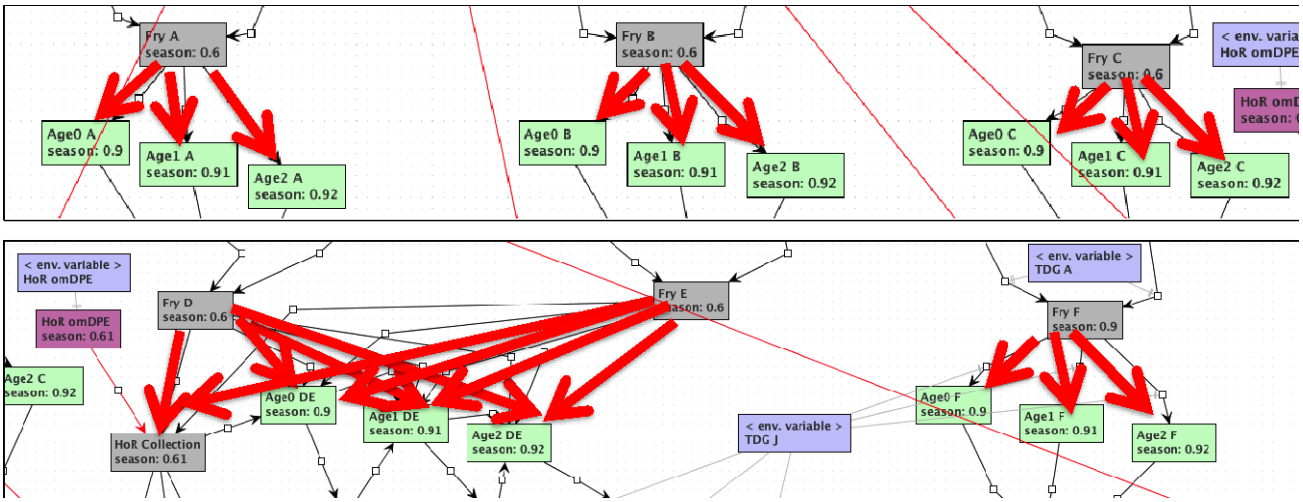
From	To	Proportion
Virgin Spawners to Trib	VirginAdult to ReachA	Split influence (otherwise 0.003)
	VirginAdult to ReachB	Split influence (otherwise 0.086)
	VirginAdult to ReachC	Split influence (otherwise 0.085)
	VirginAdult to ReachD	Split influence (otherwise 0.34)
	VirginAdult to ReachE	Split influence (otherwise 0.48)
	VirginAdult to ReachF	Split influence (otherwise 0.006)
Respawn to Trib	Respawn to ReachA	Split influence (otherwise 0)
	Respawn to ReachB	Split influence (otherwise 0)
	Respawn to ReachC	Split influence (otherwise 0.3)
	Respawn to ReachD	Split influence (otherwise 0.5)
	Respawn to ReachE	Split influence (otherwise 0.05)
	Respawn to ReachF	Split influence (otherwise 0.15)



Black lines show that five boxes (Tot ReachA, Tot ReachB, Tot ReachC, Tot ReachDE, and Tot ReachF) are used to influence the split of fish from Virgin Spawners. Tot ReachA, Tot ReachB, Tot ReachC, Tot ReachDE, and Tot ReachF sum all the juveniles that exit Reach A, B, C, DE, and F respectively.

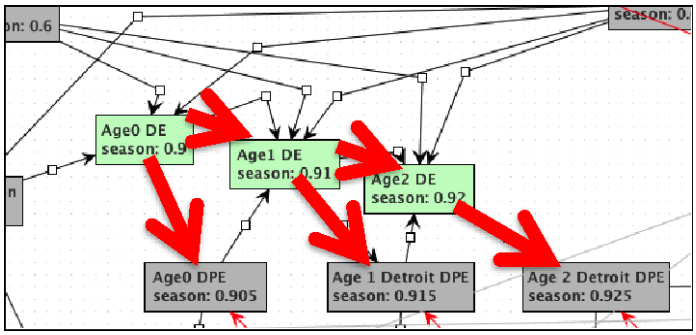
Proportion of Fry that become each of three age classes (Age0, Age1, and Age2).

From	To	Proportion
Fry A	Age0 A	0.25
	Age1 A	0.4
	Age2 A	0.35
Fry B	Age0 B	0.25
	Age1 B	0.4
	Age2 B	0.35
Fry C	Age0 C	0.25
	Age1 C	0.4
	Age2 C	0.35
Fry D	Age0 D	0.7
	Age1 D	0.1
	Age2 D	0.2
	HoR Collection	0
Fry E	Age0 E	0.7
	Age1 E	0.1
	Age2 E	0.2
	HoR Collection	0
Fry F	Age0 F	0.25
	Age1 F	0.4
	Age2 F	0.35



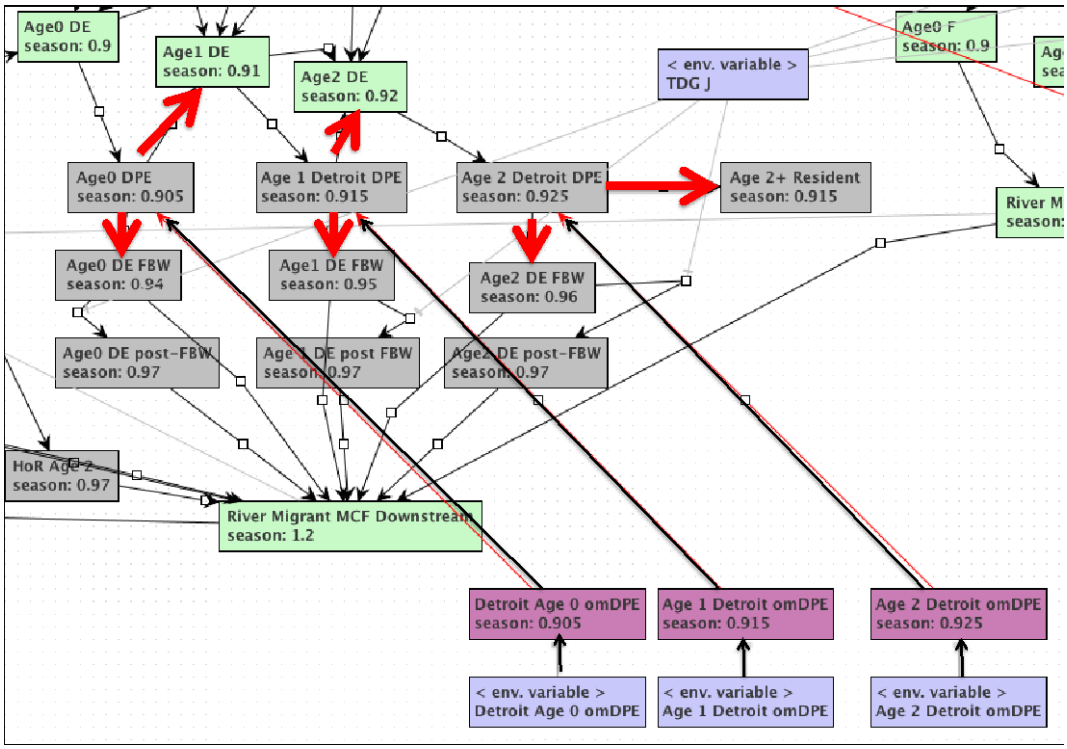
Proportion of each of three age classes (Age0, Age1, and Age2) in Reach D and E (above Detroit Dam) to Detroit reservoir where their age class remains the same or they become the next age class. These values are from parameter workshops 2014 (see Chapter 3, appendix 3.6).

Reach	From	To	Curve type	Capacity & Productivity	Dist. type	Proportion of fish that survive Max
DE	Age0 DE	Age1 DE	Linear	Productivity	Triangular	0.2 (mean), 0.1-0.25 (min & max)
		Age0 DPE	Linear	Productivity	Triangular	0.8 (mean), 0.7-0.9 (min & max)
	Age1 DE	Age2 DE	Linear	Productivity	Triangular	0.05 (mean), 0.0-0.1 (min & max)
		Age1 Detroit DPE	Linear	Productivity	Triangular	0.95 (mean), 0.9-1.0 (min & max)



Proportion of individuals in Detroit reservoir that are available to pass Detroit Dam or unavailable to pass and thus remain in the reservoir to become the next age class. These are the proportion of Age 0 individuals in Detroit reservoir (Age0 DPE) that are available to pass Detroit Dam (Age0 DE FBW) or unavailable to pass and thus remain in the reservoir to become Age 1 individuals (Age1 DE), proportion of Age 1 individuals in Detroit reservoir (Age1 Detroit DPE) that are available to pass Detroit Dam (Age1 DE FBW) or unavailable to pass and thus remain in the reservoir and become Age 2 individuals (Age2 DE), and proportion of Age 2 individuals in Detroit reservoir (Age 2 Detroit DPE) that are available to pass Detroit Dam (Age2 DE FBW) or unavailable to pass, and are removed from the simulation (Age2 + Resident). These proportions use dam passage efficiency (DPE) data that were specific to particular dam project alternatives and were provided by USACE (Fish Benefits Workbooks User Guide 2014).

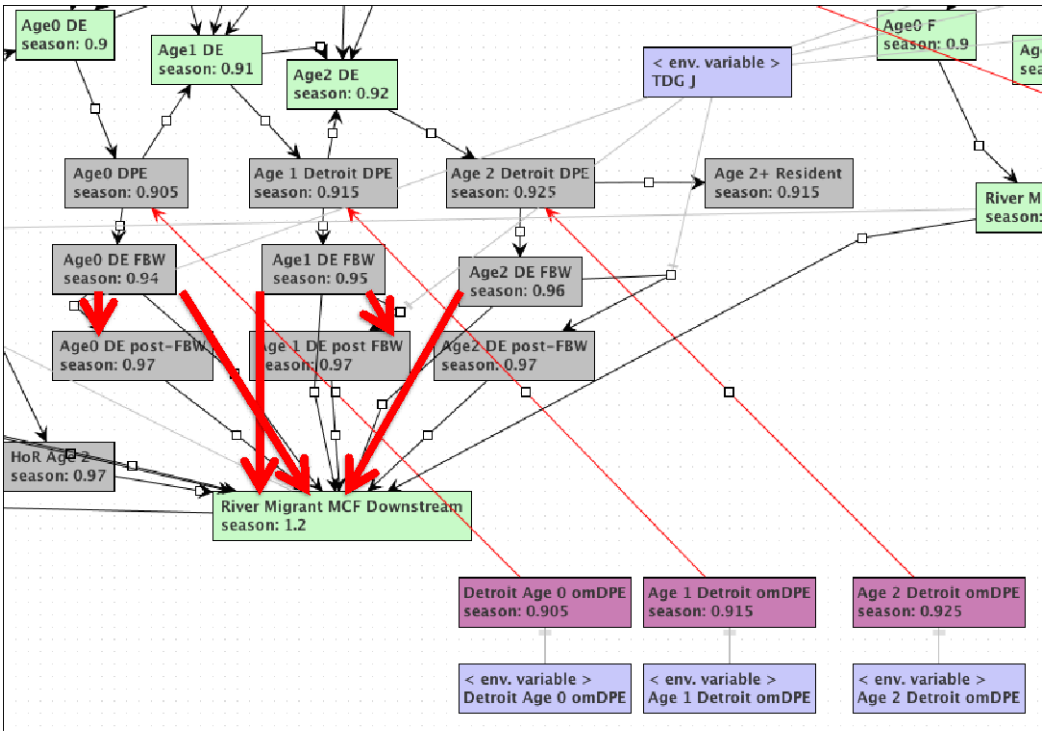
From	To	Proportion
Age0 DPE	Age0 DE FBW	Split influencer determined by DPE file
	Age1 DE	Split influencer determined by DPE file
Age 1 Detroit DPE	Age1 DE FBW	Split influencer determined by DPE file
	Age2 DE	Split influencer determined by DPE file
Age 2 Detroit DPE	Age2 DE FBW	Split influencer determined by DPE file
	Age2 + Resident	Split influencer determined by DPE file



Black arrows represent the split influence from dam passage efficiency data.

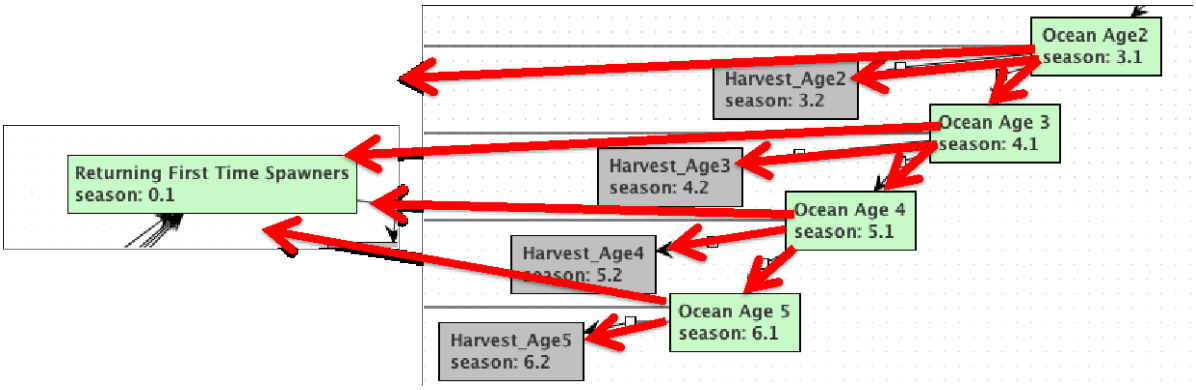
Proportion of individuals that bypass Detroit Dam and are transported downstream of Minto Collection Facility. When alternatives are being run that bypass fish around Detroit Dam all fish (100%) of each age class (Age0 DE post-FBW, Age 1 DE post-FBW, and Age2 DE post-FBW) are released downstream of Minto Collection Facility (River Migrant MCF Downstream) and thus are not impacted by TDG.

From	To	Proportion
Age0 DE FBW	Age0 DE post-FBW	1
	River Migrant MCF Downstream	0
Age1 DE FBW	Age1 DE post-FBW	1
	River Migrant MCF Downstream	0
Age2 DE FBW	Age2 DE post-FBW	1
	River Migrant MCF Downstream	0



Proportional splits of ocean adults (Ocean Age2, 3, 4, and 5) that stay in the ocean for another year, are harvested in the ocean, or return to freshwater.

From	To	Proportion
Ocean Age2	Returning First Time Spawners	0.0125
	Ocean Age 3	0.9375
	Harvest_Age2	0.05
Ocean Age3	Returning First Time Spawners	0.55
	Ocean Age 4	0.4
	Harvest_Age3	0.05
Ocean Age4	Returning First Time Spawners	0.85
	Ocean Age 5	0.1
	Harvest_Age4	0.05
Ocean Age5	Returning First Time Spawners	1
	Harvest_Age5	0



8.3. Datafiles

Most parameter values are scalars are drawn from distributions according to parameters within SLAM, however there are stage transitions within the life-cycle model where survivals or splits come from datafiles. For example, dam passage survival and efficiency, enter into SLAM as a datafile. The following are the stages or stage transitions that call a datafile with survivals or splits.

8.3.1. Survivals

Stage at which datafile is located	Name of datafile	Name of series
Age0 DE FBW	Detroit_FBW_Alternatives_toSLAM-May 27 2014.csv	1.Baseline-May 23 2014-FBW-Age0-146yr
Age1 DE FBW	Detroit_FBW_Alternatives_toSLAM-May 27 2014.csv	1.Baseline-May 23 2014-FBW-Age1-146yr
Age2 DE FBW	Detroit_FBW_Alternatives_toSLAM-May 27 2014.csv	1.Baseline-May 23 2014-FBW-Age2-146yr
Kelts in Ocean	ChSOcean4thRt_modified_1_2013.csv	ChSAge2 x 2 (200yrs)
Smolt	EstuaryCurrent_modified_1_2013.csv	EstuaryCurrent x 2 (200yrs)
Ocean Age2	ChSOcean4thRt_modified_1_2013.csv	ChSAge2 x 2 (200yrs)
Ocean Age3	ChSOcean4thRt_modified_1_2013.csv	ChSAge3 x 2 (200yrs)
Ocean Age4	ChSOcean4thRt_modified_1_2013.csv	ChSAge4 x 2 (200yrs)
Ocean Age5	ChSOcean4thRt_modified_1_2013.csv	ChSAge5 x 2 (200yrs)
TDGJ	TDG_NS_modified_1_2013.csv	BC_WorstScenario_JuvenileF (146yrs)
TDGA	TDG_NS_modified_1_2013.csv	BC_WorstScenario_AlevinF (146yrs)
Detroit Age 0 omDPE	STL-Detroit_1-DPE_Alternatives_toSLAM-May 23 2014.csv	1.Baseline-May 23 2014-1-DPE-Age0-146yr
Age 1 Detroit omDPE	STL-Detroit_1-DPE_Alternatives_toSLAM-May 23 2014.csv	1.Baseline-May 23 2014-1-DPE-Age1-146yr
Age 2 Detroit omDPE	STL-Detroit_1-DPE_Alternatives_toSLAM-May 23 2014.csv	1.Baseline-May 23 2014-1-DPE-Age2-146yr
HoR omDPE	Constant	0

USACE provided R2 Consultants, who in turn provided NWFSC, with the following SLAM datafiles; EstuaryCurrent_modified_1_2013, ChSOcean4thRt_modified_1_2013, TDG_NS_modified_1_2013,. Each of the aforementioned files was expanded by NWFSC by repeating from the beginning, such that the files that were 74 years became 146 years, and those that were 100 years became 200 years. USACE provided Fish Benefits Workbooks datafiles that correspond to dam passage survival (e.g. STL-Detroit_FBW_Alternatives_toSLAM-May 23 2014) and dam passage efficiency (e.g., STL-Detroit_1-DPE_Alternatives_toSLAM-May 23 2014) (Fish Benefits Workbooks User Guide 2014).

8.3.2. Splits

Stage at which datafile is used	Name of datafile	Recruit stage datafile is applied	Name of series
Age0 DE	Age0 DE.csv	Age1 DE	Age1 DE
		Age0 DPE	Age0 DPE
Age1 DE	Age1 DE.csv	Age2 DE	Age2 DE
		Age 1 Detroit DPE	Age1 Detroit DPE
		Age 1 Detroit DPE	Age1 Detroit DPE

8.4. Dynamic Drivers and Influence Scripts

In some cases we used scripts to influence life stage transitions and splits. These were written in a Java-compatible syntax and are called groovy script. These gave us the ability to dynamically influence splits such as apportioning adults to natal reaches based on juvenile outmigrants four years earlier, or for applying the dam passage efficiency (DPE) to juveniles attempting to pass the dam. Below is a list of boxes where dynamic drivers are applied.

Box where dynamic driver is located	**Dynamic driver file name**	**What does dynamic driver do?**
ctr incr	ctr_incr.groovy	A counter to keep track of the year number being simulated.
%Virgin ABCDEF	%Virgin.groovy	Calculates percent of virgin spawners in each Reach.
Tot Reach A, B, C, D, E, & F	Tot ReachABCDEF.groovy	Calculates total number of juveniles that exit each Reach that is then used to calculate proportion of adults that return to each reach (see Split Influencer below).
Stage where influence script is located	**Groovy script file name**	**What does script do?**
Age0 DE post-FBW	TDG.groovy	Calculates proportion of juveniles that survive the total dissolved gas.
Age1 DE post-FBW	TDG.groovy	Calculates proportion of juveniles that survive the total dissolved gas.
Age2 DE post-FBW	TDG.groovy	Calculates proportion of juveniles that survive the total dissolved gas.
Fry F	TDG.groovy	Calculates proportion of fry that survive the total dissolved gas.
Age0 F		Calculates proportion of juveniles that survive the total dissolved gas.
Age1 F		Calculates proportion of juveniles that survive the total dissolved gas.
Age2 F		Calculates proportion of juveniles that survive the total dissolved gas.

Stage where split influencer is located	**Stage where groovy script is located**	**Groovy script file name**	**What does split influencer do?**
Virgin Spawners to Trib	VirginAdult to ReachA	VirginAdult to ReachA.groovy	Calculates the proportion of virgin Adults that go to Reach A
Virgin Spawners to Trib	VirginAdult to ReachB	VirginAdult to ReachB.groovy	Calculates the proportion of virgin Adults that go to Reach B
Virgin Spawners to Trib	VirginAdult to ReachC	VirginAdult to ReachC.groovy	Calculates the proportion of virgin Adults that go to Reach C
Virgin Spawners to Trib	VirginAdult to ReachD	VirginAdult to ReachD.groovy	Calculates the proportion of virgin Adults that go to Reach D
Virgin Spawners to Trib	VirginAdult to ReachE	VirginAdult to ReachE.groovy	Calculates the proportion of virgin Adults that go to Reach E
Virgin Spawners to Trib	VirginAdult to ReachF	VirginAdult to ReachF.groovy	Calculates the proportion of virgin Adults that go to Reach F
Respawn to Trib	Respawn to ReachA	Respawn to ReachA.groovy	Calculates the proportion of respawners that go to Reach A
Respawn to Trib	Respawn to ReachB	Respawn to ReachB.groovy	Calculates the proportion of respawners that go to Reach B
Respawn to Trib	Respawn to ReachC	Respawn to ReachC.groovy	Calculates the proportion of respawners that go to Reach C
Respawn to Trib	Respawn to ReachD	Respawn to ReachD.groovy	Calculates the proportion of respawners that go to Reach D
Respawn to Trib	Respawn to ReachE	Respawn to ReachE.groovy	Calculates the proportion of respawners that go to Reach E
Respawn to Trib	Respawn to ReachF	Respawn to ReachF.groovy	Calculates the proportion of respawners that go to Reach F

8.5. Initialization Values

When SLAM begins a simulation not all of the boxes are populated with fish. As a result, the first several simulated years can show large fluctuations in abundance and frequent extinctions. To reduce these fluctuations many of the boxes are initialized with some number of fish at the start of the model. The values used to initialize these boxes were taken from the 100th year in a previous baseline simulation.

Stage	Initialized
Returning First Time Spawners	950
ctr incr	0
Respawn Post Harvest	75
Tot Respawn ABCDEF	10
%Virgin ABCDEF	10
HoR omDPE	-
Age0 A	50
Age0 B	1000
Age0 C	750
Age0 DE	-
Age0 F	300
Age1 A	250
Age1 B	1,250
Age1 C	1000
Age1 DE	-
Age1 F	500
Age 1 Detroit omDPE	50
Age2 A	50
Age2 B	1750
Age2 C	1,750
Age2 DE	-
Age2 F	750
Age 2 Detroit omDPE	50
Tot ReachABCDEF	-
River Migrant F	500
River Migrant A	100
River Migrant B	6000
River Migrant C	4500
River Migrant MCF Downstream	1,000
Kelts in Ocean	60
Smolt	9000
Ocean Age2	1750
Ocean Age 3	1500
Ocean Age 4	100
Ocean Age 5	10

8.5.1. Model demonstration & Alternative Scenarios

Below (Table 8.3) is a list of a set of the most recent alternatives selected by the USACE (Fish Benefit Workbook; received May 23, 2014) that represent various operational and structural modifications to Detroit Dam whose goal is to improve access to Reach D and E (above Detroit Dam). Each alternative was run in SLAM and estimates were produced of several variables including abundance of natural origin spawners and each life history strategy, and percent wild. Each alternative was run 500 times, and each run is 100 years long. We used 500 runs because output stabilized at this level. USACE provided datafiles of dam passage survival and efficiency, which were 73 years, and these files were duplicated to produce datafiles that were 146 years.

Table 8.3: Set of alternatives run in the SLAM model of North Santiam River Steelhead salmon. Description of each alternative can be found in Appendix D.

	Alternative Description	SLAM output name	Bypass dam? If so, no TDG.	Passage survival (average %)			1-DPE (average %)		
				Age0	Age 1	Age 2	Age 0	Age 1	Age 2
1	Baseline	Baseline	N	48	42	40	57	53	50
2	Selective Withdrawal Str with Weir Box	SWS Weir	N	45	37	34	41	41	41
3	Selective Withdrawal Str, Floating Screen Str	SWS-FSS	Y	97	96	97	41	41	41
4	Floating Surface Collector @ 220 cfs. No temp	FSC220	Y	73	68	66	41	41	41
5	Floating Surface Collector @ 750. No temp	FSC750	Y	76	72	69	41	41	41
6	Floating Surface Collector @ 1000. No temp	FSC1000	Y	76	72	69	41	41	41
7	Glory Hole. Floating Surface Outlet	FSO	N	63	62	57	41	41	41

8.5.2. Parameter Variability

The following tables identify parameters that vary among years in each model run. In all the parameters listed below (except passage survival) values are randomly selected each model year from the specified distribution and these distributions and the parameters that define them do not vary among alternatives. Passage survival does vary among alternatives. For any given alternative, passage survival values vary among years of a model run, but do not vary among the 500 model runs (passage survival values are taken from a datafile).

Table 8.4: Capacity and survival parameters whose values vary among years in each model run and vary among model runs.

Location in Life Cycle	From	To	Curve type	Capacity &/or Productivity	Distribution type	Mean	SD	Min	Max
Reach A Downstream of Bennett Dam (18.8miles)	FTS Adults	FTS Eggs	Beverton-Holt	Capacity	Normal	50,000	10,000	25,000	250,000
Reach B Bennett to Minto Collection Facility (26.5miles)	FTS Adults	FTS Eggs	Beverton-Holt	Capacity	Normal	3,000,000	100,000	1,000,000	6,000,000
Reach C Little North Santiam River (17.5miles)	FTS Adults	FTS Eggs	Beverton-Holt	Capacity	Normal	2,500,000	100,000	500,000	4,000,000
Reach D Breitenbush River (14.2miles)	FTS Adults	FTS Eggs	Beverton-Holt	Capacity	Normal	4,000,000	100,000	2,000,000	7,500,000
Reach E Upper North Santiam (27.4miles)	FTS Adults	FTS Eggs	Beverton-Holt	Capacity	Normal	10,000,000	250,000	4,000,000	12,000,000
Reach F Minto to Big Cliff (2.9miles)	FTS Adults	FTS Eggs	Beverton-Holt	Capacity	Normal	250,000	50,000	100,000	600,000
Reach A Downstream of Bennett Dam (18.8miles)	Spawning Respawns	Respawn Eggs	Beverton-Holt	Capacity	Normal	50,000	10,000	25,000	250,000
Reach B Bennett to Minto Collection Facility (26.5miles)	Spawning Respawns	Respawn Eggs	Beverton-Holt	Capacity	Normal	3,000,000	100,000	1,000,000	6,000,000
Reach C Little North Santiam River (17.5miles)	Spawning Respawns	Respawn Eggs	Beverton-Holt	Capacity	Normal	2,500,000	100,000	500,000	4,000,000
Reach D Breitenbush River (14.2miles)	Spawning Respawns	Respawn Eggs	Beverton-Holt	Capacity	Normal	4,000,000	100,000	2,000,000	7,500,000
Reach E Upper North Santiam (27.4miles)	Spawning Respawns	Respawn Eggs	Beverton-Holt	Capacity	Normal	10,000,000	250,000	4,000,000	12,000,000
Reach F Minto to Big Cliff (2.9miles)	Spawning Respawns	Respawn Eggs	Beverton-Holt	Capacity	Normal	250,000	50,000	100,000	600,000
Reach DE	Age0 DE	Age1 DE	Linear	Productivity	Triangular	0.20		0.10	0.30
Reach DE	Age0 DE	Age0 DPE	Linear	Productivity	Triangular	0.40		0.30	0.50
Reach DE	Age1 DE	Age2 DE	Linear	Productivity	Triangular	0.50		0.40	0.60
Reach DE	Age1 DE	Age 1 Detroit DPE	Linear	Productivity	Triangular	0.50		0.40	0.60
Reach DE	Age2 DE	Age 2 Detroit DPE	Linear	Productivity	Triangular	0.85		0.80	0.95

Table 8.5: Average, minimum, and maximum passage survival for each alternative and life history strategy. These values vary among years of a model run but do not vary among model runs.

FBW		Average Passage Survival			Min Passage Survival			Max Passage Survival		
Output File name	Alternative	Age0	Age1	Age2	Age0	Age1	Age2	Age0	Age1	Age2
ST_NS #1_052314	Baseline	0.48	0.42	0.40	0.43	0.34	0.30	0.50	0.44	0.43
ST_NS #2_052314	Selective Withdrawal Str with Weir Box	0.45	0.37	0.34	0.45	0.37	0.33	0.46	0.38	0.35
ST_NS #3_052314	Selective Withdrawal Str, Floating Screen Str	0.97	0.96	0.97	0.94	0.91	0.93	0.98	0.98	0.98
ST_NS #6_052314	Floating Surface Collector @ 220 cfs. No temp	0.73	0.68	0.66	0.70	0.64	0.61	0.76	0.71	0.69
ST_NS #6a_052314	Floating Surface Collector @ 750. No temp	0.76	0.72	0.69	0.74	0.68	0.67	0.77	0.73	0.70
ST_NS #6b_052314	Floating Surface Collector @ 1000. No temp	0.76	0.72	0.69	0.74	0.68	0.67	0.77	0.73	0.70
ST_NS #7_052314	Glory Hole. Floating Surface Outlet	0.63	0.62	0.57	0.54	0.52	0.44	0.83	0.83	0.83

Table 8.6: Average, minimum, and maximum survival values during estuary and ocean stages. Age-specific time series of estuary and ocean survival were generated by ODFW, and incorporated into SLAM as datafiles.

Stage	Min	Average	Max
Estuary	0.44	0.48	0.51
Ocean 2yr olds	0.24	0.39	0.57
Ocean 3yr olds	0.31	0.51	0.74
Ocean 4yr olds	0.37	0.60	0.87
Ocean 5yr olds	0.42	0.68	0.99

8.5.3. SLAM Output and VSP Scores

For each alternative run in SLAM, four categories of model output are produced; abundance and productivity, age diversity, and spatial structure (see Chapter 3, Parameterization of VSP Criteria). For each of these categories we generate VSP scores, and then use the following equation to produce a Total VSP score:

$$Total\ VSP\ score = \frac{4(Abundance + Productivity) + Diversity + Spatial\ Structure}{6}$$

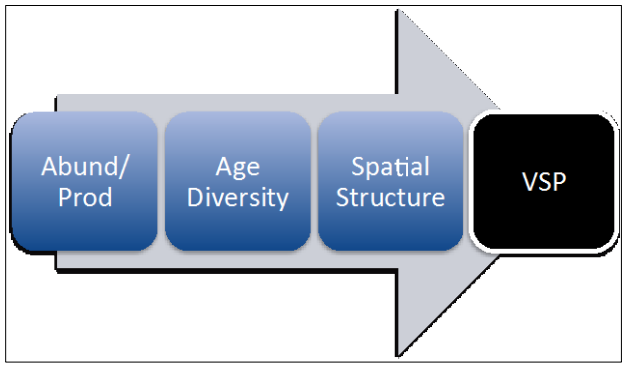


Figure 8.3: Representation of the three components (abundance and productivity, age diversity, and spatial structure) that comprise VSP score.

Abundance and Productivity

Under Baseline (i.e., current) conditions for North Santiam River, a median of 867 first-time and repeat spawners was estimated while Selective Withdrawal Structure with Floating Screen Structure (SWS-FSS) was estimated to have a median of 6,412 (Table 8.3 and Figure 8.4).

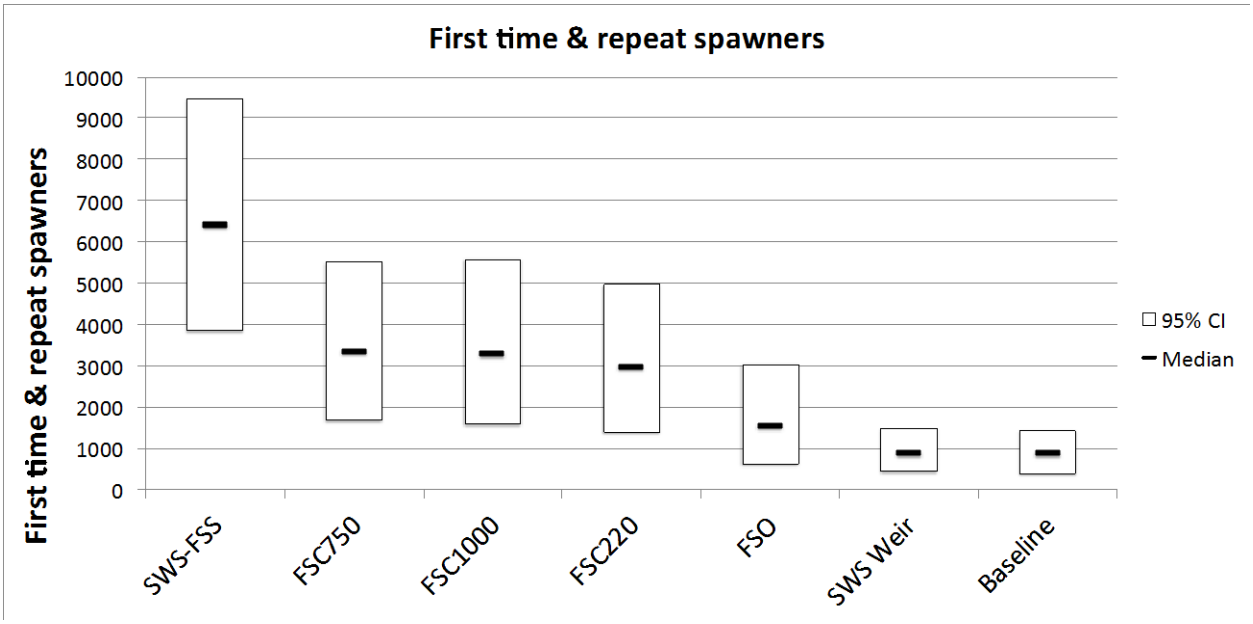


Figure 8.4: Abundance of first-time and repeat spawners among North Santiam River alternatives (see Table

8.3). Median and 95% confidence limits (line and box, respectively) were calculated from the 500 geomeans (1 geomean per run) of abundance, each of which was for a 100-year period.

We estimated the probability quasi-exinction threshold (QET) for each alternative under the following conditions; critical abundance was set as 200 individuals, a four-year moving average was used over a 100-year period (from year 6 to year 105). We started QET calculation at year 6 because the model was fully initialized beyond this point and reflected system dynamics rather than the influences of starting values. Under Baseline (i.e., current) conditions, QET was estimated as 24% for North Santiam River, while QET was <4% for all other alternatives except Selective Withdrawal Structure with Weir (SWS Weir) (Figure 8.5).

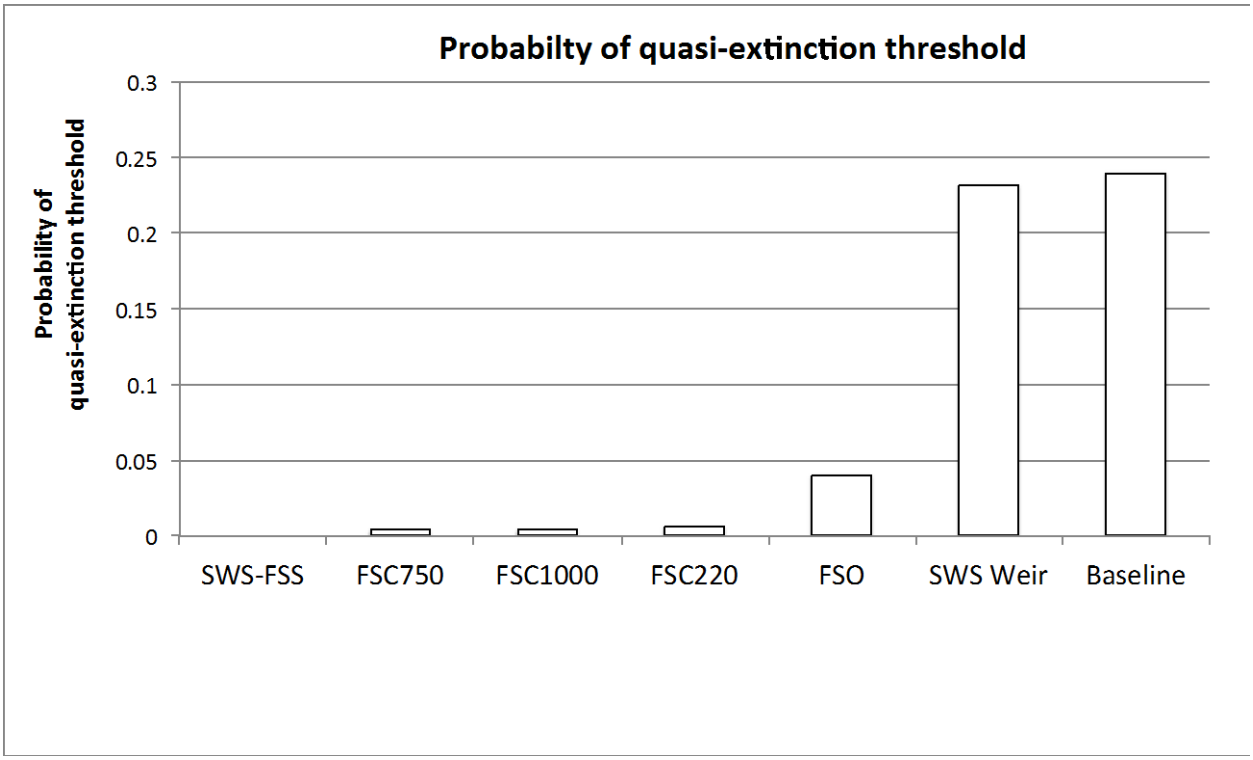


Figure 8.5: Probability of quasi-extinction among North Santiam River alternatives. The maximum value on the y-axis is 0.25 (instead of 1.0) to improve visibility of QET for several alternatives.

Based on a relationship between VSP score and abundance and productivity (see Chapter 3, Parameterization of VSP Criteria), the Baseline (i.e., current) conditions was given a median VSP score of 1.9, while four alternatives had VSP scores greater than 3.8 (SWS-FSS, FSC-220, FSC-750, FSC-1000)(Figure 8.6).

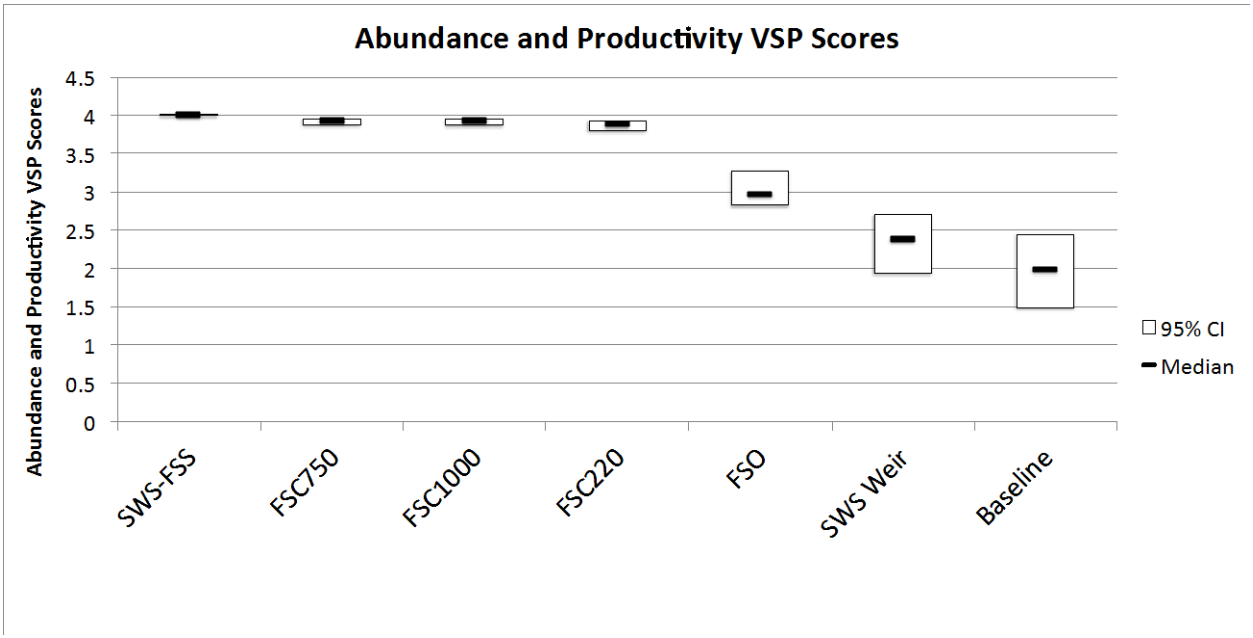


Figure 8.6: Abundance and Productivity VSP scores among North Santiam River alternatives.

Age Diversity

Age diversity was not calculated for the alternatives because the model structure for such calculations have not been developed and implemented in this iteration of SLAM. Therefore, all alternatives were given a VSP score of 3.0.

Spatial Structure

Spatial structure is a measure of population replacement in reaches above Detroit Dam. To assess replacement above Detroit Dam (i.e., Reach D & E) we used recruits per spawner, measured as returning spawners (i.e., first time spawners and returning respawners) referenced to the spawning brood that produced them. According to age structure data the majority of spawning steelhead are age 4 and 5 (approximately 48% & 42%, respectively; Upper Willamette Recovery Plan. 2011).

Table 8.4: Recruits-per-spawner ratio and VSP scores for ratio values for steelhead in North and South Santiam rivers (see Chapter 3, Qualitative Spatial Considerations).

Upper Willamette	DIP	SS Score Passage (R/S<0.75)	SS Score Passage (0.75<R/S<0.95)	SS Score Passage (R/S>0.95)
Spring Run Chinook Salmon ESU				
	North Santiam (Detroit)	1.5	2.83	3.5
	South Santiam (Foster)	1.0	2.0	2.5
	South Santiam (Green Peter)[1]	2.5	3.17	3.5
	McKenzie (Cougar)	2.0	2.67	3.0
Winter Steelhead DPS				
	North Santiam	1.5	2.83	3.5
	South Santiam (Foster)	2.0	2.33	2.5
	South Santiam (Green Peter)	2.5	3.17	3.5

$$Recruit{:}Spawner = \frac{(Spawners\ in\ Reach\ DE\ at\ time\ y + 2yrs * 0.65) + (Spawners\ in\ Reach\ DE\ at\ time\ y + 3yrs * 0.35)}{Spawners\ in\ Reach\ DE\ at\ time\ y}$$

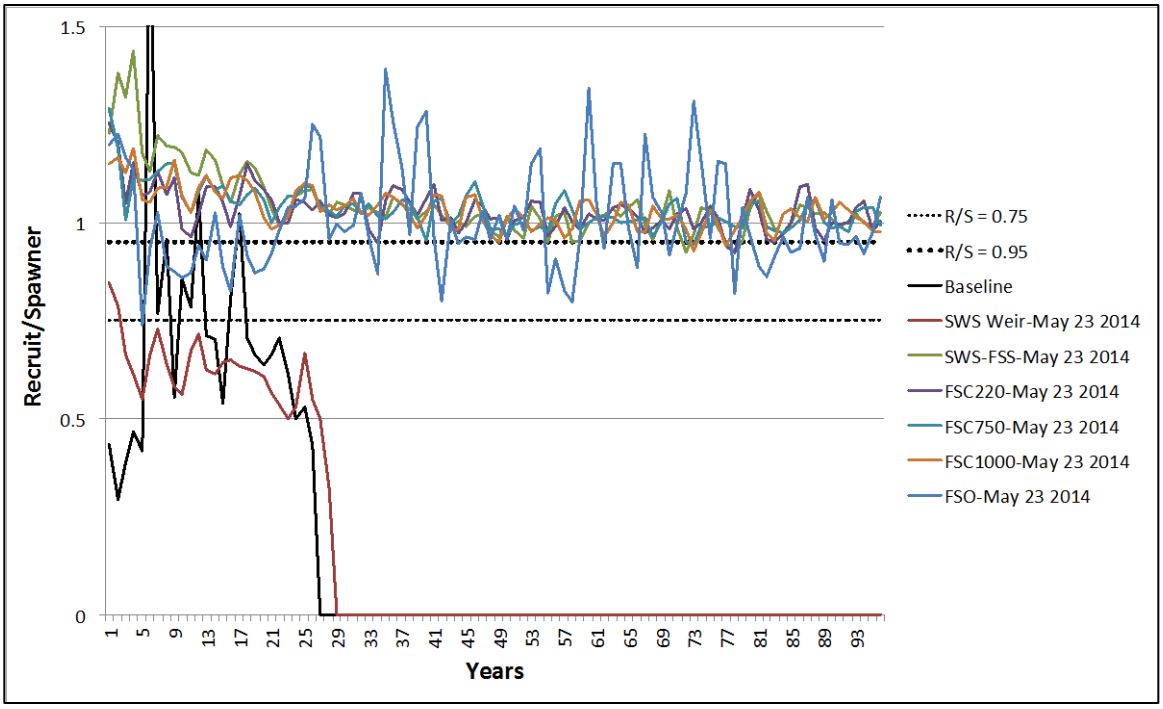


Figure 8.9: Times series of recruits-per-spawner ratio for each North Santiam River alternative. Baseline and SWS-Weir drop to zero just after simulation year 25.

Under Baseline conditions the VSP score for spatial structure is 1.5, while the median score for six alternatives is 3.5 (SWS-FSS, FSC-220, FSC-750, FSC-1000, and FSO) (see Figure 8.12).

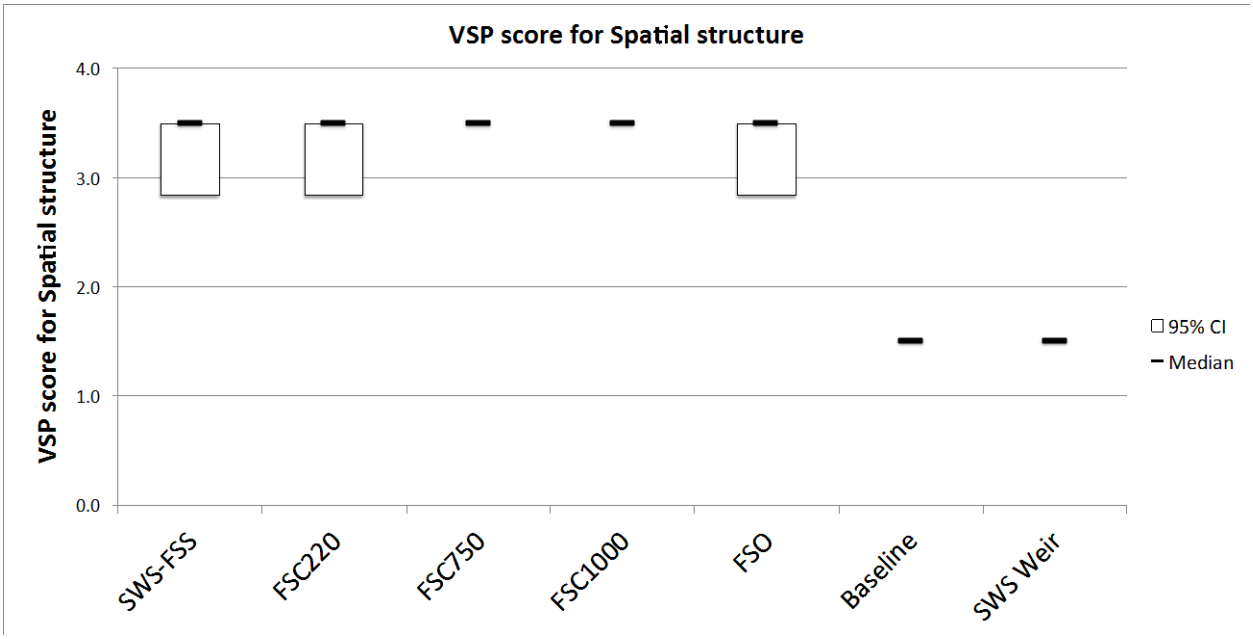


Figure 8.12: Spatial Structure VSP scores among North Santiam River alternatives. Median and standard deviation are shown (line and box, respectively), which were calculated using the median and standard deviation of recruits-to-spawner ratio.

Total VSP Score

To estimate the Total VSP score, we combined all the component VSP scores according to the following equation:

$$Total\ VSP\ score = \frac{4(Abundance + Productivity) + Diversity + Spatial\ Structure}{6}$$

Of the North Santiam River alternatives, SWS-FSS, FSC-750, and FSC-1000 produced the highest Total VSP Score of 3.7, while Baseline conditions yielded a score of 2.1 (Figure 8.13).

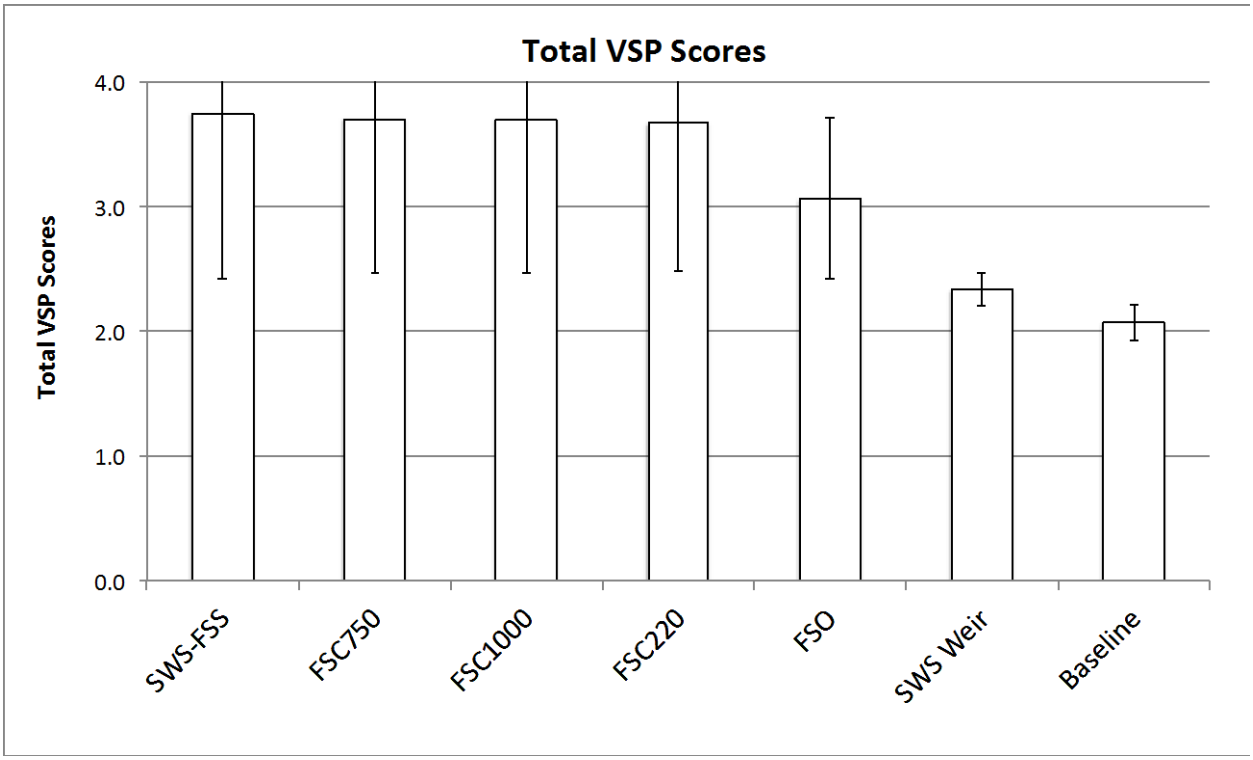


Figure 8.13: Total VSP scores among North Santiam alternatives. Whiskers denote +/- one standard deviation.

8.6. References

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Upper Willamette River conservation and recovery plan for Chinook salmon and steelhead. 2011. Pp. 363.

Willis, C., Cramer, S., Cramer, D., Smith, M., Downey, T., and Montagne, R.. 1995. Status of Willamette River Spring Chinook salmon in regards to the federal endangered species act. Part 1, Pp. 84.

CHAPTER 9. SLAM MODEL OF SOUTH SANTIAM RIVER WINTER STEELHEAD

This chapter provides a description of the parameter values used in the South Santiam River SLAM model for steelhead salmon. Below, we provide a short description of the model parameters used in each of five categories (1. Productivity, capacity, & survivals, 2. Splits, 3. Datafiles, 4. Dynamic drivers & influencers, and 5. Initialized). For reference purposes, a map of South Santiam River (Figure 9.1) is provided that highlights each reach used in SLAM. Figure 9.2 shows how the life-cycle model is modeled within SLAM. Lastly, Table 9.1 is a list of definitions corresponding to each box within the life-cycle model, while Table 9.2 is a list of abbreviations used throughout this chapter.

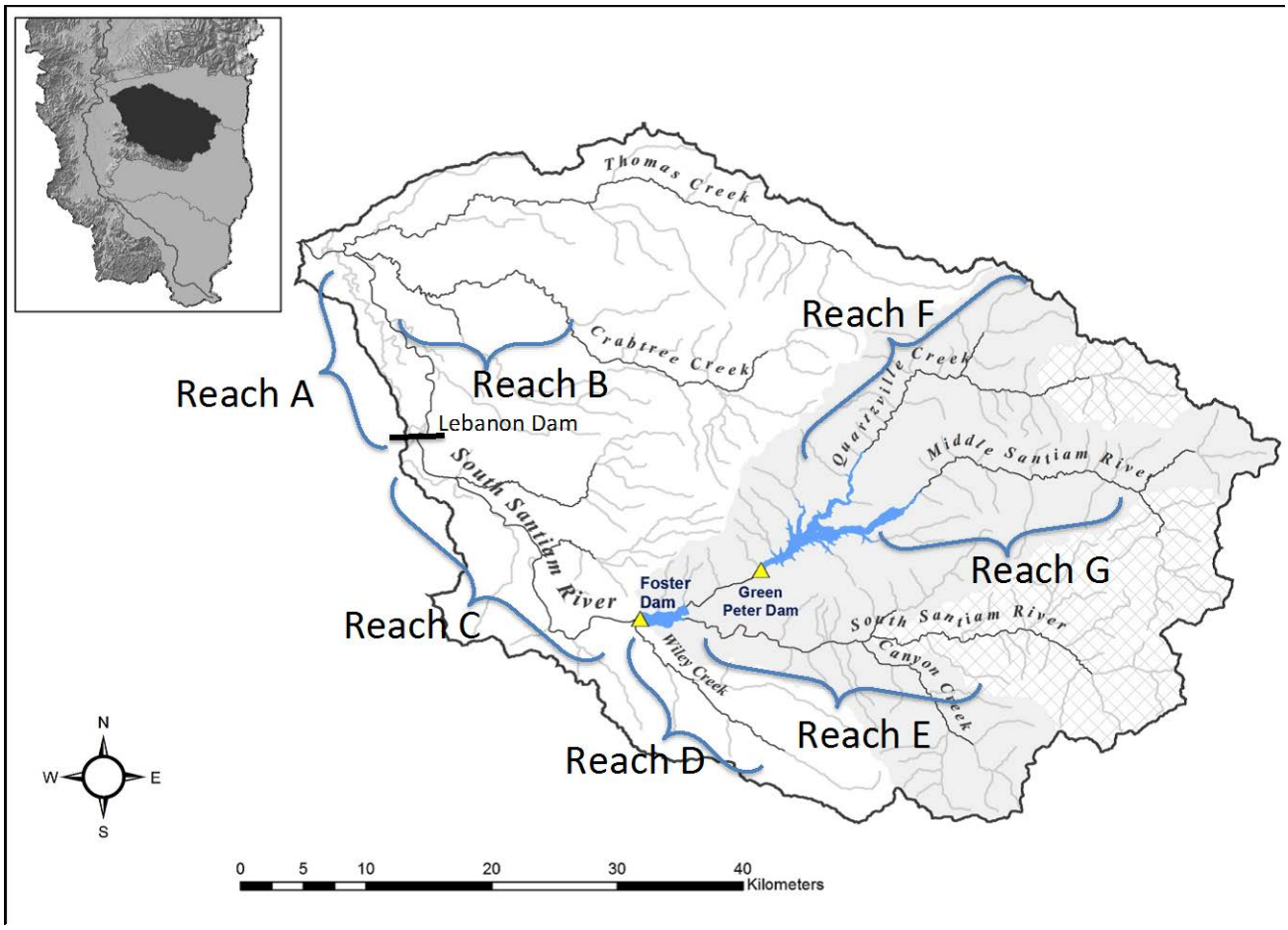


Figure 9.1: Map showing South Santiam River and the seven reaches (A-G) that are modeled in SLAM; Reach A corresponds to mainstem South Santiam River downstream of Lebanon Diversion Dam, Reach B corresponds to tributaries off of the mainstem, including Thomas Creek and Crabtree Creek, Reach C corresponds to mainstem South Santiam River between Lebanon Diversion Dam and Foster Dam, Reach D corresponds to Wiley Creek, Reach E corresponds South Santiam River upstream of Foster Reservoir, and upstream of Green Peter Dam are Reach F and G that correspond to Quartzville Creek and Middle Santiam River, respectively.

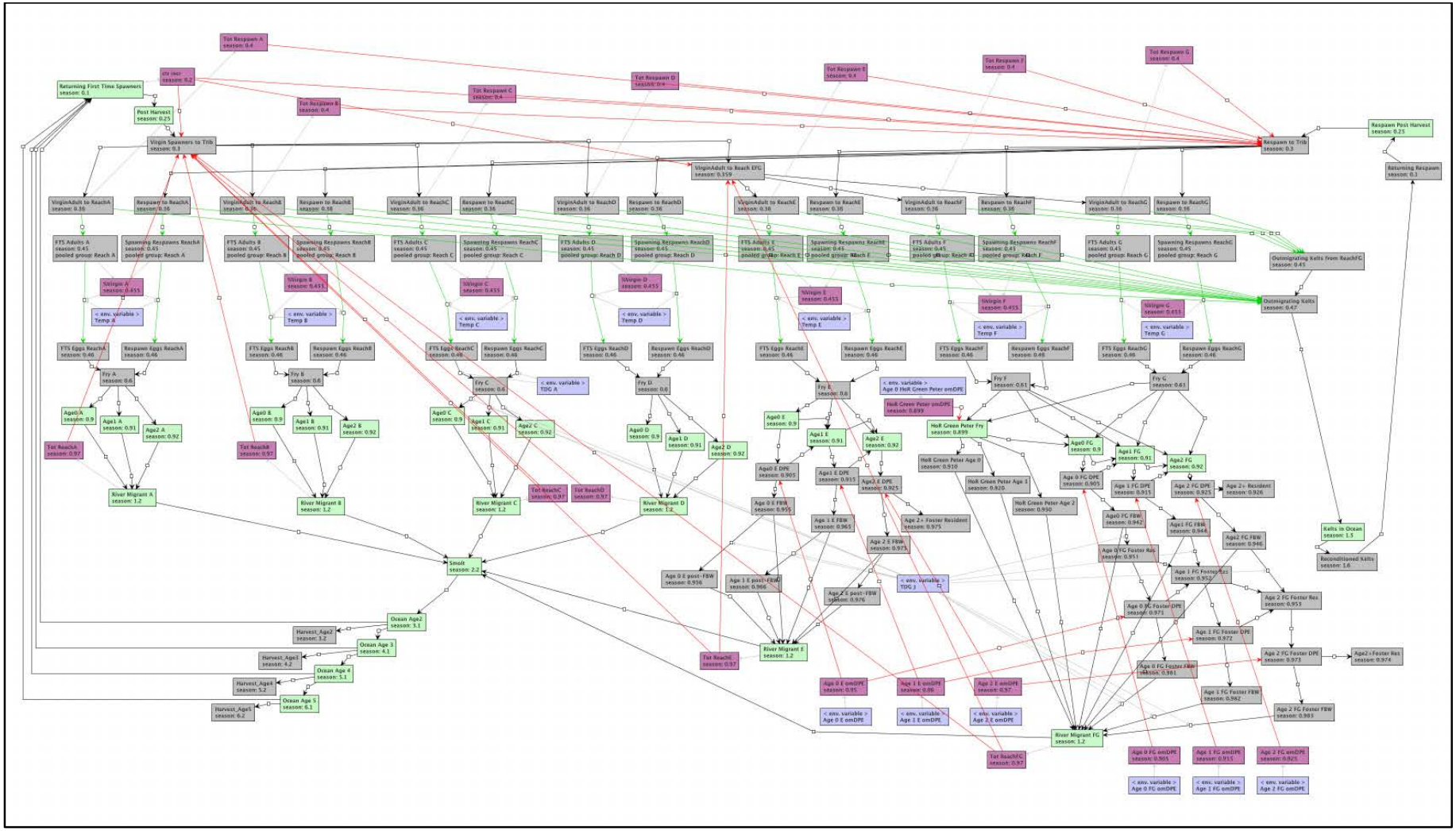


Figure 9.2: SLAM generated flow diagram of South Santiam River Steelhead salmon life cycle model. Details of this model are provided in Table 8.1 and subsequent figures in this chapter will emphasize components of this diagram.

Table 9.1: Life history stages and transitions for the South Santiam River Steelhead salmon life cycle model (Figure 9.2).

Life Stage	Definition
Returning Respawn	Kelts returning to freshwater
Returning First Time Spawners	Virgin adults returning to freshwater
Post Harvest	Freshwater harvest of returning virgin adults
Repsawn Post Harvest	Freshwater harvest of returning Kelts
Virgin Spawners to Trip	Returning virgin adults to mouth of South Santiam
Respawn to Trib	Returning Kelts to mouth of South Santiam
Respawn to Reach A	Returning Kelts to below Lebanon Dam (Reach A)
Respawn to Reach B	Returning Kelts to tributaries off of the mainstem, including Thomas Creek and Crabtree Creek (Reach B)
Respawn to Reach C	Returning Kelts to between Lebanon Diversion Dam and Foster Dam (Reach C)
Respawn to Reach D	Returning Kelts to Wiley Creek (Reach D)
Respawn to Reach E	Returning Kelts to upstream of Foster Dam (Reach E)
Respawn to Reach F	Returning Kelts to Quartsville Creek above Green Peter Dam (Reach F)
Respawn to Reach G	Returning Kelts to Middle South Santiam above Green Peter Dam (Reach G)
VirginAdult to ReachA	Returning virigin adults to below Lebanon Dam (Reach A)
VirginAdult to ReachB	Returning virigin adults to tributaries off of the mainstem, including Thomas Creek and Crabtree Creek (Reach B)
VirginAdult to ReachC	Returning virigin adults to between Lebanon Diversion Dam and Foster Dam (Reach C)
VirginAdult to ReachD	Returning virigin adults to Wiley Creek (Reach D)
VirginAdult to ReachEFG	Returning virigin adults to above Green Peter Dam (Reach EFG)
Spawning Respawns ReachA	Adults available to respawn in Reach A
Spawning Respawns ReachB	Adults available to respawn in Reach B
Spawning Respawns ReachC	Adults available to respawn in Reach C
Spawning Respawns ReachD	Adults available to respawn in Reach D
Spawning Respawns ReachE	Adults available to respawn in Reach E
Spawning Respawns ReachF	Adults available to respawn in Reach F
Spawning Respawns ReachG	Adults available to respawn in Reach G
VirginAdult to ReachE	Returning virigin adults to to upstream of Foster Dam (Reach E)
VirginAdult to ReachF	Returning virigin adults to Quartsville Creek above Green Peter Dam (Reach F)
VirginAdult to ReachG	Returning virigin adults to Middle South Santiam above Green Peter Dam (Reach G)
FTS Adults A	Adults available to spawn in Reach A
FTS Adults B	Adults available to spawn in Reach B
FTS Adults C	Adults available to spawn in Reach C
FTS Adults D	Adults available to spawn in Reach D
FTS Adults E	Adults available to spawn in Reach E
FTS Adults F	Adults available to spawn in Reach F
FTS Adults G	Adults available to spawn in Reach G
Outmigrating Kelts from	Adults from Reach F and G that return to ocean as Kelts

ReachFG	
Outmigrating Kelts	Adults from Reach A, B, C, D, & E that return to ocean as Kelts
Respawn Eggs ReachA	Eggs in Reach A produced by adult respawners in Reach A
Respawn Eggs ReachB	Eggs in Reach B produced by adult respawners in Reach B
Respawn Eggs ReachC	Eggs in Reach C produced by adult respawners in Reach C
Respawn Eggs ReachD	Eggs in Reach D produced by adult respawners in Reach D
Respawn Eggs ReachE	Eggs in Reach E produced by adult respawners in Reach E
Respawn Eggs ReachF	Eggs in Reach F produced by adult respawners in Reach F
Respawn Eggs ReachG	Eggs in Reach G produced by adult respawners in Reach G
FTS Eggs ReachA	Eggs in Reach A produced by adult virgins in Reach A
FTS Eggs ReachB	Eggs in Reach B produced by adult virgins in Reach B
FTS Eggs ReachC	Eggs in Reach C produced by adult virgins in Reach C
FTS Eggs ReachD	Eggs in Reach D produced by adult virgins in Reach D
FTS Eggs ReachE	Eggs in Reach E produced by adult virgins in Reach E
FTS Eggs ReachF	Eggs in Reach F produced by adult virgins in Reach F
FTS Eggs ReachG	Eggs in Reach G produced by adult virgins in Reach G
Fry A	Fry in Reach A produced adult virgins and respawners in Reach A
Fry B	Fry in Reach B produced adult virgins and respawners in Reach B
Fry C	Fry in Reach C produced adult virgins and respawners in Reach C
Fry D	Fry in Reach D produced adult virgins and respawners in Reach D
Fry E	Fry in Reach E produced adult virgins and respawners in Reach E
Fry F	Fry in Reach F produced adult virgins and respawners in Reach F
Fry G	Fry in Reach G produced adult virgins and respawners in Reach G
HoR Green Peter Fry	Fry from Reach F & G collected at head of Green Peter reservoir
Age0 A	Fish of age class 0 in Reach A
Age0 B	Fish of age class 0 in Reach B
Age0 C	Fish of age class 0 in Reach C
Age0 D	Fish of age class 0 in Reach D
Age0 E	Fish of age class 0 in Reach E
Age0 FG	Fish of age class 0 in Reach FG
Age1 A	Fish of age class 1 in Reach A
Age1 B	Fish of age class 1 in Reach B
Age1 C	Fish of age class 1 in Reach C
Age1 D	Fish of age class 1 in Reach D
Age1 E	Fish of age class 1 in Reach E
Age1 FG	Fish of age class 1 in Reach FG
Age2 A	Fish of age class 2 in Reach A
Age2 B	Fish of age class 2 in Reach B
Age2 C	Fish of age class 2 in Reach C
Age2 D	Fish of age class 2 in Reach D
Age2 E	Fish of age class 2 in Reach E

Age2 FG	Fish of age class 2 in Reach FG
Age0 FG DPE	Fish of age class 0 available to pass Green Peter Dam
Age0 E DPE	Fish of age class 0 available to pass Foster Dam
Age1 FG DPE	Fish of age class 1 available to pass Green Peter Dam
Age1 E DPE	Fish of age class 1 available to pass Foster Dam
Age2 FG DPE	Fish of age class 2 available to pass Green Peter Dam
Age2 E DPE	Fish of age class 2 available to pass Foster Dam
Age0 FG FBW	Fish of age class 0 that pass Green Peter Dam
Age1 FG FBW	Fish of age class 1 that pass Green Peter Dam
Age2 FG FBW	Fish of age class 2 that pass Green Peter Dam
Age 0 FG Foster Res	Fish of age class 0 from Reach FG that are in Foster reservoir
Age 1 FG Foster Res	Fish of age class 1 from Reach FG that are in Foster reservoir
Age 2 FG Foster Res	Fish of age class 2 from Reach FG that are in Foster reservoir
Age0 E FBW	Fish of age class 0 that pass Foster Dam
Age1 E FBW	Fish of age class 1 that pass Foster Dam
Age2 E FBW	Fish of age class 2 that pass Foster Dam
Age 0 E post-FBW	Fish of age class 0 from Reach E that are downstream of Foster Dam
Age 1 E post-FBW	Fish of age class 1 from Reach E that are downstream of Foster Dam
Age 2 E post-FBW	Fish of age class 2 from Reach E that are downstream of Foster Dam
Age 0 FG Foster DPE	Fish of age class 0 from Reach FG that are available to pass Foster Dam
Age 1 FG Foster DPE	Fish of age class 1 from Reach FG that are available to pass Foster Dam
Age 2 FG Foster DPE	Fish of age class 2 from Reach FG that are available to pass Foster Dam
Age 0 FG Foster FBW	Fish of age class 0 from Reach FG that passed Foster Dam
Age 1 FG Foster FBW	Fish of age class 1 from Reach FG that passed Foster Dam
Age 2 FG Foster FBW	Fish of age class 2 from Reach FG that passed Foster Dam
River Migrant A	Fish from Reach A leaving South Santiam River
River Migrant B	Fish from Reach B leaving South Santiam River
River Migrant C	Fish from Reach C leaving South Santiam River
River Migrant D	Fish from Reach D leaving South Santiam River
River Migrant E	Fish from Reach E leaving South Santiam River
River Migrant FG	Fish from Reach FG leaving South Santiam River
Kelts in Ocean	Outmigrating Kelts that enter the ocean
Reconditioned Kelts	Kelts returning to freshwater
Smolt	River Migrants from all Reaches that survive to become smolts
Ocean Age2	Smolts that survive to enter the ocean as age class 2
Ocean Age3	Fish in the ocean as age class 3
Ocean Age4	Fish in the ocean as age class 4
Ocean Age5	Fish in the ocean as age class 5

Table 9.2: List of Acronyms and Abbreviations.

Abbreviation	Definition
0+	Juveniles less than one year old
1+	Juveniles older than one year but less than two years old
Beverton-Holt	Beverton-Holt spawner-recruit relationship
FOS	Foster Dam
d/s	Downstream
Harvest_Age#	Fishery harvest of age N# fish (# = 2, 3, 4, 5, & 6 for spring Steelhead)
Hockey-Stick	Spawner-recruit relationship in the Hockey-stick shape
FTS	First Time Spawners
FBW	Fish Benefits Workbook
Res	Reservoir
HoR	Head of reservoir
ODFW	Oregon Department of Fish and Wildlife
SE	Standard Error
SLAM	Species Life-Cycle Analysis Modules
u/s	Upstream
TDG	Total Dissolved Gas
DPE	Dam Passage Efficiency
omDPE	One minus Dam Passage Efficiency

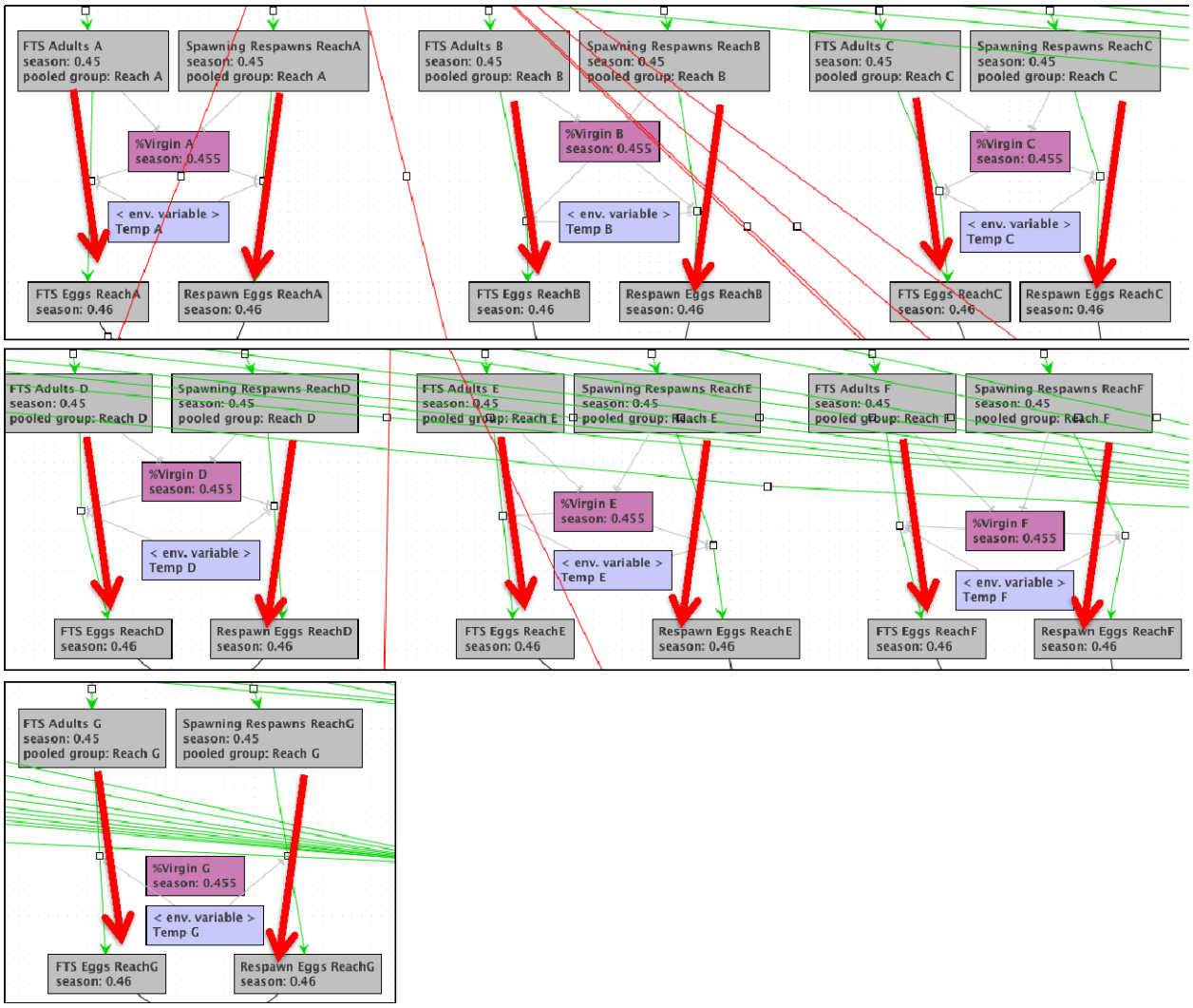
9.1. Productivity, Capacity, & Survivals

This section describes the reproductive capability of spawners within each reach, reach-specific capacity, and the proportion of individuals that survive as they move among stages in the life-cycle model (Figure 9.2, Tables 9.1 and 9.2).

Productivity and capacity parameter values of first time spawners (FTS Adults) and those adults that are spawning again (Spawning Respawns). Within each reach spawners are pooled by reach, and a reach-specific Beverton-Holt capacity function is applied to determine the number of eggs.

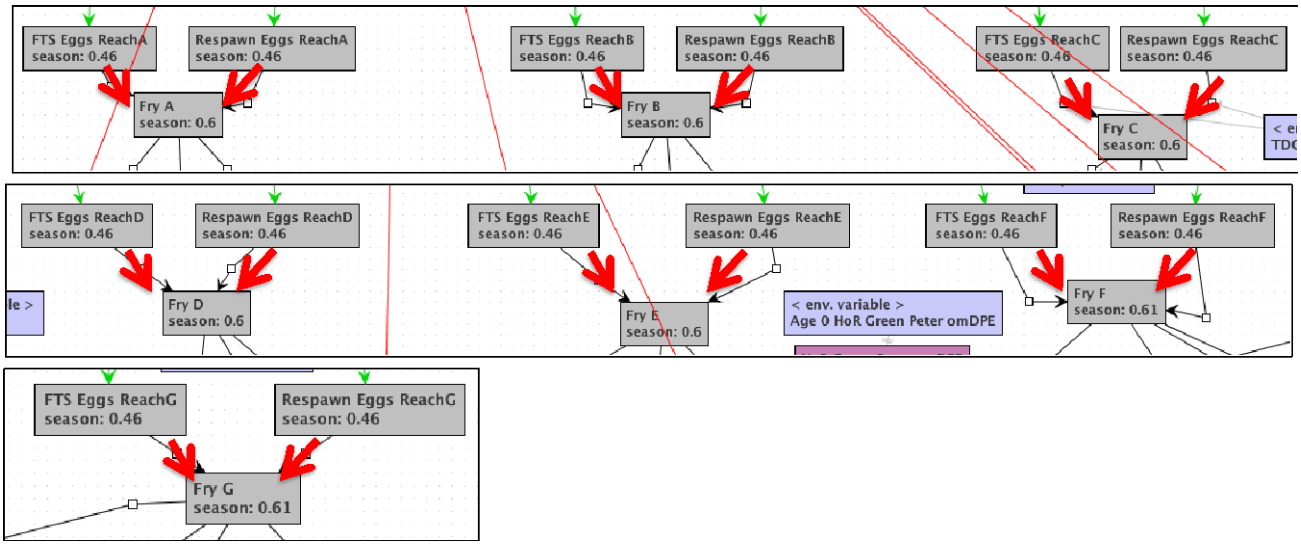
The Beverton-Holt productivity term is fixed at 0.5 times fecundity, with the assumption that the sex ratio of spawning fish is 50:50. (see Chapter 3, Steelhead, Capacity Estimates). Egg capacity is stochastic, and each year reach-specific egg capacity is drawn from a normal distribution according to the following parameters:

Reach	From	To	Capacity & Productivity	Mean	SD	Min	Max
A	FTS Adults	FTS Eggs	Capacity	50,000	10,000	25,000	250,000
			Productivity	2,000	100	1,000	2,250
B	FTS Adults	FTS Eggs	Capacity	1,500,000	100,000	750,000	4,000,000
			Productivity	2,000	100	1,000	2,250
C	FTS Adults	FTS Eggs	Capacity	2,500,000	100,000	500,000	4,000,000
			Productivity	2,000	100	1,000	2,250
D	FTS Adults	FTS Eggs	Capacity	1,500,000	100,000	750,000	2,500,000
			Productivity	2,000	100	1,000	2,250
E	FTS Adults	FTS Eggs	Capacity	5,000,000	250,000	2,500,000	7,000,000
			Productivity	2,000	100	1,000	2,250
F	FTS Adults	FTS Eggs	Capacity	2,000,000	100,000	1,000,000	2,500,000
			Productivity	2,000	100	1,000	2,250
G	FTS Adults	FTS Eggs	Capacity	4,500,000	250,000	2,000,000	6,000,000
			Productivity	2,000	100	1,000	2,250
A	Spawning Respawns	FTS Eggs	Capacity	50,000	10,000	25,000	250,000
			Productivity	4,160	100	2,000	5,600
B	Spawning Respawns	FTS Eggs	Capacity	1,500,000	100,000	750,000	4,000,000
			Productivity	4,160	100	2,000	5,600
C	Spawning Respawns	FTS Eggs	Capacity	2,500,000	100,000	500,000	4,000,000
			Productivity	4,160	100	2,000	5,600
D	Spawning Respawns	FTS Eggs	Capacity	1,500,000	100,000	750,000	2,500,000
			Productivity	4,160	100	2,000	5,600
E	Spawning Respawns	FTS Eggs	Capacity	5,000,000	250,000	2,500,000	7,000,000
			Productivity	4,160	100	2,000	5,600
F	Spawning Respawns	FTS Eggs	Capacity	2,000,000	100,000	1,000,000	2,500,000
			Productivity	4,160	100	2,000	5,600
G	Spawning Respawns	FTS Eggs	Capacity	4,500,000	250,000	2,000,000	6,000,000
			Productivity	4,160	100	2,000	5,600



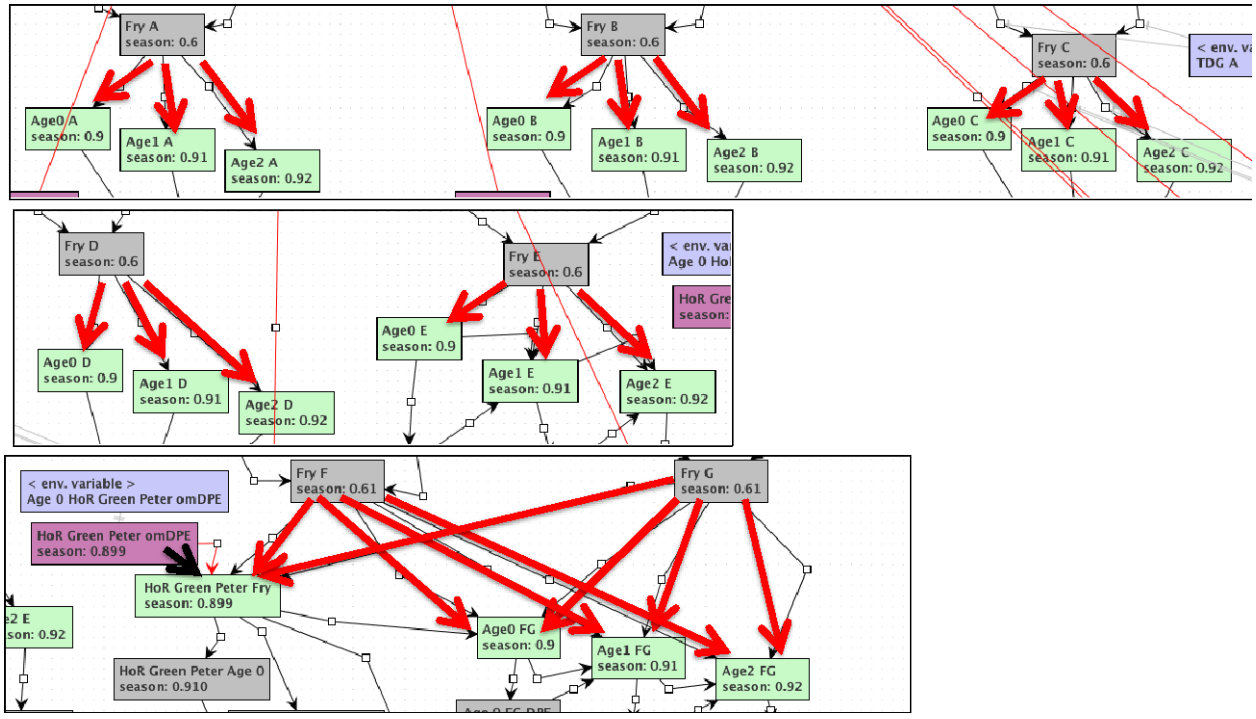
Survival parameter values from Egg to Fry stage, First time and Respawners. The below values correspond to the reach-specific proportion of Eggs that survive to become Fry (see Chapter 3, Steelhead, Survival).

Reach	From	To	Curve type	Capacity & Productivity	Distr. type	Proportion of fish that survive
A	FTS & Respawn Eggs	Fry A	Linear	Productivity	Constant	0.3
B	FTS & Respawn Eggs	Fry B	Linear	Productivity	Constant	0.325
C	FTS & Respawn Eggs	Fry C	Linear	Productivity	Constant	0.36
D	FTS & Respawn Eggs	Fry D	Linear	Productivity	Constant	0.325
E	FTS & Respawn Eggs	Fry E	Linear	Productivity	Constant	0.425
F	FTS & Respawn Eggs	Fry F	Linear	Productivity	Constant	0.45
G	FTS & Respawn Eggs	Fry G	Linear	Productivity	Constant	0.45



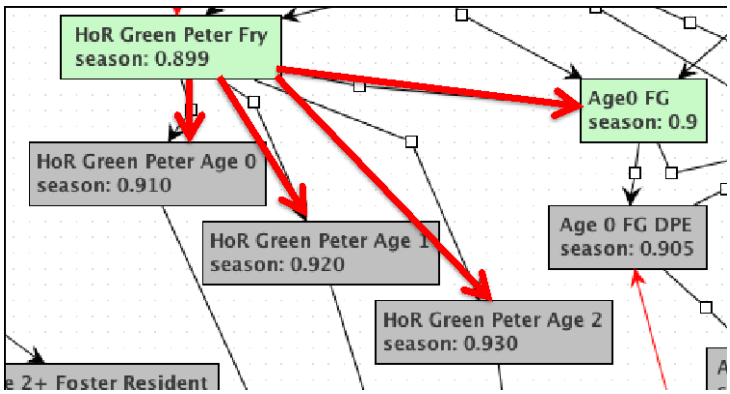
Survival parameter values from Fry to each year class. The values below correspond to the reach-specific proportion of Fry that survive to become Age 0, 1, and 2.

Reach	From	To	Curve type	Capacity & Productivity	Distribution type	Proportion of fish that survive
A	Fry A	Age0 A	Linear	Productivity	Constant	0.25
		Age1 A	Linear	Productivity	Constant	0.14
		Age2 A	Linear	Productivity	Constant	0.073
B	Fry B	Age0 B	Linear	Productivity	Constant	0.25
		Age1 B	Linear	Productivity	Constant	0.145
		Age2 B	Linear	Productivity	Constant	0.085
C	Fry C	Age0 C	Linear	Productivity	Constant	0.25
		Age1 C	Linear	Productivity	Constant	0.16
		Age2 C	Linear	Productivity	Constant	0.1
D	Fry D	Age0 D	Linear	Productivity	Constant	0.25
		Age1 D	Linear	Productivity	Constant	0.145
		Age2 D	Linear	Productivity	Constant	0.085
E	Fry E	Age0 E	Linear	Productivity	Constant	0.525
		Age1 E	Linear	Productivity	Constant	0.325
		Age2 E	Linear	Productivity	Constant	0.25
F	Fry F	Age0 FG	Linear	Productivity	Constant	0.6
		Age1 FG	Linear	Productivity	Constant	0.35
		Age2 FG	Linear	Productivity	Constant	0.275
		HoR Green Peter Fry	Linear	Productivity	Constant	0.65
G	Fry G	Age0 FG	Linear	Productivity	Constant	0.6
		Age1 FG	Linear	Productivity	Constant	0.35
		Age2 FG	Linear	Productivity	Constant	0.275
		HoR Green Peter Fry	Linear	Productivity	Constant	0.65



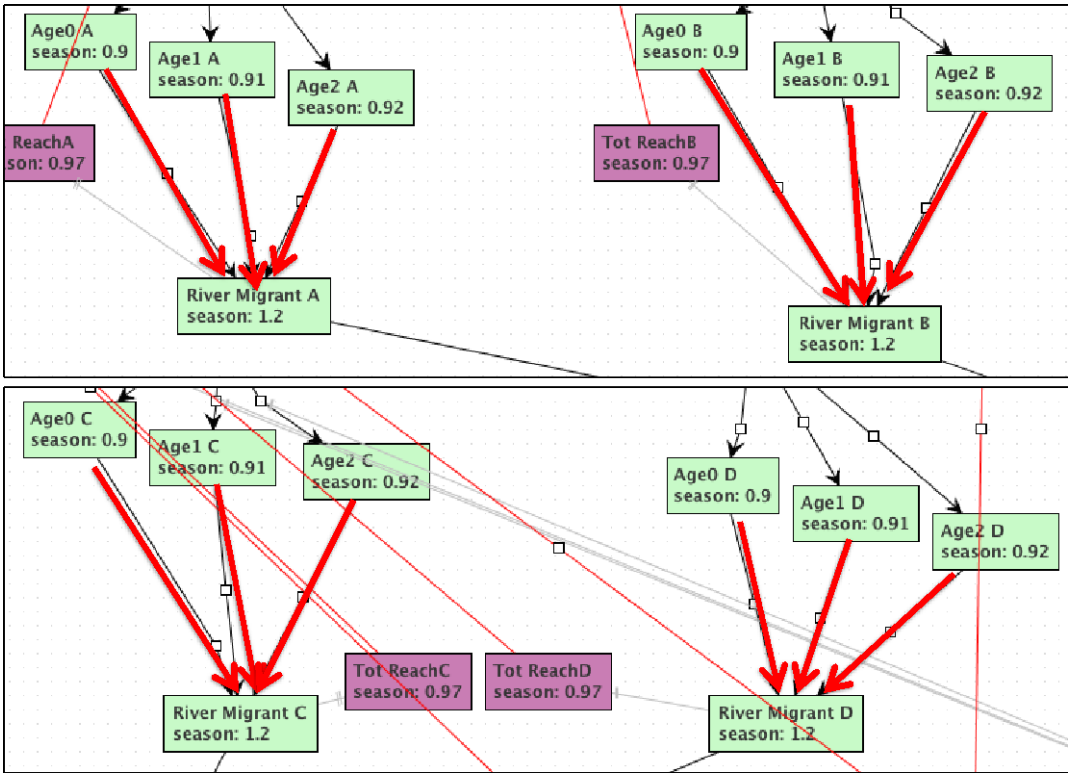
Survival parameter values of Fry collected at Head of Green Peter reservoir (HoR Green peter Fry) to each age class (HoR Green Peter Age0, HoR Green Peter Age1, and HoR Green Peter Age2) and those individuals that were not collected (Age0 FG).

Reach	From	To	Curve type	Capacity & Productivity	Distribution type	Proportion of fish that survive
FG	HoR Collection	HoR Age0	Linear	Productivity	Constant	0.05
		HoR Age1	Linear	Productivity	Constant	0.065
		HoR Age2	Linear	Productivity	Constant	0.0825
		Age0 FG	Linear	Productivity	Constant	1



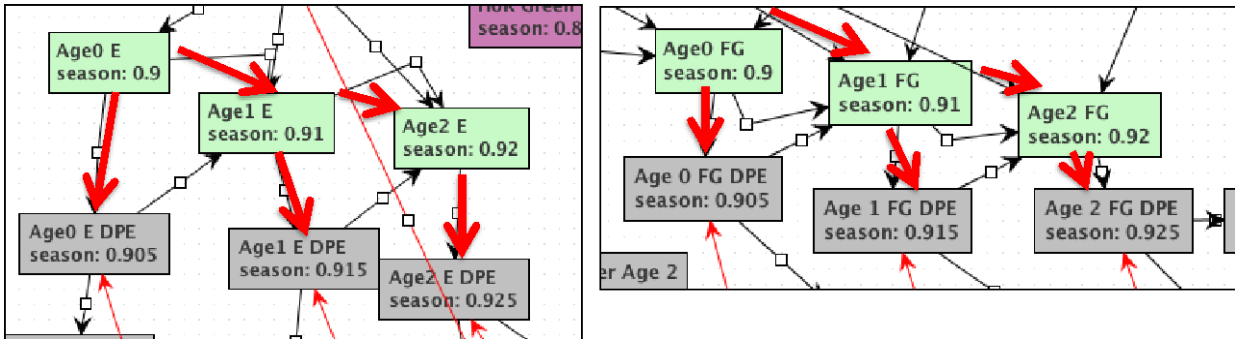
Survival parameter values of each of three age classes (Age0, Age1, and Age2) in Reach A, B, C, and D to the River Migrant stage downstream of South Santiam.

Reach	From	To	Curve type	Capacity & Productivity	Distribution type	Proportion of fish that survive Max
A	Age0 A	River Migrant A	Linear	Productivity	Constant	0.07
	Age1 A	River Migrant A	Linear	Productivity	Constant	0.175
	Age2 A	River Migrant A	Linear	Productivity	Constant	0.4
B	Age0 B	River Migrant B	Linear	Productivity	Constant	0.07
	Age1 B	River Migrant B	Linear	Productivity	Constant	0.175
	Age2 B	River Migrant B	Linear	Productivity	Constant	0.45
C	Age0 C	River Migrant C	Linear	Productivity	Constant	0.07
	Age1 C	River Migrant C	Linear	Productivity	Constant	0.175
	Age2 C	River Migrant C	Linear	Productivity	Constant	0.45
D	Age0 D	River Migrant D	Linear	Productivity	Constant	0.07
	Age1 D	River Migrant D	Linear	Productivity	Constant	0.175
	Age2 D	River Migrant D	Linear	Productivity	Constant	0.45



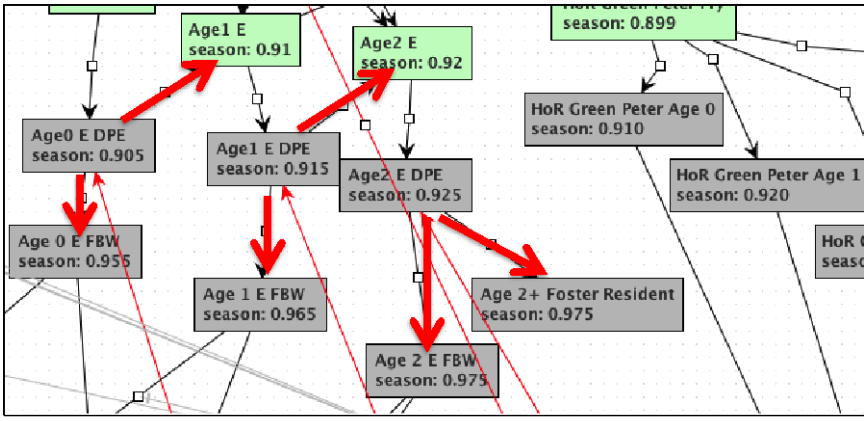
Survival parameter values of each of three age classes (Age0, Age1, and Age2) in Reach E and FG (above Foster and Green Peter dams, respectively) to Foster and Green Peter reservoirs, respectively. These values are from parameter workshops (see Chapter 3, appendix 3.6).

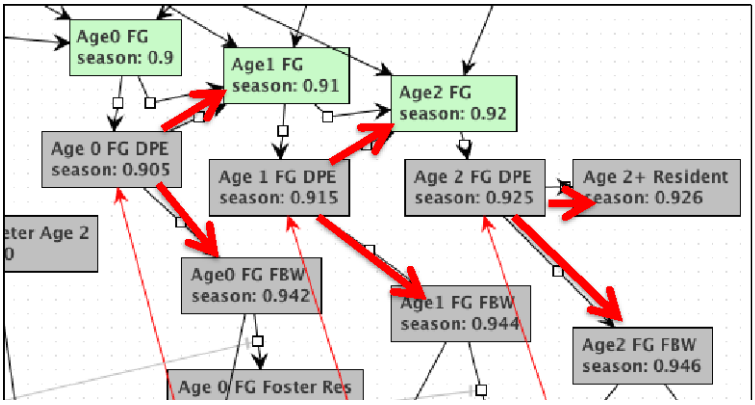
Reach	From	To	Curve type	Capacity & Productivity	Distribution type	Proportion of fish that survive Max
E	Age0 E	Age1 E	Linear	Productivity	Triangular	0.15 (mean), 0.1-0.3 (min & max)
		Age0 E DPE	Linear	Productivity	Triangular	0.4 (mean), 0.3-0.5 (min & max)
	Age1 E	Age2 E	Linear	Productivity	Triangular	0.5 (mean), 0.4-0.6 (min & max)
		Age1 E DPE	Linear	Productivity	Triangular	0.5 (mean), 0.4-0.6 (min & max)
	Age2 E	Age2 E DPE	Linear	Productivity	Triangular	0.85 (mean), 0.8-0.95 (min & max)
FG	Age0 FG	Age1 FG	Linear	Productivity	Triangular	0.2 (mean), 0.1-0.25 (min & max)
		Age0 FG DPE	Linear	Productivity	Triangular	0.3 (mean), 0.2-0.4 (min & max)
	Age1 FG	Age2 FG	Linear	Productivity	Triangular	0.45 (mean), 0.3-0.6 (min & max)
		Age1 FG DPE	Linear	Productivity	Triangular	0.5 (mean), 0.4-0.6 (min & max)
	Age2 FG	Age2 FG DPE	Linear	Productivity	Triangular	0.85 (mean), 0.8-0.95 (min & max)



Survival parameter values of each age class in Foster reservoir (Reach E) that will either attempt to pass Foster Dam or remain in the reservoir and become the next age class.
Survival parameter values of each age class in Green Peter reservoir (Reach FG) that will either attempt to pass Green Peter Dam or remain in the reservoir and become the next age class. Dam passage survival ('Passage survival' in the below table) is one of two datafiles from the Fish Benefits Workbook, the other being dam passage efficiency (DPE) (Fish Benefits Workbooks User Guide 2014), both of which are provided by USACE. Dam passage efficiency is the fraction of fish available to pass a dam that actually pass, those that do not pass remain in the reservoir.

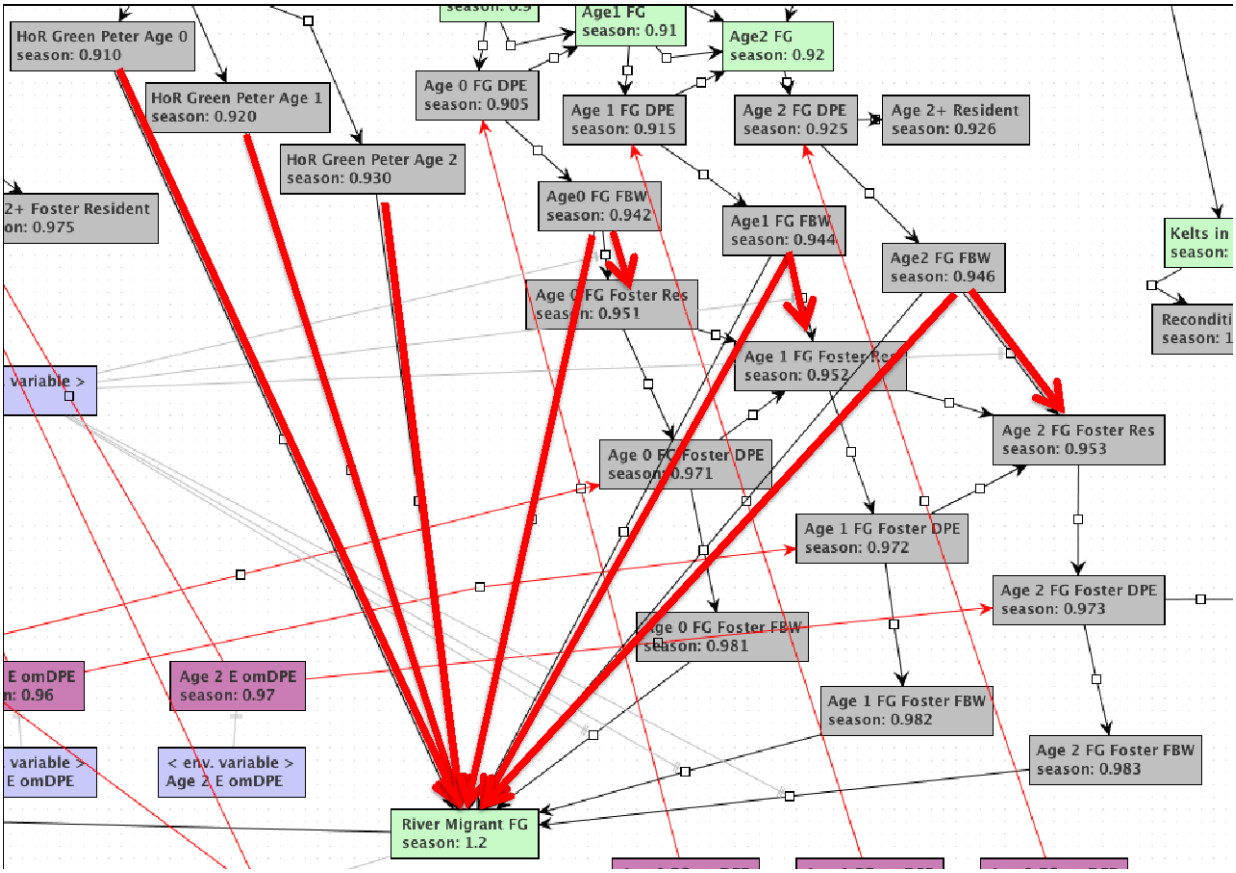
Reach	From	To	Curve type	Capacity & Productivity	Distr. type	Proportion of fish that survive Max
DE	Age0 DPE	Age0 E FBW	Linear	Productivity	Datafile	Passage survival
		Age1 E	Linear	Productivity	Constant	0.375
	Age1 E DPE	Age1 E FBW	Linear	Productivity	Datafile	Passage survival
		Age2 E	Linear	Productivity	Constant	1
	Age2 E DPE	Age2 E FBW	Linear	Productivity	Datafile	Passage survival
		Age2+ Resident	Linear	Productivity	Constant	0
FG	Age0 FG DPE	Age0 FG FBW	Linear	Productivity	Datafile	Passage survival
		Age1 FG	Linear	Productivity	Constant	0.375
	Age1 FG DPE	Age1 FG FBW	Linear	Productivity	Datafile	Passage survival
		Age2 FG	Linear	Productivity	Constant	0.9
	Age2 FG DPE	Age2 FG FBW	Linear	Productivity	Datafile	Passage survival
		Age2+ Resident	Linear	Productivity	Constant	0





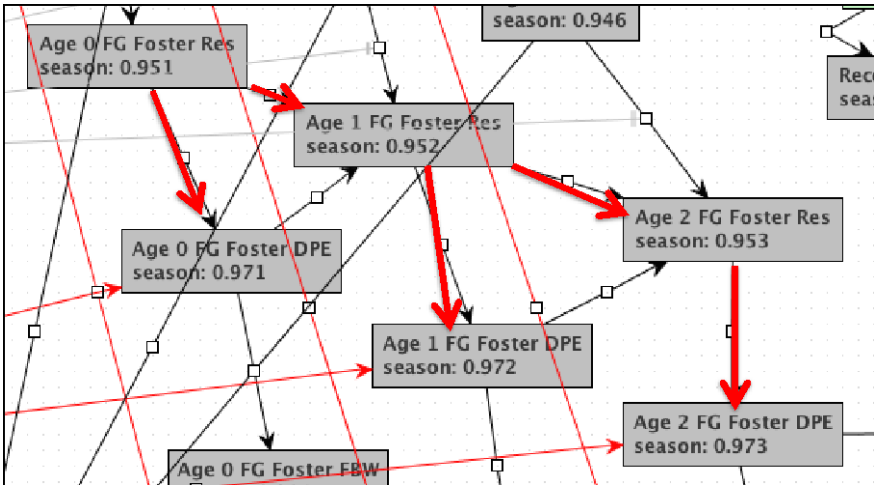
Survival parameter values of each age class collected at head of Green Peter reservoir (Reach FG) and transported downstream of Foster Dam (River Migrant FG). Survival parameter values of each age class collected at Green Peter Dam (Reach FG) and transported downstream of Foster Dam (River Migrant FG) and those that pass Green Peter Dam and go to Foster reservoir (Age 0 FG Foster Res, Age1 FG Foster Res, and Age 2 FG Foster Res).

Reach	From	To	Curve type	Capacity & Productivity	Distr..type	Proportion of fish that survive
FG	HoR Green Peter Age 0	River Migrant FG	Linear	Productivity	Constant	0.075
	HoR Green Peter Age 1	River Migrant FG	Linear	Productivity	Constant	0.22
	HoR Green Peter Age 2	River Migrant FG	Linear	Productivity	Constant	0.5
	Age 0 FG FBW	Age 0 FG Foster Res	Linear	Productivity	Constant	1
		River Migrant FG	Linear	Productivity	Constant	0.115
	Age 1 FG FBW	Age 1 FG Foster Res	Linear	Productivity	Constant	1
		River Migrant FG	Linear	Productivity	Constant	0.45
	Age 2 FG FBW	Age 2 FG Foster Res	Linear	Productivity	Constant	1
		River Migrant FG	Linear	Productivity	Constant	0.6



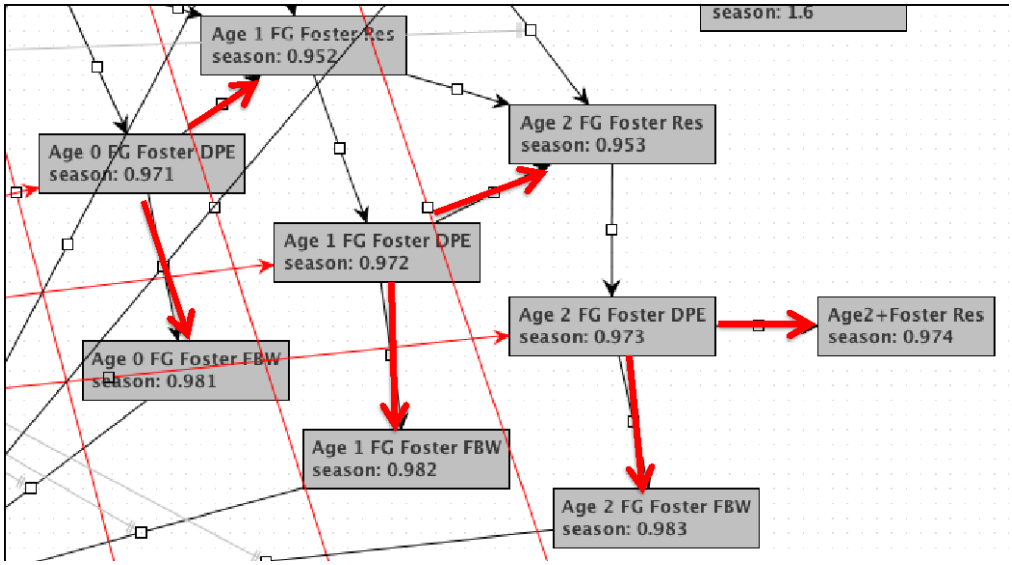
Survival parameter values of each age class from Reach FG (above Green Peter Dam) that are in Foster reservoir and either move toward Foster Dam as their current age class or remain in the reservoir and become the next age class.

Reach	From	To	Curve type	Capacity & Productivity	Distr. type	Proportion of fish that survive
FG	Age 0 FG Foster Res	Age 0 FG Foster DPE	Linear	Productivity	Triangular	0.8 (mean), 0.6-0.95 (min & max)
		Age 1 FG Foster Res	Linear	Productivity	Triangular	0.3 (mean), 0.6-0.95(min & max)
	Age 1 FG Foster Res	Age 1 FG Foster DPE	Linear	Productivity	Triangular	0.8 (mean), 0.6-0.95 (min & max)
		Age 2 FG Foster Res	Linear	Productivity	Triangular	0.8 (mean), 0.6-0.95 (min & max)
	Age 2 FG Foster Res	Age 2 FG Foster DPE	Linear	Productivity	Triangular	0.8 (mean), 0.6-0.95 (min & max)



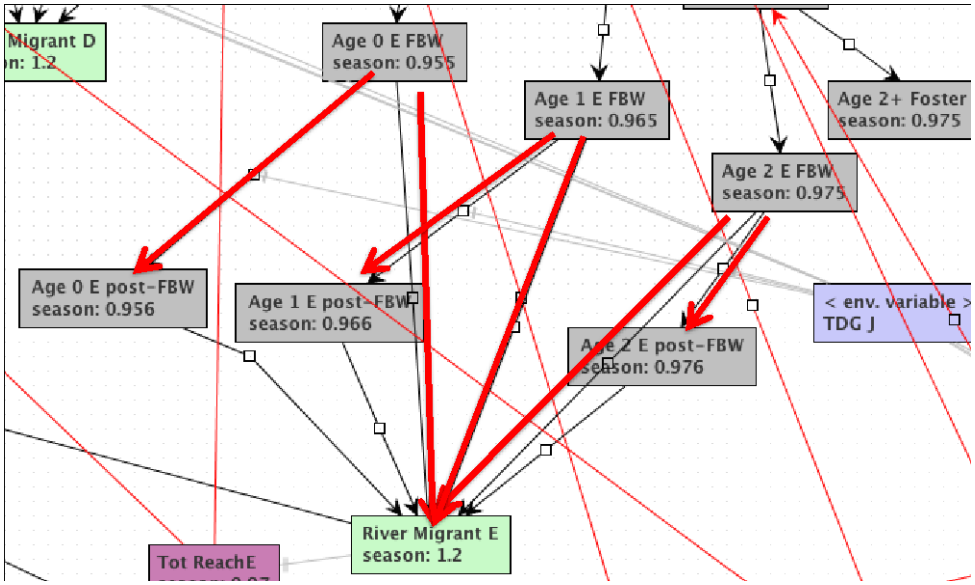
Survival parameter values of each age class from Reach FG (above Green Peter Dam) that pass Foster Dam (Age 0 FG Foster FBW, Age 1 FG Foster FBW, and Age 2 FG Foster FBW) and remain in Foster reservoir as the next age class (Age 1 FG Foster Res, Age 2 FG Foster Res, and Age2+ Foster Res).

Reach	From	To	Curve type	Capacity & Productivity	Distr. type	Proportion of fish that survive
FG	Age 0 FG Foster DPE	Age 1 FG Foster Res	Linear	Productivity	Constant	0.375
		Age 0 FG Foster FBW	Linear	Productivity	Datafile	Passage survival
	Age 1 FG Foster DPE	Age 2 FG Foster Res	Linear	Productivity	Constant	0.9
		Age 1 FG Foster FBW	Linear	Productivity	Datafile	Passage survival
	Age 2 FG Foster DPE	Age 2+ FG Foster Res	Linear	Productivity	Constant	0
		Age 2 FG Foster FBW	Linear	Productivity	Datafile	Passage survival



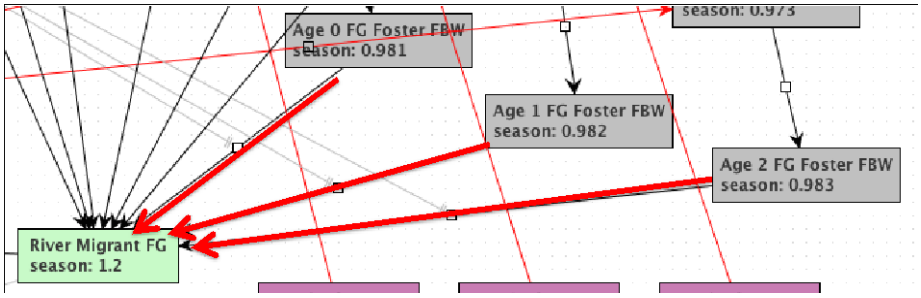
Survival parameter values of each age class from Reach E (above Foster Dam) that passed Foster Dam and are impacted by TDG (Age 0 E post-FBW, Age 1 E post-FBW, and Age 2 post-FBW) and those fish that were released downstream of TDG impact (River Migrant E).

Reach	From	To	Curve type	Capacity & Productivity	Distr. type	Proportion of fish that survive
E	Age 0 E FBW	Age 0 E post-FBW	Linear	Productivity	Constant	0.115
		River Migrant E	Linear	Productivity	Constant	0.115
	Age 1 E FBW	Age 1 E post-FBW	Linear	Productivity	Constant	0.425
		River Migrant E	Linear	Productivity	Constant	0.425
	Age 2 E FBW	Age 2 E post-FBW	Linear	Productivity	Constant	0.6
		River Migrant E	Linear	Productivity	Constant	0.6



Survival parameter values of each age class from Reach FG (above Green Peter Dam) that passed Foster Dam and are impacted by TDG (River Migrant FG).

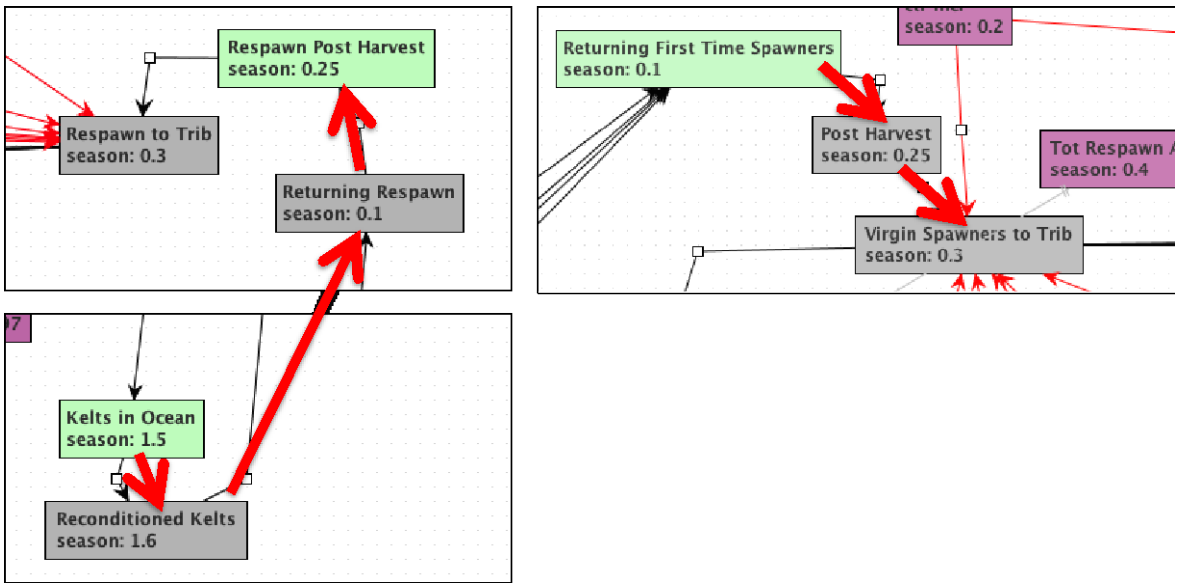
Reach	From	To	Curve type	Capacity & Productivity	Distr. type	Proportion of fish that survive
FG	Age 0 FG Foster FBW	River Migrant FG	Linear	Productivity	Constant	0.115
	Age 1 FG Foster FBW	River Migrant FG	Linear	Productivity	Constant	0.45
	Age 2 FG Foster FBW	River Migrant FG	Linear	Productivity	Constant	0.65



Estuary and ocean survival. Juveniles below Willamette Falls have an estuary survival time series applied, and in subsequent ocean years from, from 1, up to 4 ocean years, an ocean survival time series is applied.

Survival parameter values of Kelts (Kelts in Ocean) returning to respawn and first time spawners returning to spawn.

Reach	From	To	Curve type	Capacity & Productivity	Distr. type	Proportion of fish that survive
Kelts	Kelts in Ocean	Reconditioned Kelts	Linear	Productivity	Constant	0.125
	Reconditioned Kelts	Returning Respawn	Linear	Productivity	Constant	0.5
	Returning Respawn	Respawn Post Harvest	Linear	Productivity	Constant	0.825
	Respawn Post Harvest	Respawn to Trib	Linear	Productivity	Constant	0.9
	Respawn to Reach ABCDEFG	Spawning Respawns Reach ABCDEF	Linear	Productivity	Constant	1
		Outmigrating Kelts from Reach ABCDEFG	Linear	Productivity	Constant	0.8
First Time Spawners	Returning First Time Spawners	Post Harvest	Linear	Productivity	Constant	0.825
	Post Harvest	Virgin Spawners to Tribs	Linear	Productivity	Constant	0.9
	VirginAdult to Reach ABCDEFG	FTS Adults A	Linear	Productivity	Constant	1
		Outmigrating Kelts from Reach ABCDEFG	Linear	Productivity	Constant	0.8



9.2. Splits

This section describes the proportion of fish directed from an individual life-stage to two or more subsequent life-stages via different pathways (splits).

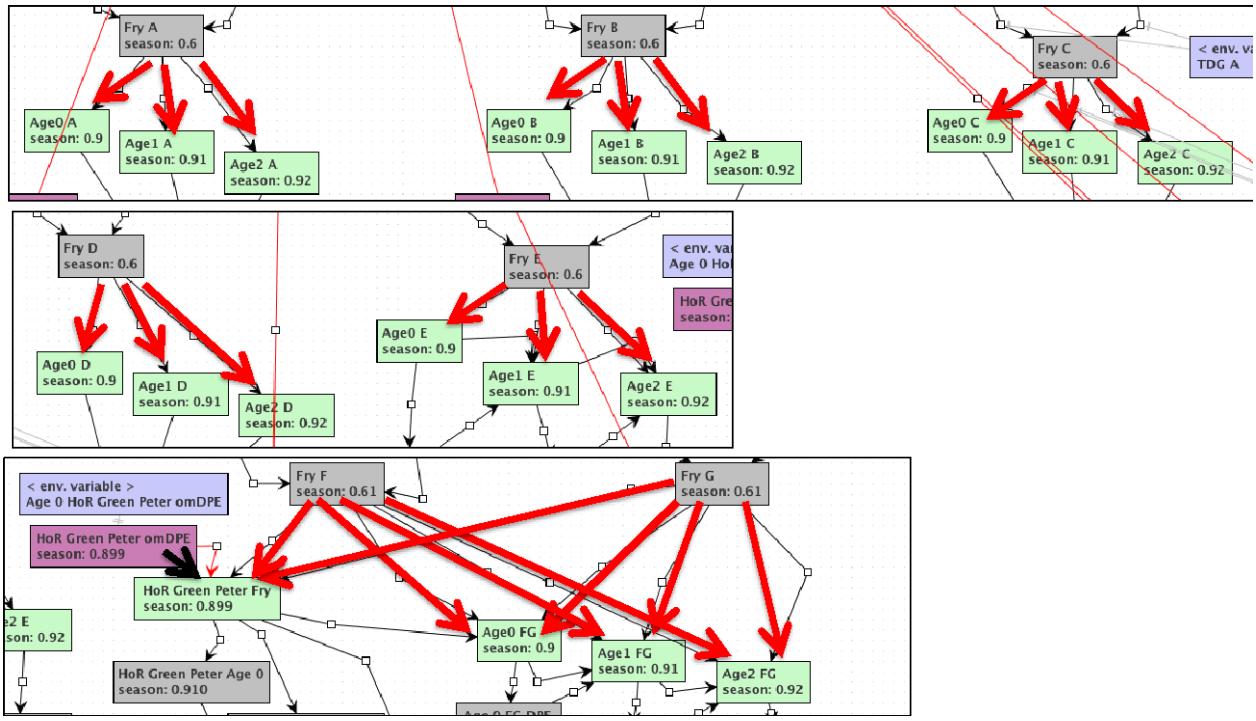
Proportion of first time spawners that return to Reach A, B, C, D, or EFG. Proportion of repeat spawners that return to Reach A, B, C, D, E, F, or G. In the process of simplifying the SLAM model structure, we pooled together juveniles from all reaches starting at the estuary stage since estuary/ocean survivals and ocean and mainstem harvest were applied equally to fish from all reaches. Because of homing of adult Steelhead salmon to their natal reaches we reapportioned returnining adults in year *t* back to their natal reaches according to the numbers of juveniles produced in year *t*-4. Specifically, for each simulated year we quantified the proportion of juveniles that exited each reach. These proportions were then used to split returning adults (four simulated years later) that survived freshwater harvest (Virgin Spawners to Trib and Respawn to Trib) to those that return to Reach A (VirginAdult to ReachA and Respawn to ReachA), Reach B (VirginAdult to Reach B and Respawn to ReachB), Reach C (VirginAdult to Reach C and Respawn to ReachC), Reach D (VirginAdult to Reach D and Respawn to ReachD), Reach E (VirginAdult to Reach E and Respawn to ReachE), Reach F (VirginAdult to Reach F and Respawn to ReachF), and Reach G (VirginAdult to Reach G and Respawn to ReachG). To achieve this in SLAM we used a tool called a Split Influence, which influences the ratios of a split (McElhany et al. 2012). After the model was initialized with a fixed set of ratios for a split, the Split Influence determined the split from the juvenile counts four years previously:

$$Proportion\ of\ fish\ returning\ to\ VirginAdult\ to\ ReachA = \left(\frac{Tot\ ReachA}{Tot\ ReachA+Tot\ ReachB+Tot\ ReachC+Tot\ ReachD+Tot\ ReachE+Tot\ ReachFG}\right)$$

From	To	Proportion
Virgin Spawners to Trib	VirginAdult to ReachA	Split influence (otherwise 0.05)
	VirginAdult to ReachB	Split influence (otherwise 0.15)
	VirginAdult to ReachC	Split influence (otherwise 0.4)
	VirginAdult to ReachD	Split influence (otherwise 0.15)
	VirginAdult to ReachEFG	Split influence (otherwise 0.25)
Respawn to Trib	Respawn to ReachA	Split influence (otherwise 0.08)
	Respawn to ReachB	Split influence (otherwise 0.12)
	Respawn to ReachC	Split influence (otherwise 0.3)
	Respawn to ReachD	Split influence (otherwise 0.09)
`	Respawn to ReachE	Split influence (otherwise 0.25)
	Respawn to ReachF	Split influence (otherwise 0.08)
	Respawn to ReachG	Split influence (otherwise 0.08)
VirginAdult to ReachEFG	VirginAdult to ReachE	Split influence (otherwise 1)
	VirginAdult to ReachF	Split influence (otherwise 0)
	VirginAdult to ReachG	Split influence (otherwise 0)

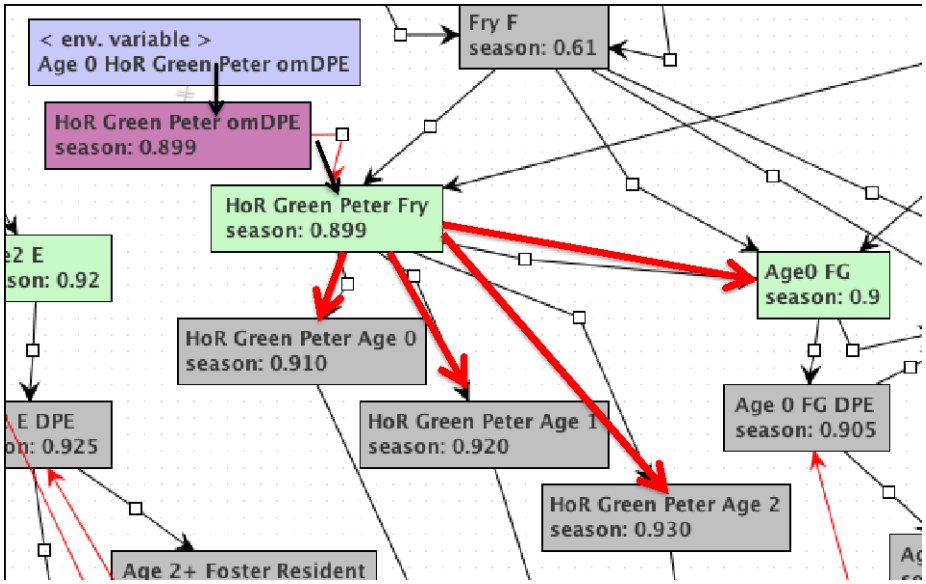
Proportion of Fry that become each of three age classes (Age0, Age1, and Age2). These values are from parameter workshops 2014 (see Chapter 3, appendix 3.6).

From	To	Proportion
Fry A	Age0 A	0.25
	Age1 A	0.4
	Age2 A	0.35
Fry B	Age0 B	0.25
	Age1 B	0.4
	Age2 B	0.35
Fry C	Age0 C	0.25
	Age1 C	0.4
	Age2 C	0.35
Fry D	Age0 D	0.25
	Age1 D	0.4
	Age2 D	0.35
Fry E	Age0 E	0.85
	Age1 E	0.12
	Age2 E	0.3
Fry F & G	Age0 F	0.7
	Age1 F	0.1
	Age2 F	0.2
	HoR Green Peter Fry	0



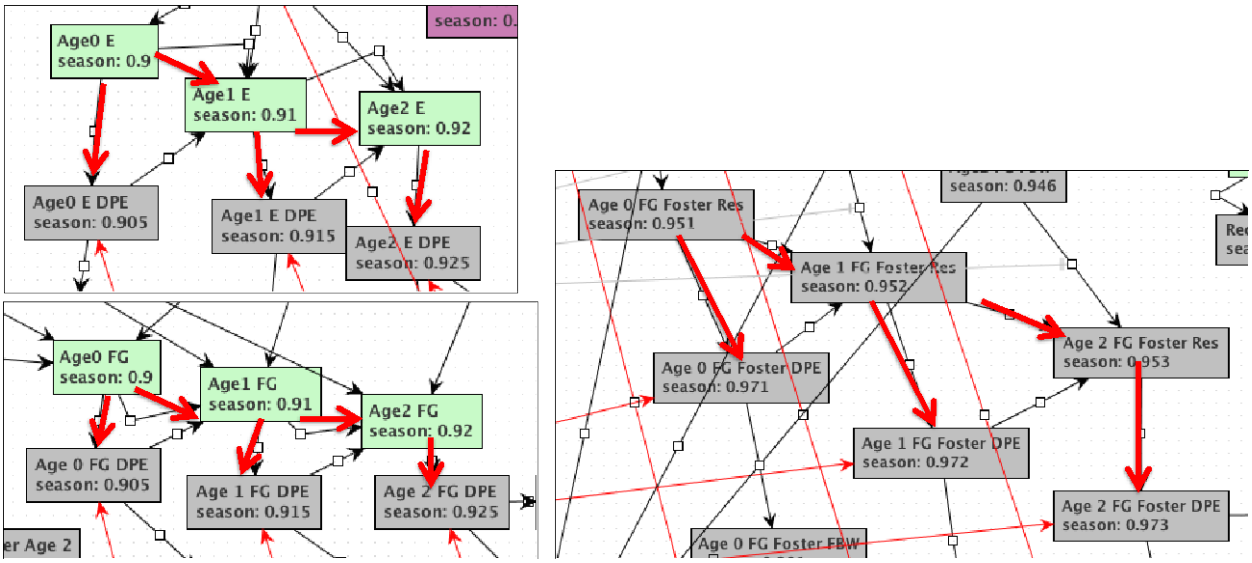
Proportion of Fry at head of Green Peter reservoir that remain in the reservoir as age class 0 (Age0 FG) and those that are collected and become each age classes (HoR Green Peter Age0, HoR Green Peter Age1, and HoR Green Peter Age2).

From	To	Proportion
HoR Green Peter Fry	Age0 FG	Split influencer determined by DPE file
	HoR Green Peter Age 0	Split influencer determined by DPE file *0.7
	HoR Green Peter Age 1	Split influencer determined by DPE file * 0.1
	HoR Green Peter Age 2	Split influencer determined by DPE file * 0.2



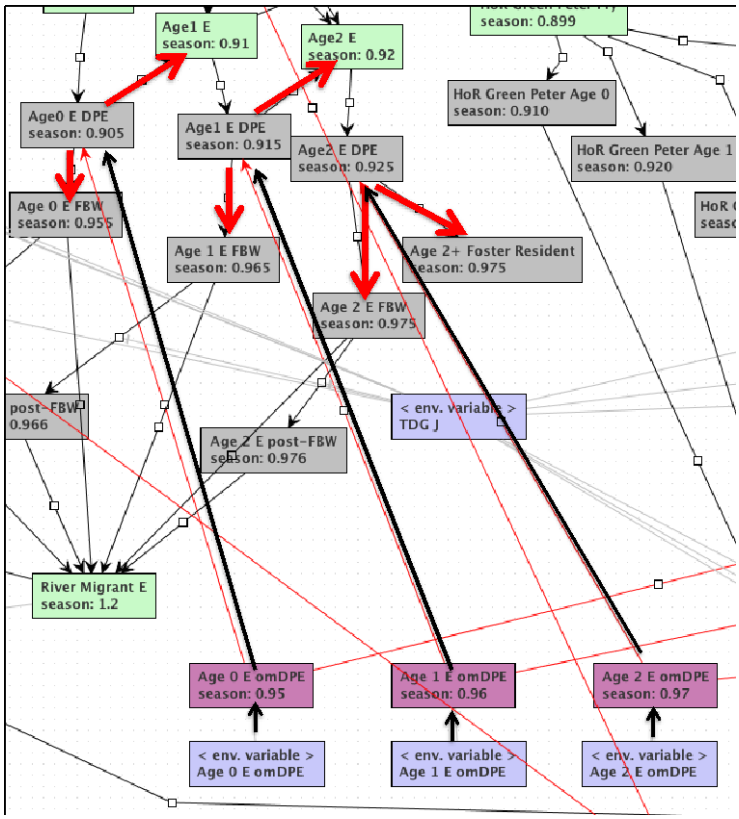
Proportion of each of three age classes (Age0, Age1, and Age2) in Reach E and FG (above Foster and Green Peter dams, respectively) to Foster or Green Peter reservoir where their age class remains the same or they become the next age class. These values are from parameter workshops (see Chapter 3, appendix 3.6).

Reach	From	To	Curve type	Capacity & Productivity	Distr. type	Proportion of fish that survive Max
E	Age0 E	Age0 E DPE	Linear	Productivity	Triangular	0.95 (mean), 0.9-1.0 (min & max)
		Age1 E	Linear	Productivity	Triangular	0.05(mean), 0.0-0.1 (min & max)
	Age1 E	Age1 E DPE	Linear	Productivity	Triangular	0.95 (mean), 0.9-1.0 (min & max)
		Age2 E	Linear	Productivity	Triangular	0.05(mean), 0.0-0.1 (min & max)
	Age2E	Age2 E DPE	Linear	Productivity	Constant	1
FG	Age0 FG	Age1 FG	Linear	Productivity	Triangular	0.25(mean), 0.2-0.3 (min & max)
		Age0 FG DPE	Linear	Productivity	Triangular	0.75(mean), 0.65-0.85 (min & max)
	Age1 FG	Age2 FG	Linear	Productivity	Triangular	0.05(mean), 0.0-0.1 (min & max)
		Age1 FG DPE	Linear	Productivity	Triangular	0.95(mean), 0.9-1.0 (min & max)
	Age2 FG	Age2 FG DPe	Linear	Productivity	Constant	1
FG	Age0 FG Foster Res	Age0 FG Foster DPE	Linear	Productivity	Triangular	0.95 (mean), 0.9-1.0 (min & max)
		Age1 FG Foster Res	Linear	Productivity	Triangular	0.05(mean), 0.0-0.1 (min & max)
	Age1 FG Foster Res	Age1 FG Foster DPE	Linear	Productivity	Triangular	0.95 (mean), 0.9-1.0 (min & max)
		Age2 FG Foster Res	Linear	Productivity	Triangular	0.05(mean), 0.0-0.1 (min & max)
	Age2 FG Foster	Age2 FG Foster Res	Linear	Productivity	Constant	1



Proportion of individuals from Reach E (above Foster Dam) that are in Foster reservoir and are available to pass Foster Dam or unavailable to pass and thus remain in the reservoir to become the next age class. These are the proportion of Age 0 individuals in Foster reservoir (Age0 E DPE) that are available to pass Foster Dam (Age0 E FBW) or unavailable to pass and thus remain in the reservoir to become Age 1 individuals (Age1 E), proportion of Age 1 individuals in Foster reservoir (Age1 E DPE) that are available to pass Foster Dam (Age1 E FBW) or unavailable to pass and thus remain in the reservoir and become Age 2 individuals (Age2 E), and proportion of Age 2 individuals in Detroit reservoir (Age2 E DPE) that are available to pass Detroit Dam (Age2 E FBW) or unavailable to pass, and are removed from the simulation (Age2 + Resident). These proportions use dam passage efficiency (DPE) data that were specific to particular dam project alternatives and were provided by USACE (Fish Benefits Workbooks User Guide 2014).

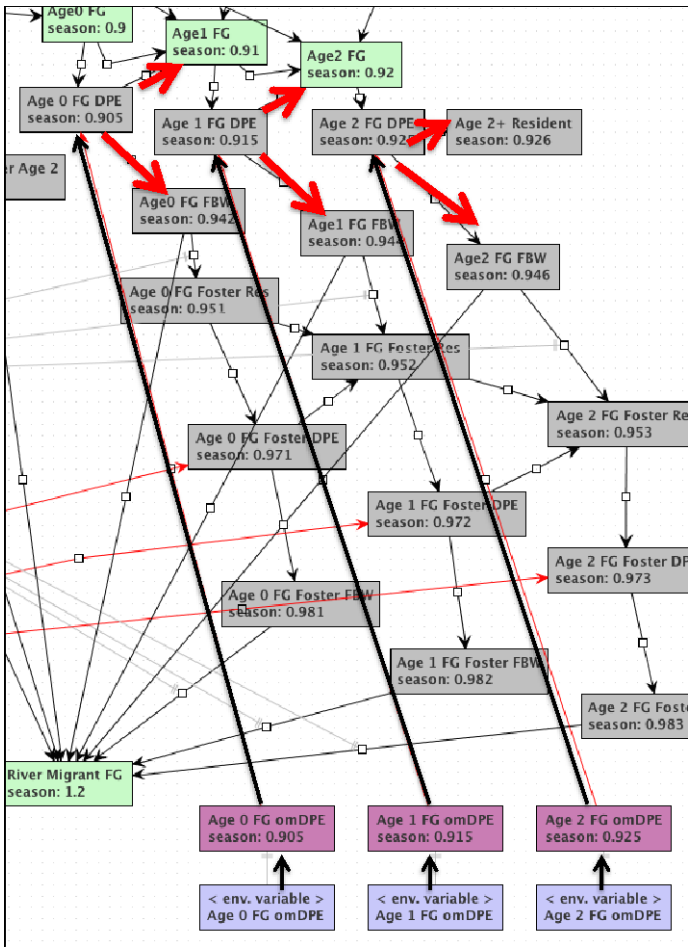
From	To	Proportion
Age0 E DPE	Age0 E FBW	Split influencer determined by DPE file
	Age1 E	Split influencer determined by DPE file
Age 1 E DPE	Age1 E FBW	Split influencer determined by DPE file
	Age2 E	Split influencer determined by DPE file
Age 2 E DPE	Age2 E FBW	Split influencer determined by DPE file
	Age2 + Resident	Split influencer determined by DPE file



Black arrows represent the split influence from dam passage efficiency data.

Proportion of individuals from Reach FG (above Green Peter Dam) that are in Green Peter reservoir and are available to pass Green Peter Dam or unavailable to pass and thus remain in the reservoir to become the next age class. These are the proportion of Age 0 individuals in Green Peter reservoir (Age0 FG DPE) that are available to pass Green Peter Dam (Age0 FG FBW) or unavailable to pass and thus remain in the reservoir to become Age 1 individuals (Age1 FG), proportion of Age 1 individuals in Green Peter reservoir (Age1 FG DPE) that are available to pass Green Peter Dam (Age1 FG FBW) or unavailable to pass and thus remain in the reservoir and become Age 2 individuals (Age2 FG), and proportion of Age 2 individuals in Green Peter reservoir (Age2 FG DPE) that are available to pass Green Peter Dam (Age2 FG FBW) or unavailable to pass, and are removed from the simulation (Age2 + Resident). These proportions use dam passage efficiency (DPE) data that were specific to particular dam project alternatives and were provided by USACE (Fish Benefits Workbooks User Guide 2014).

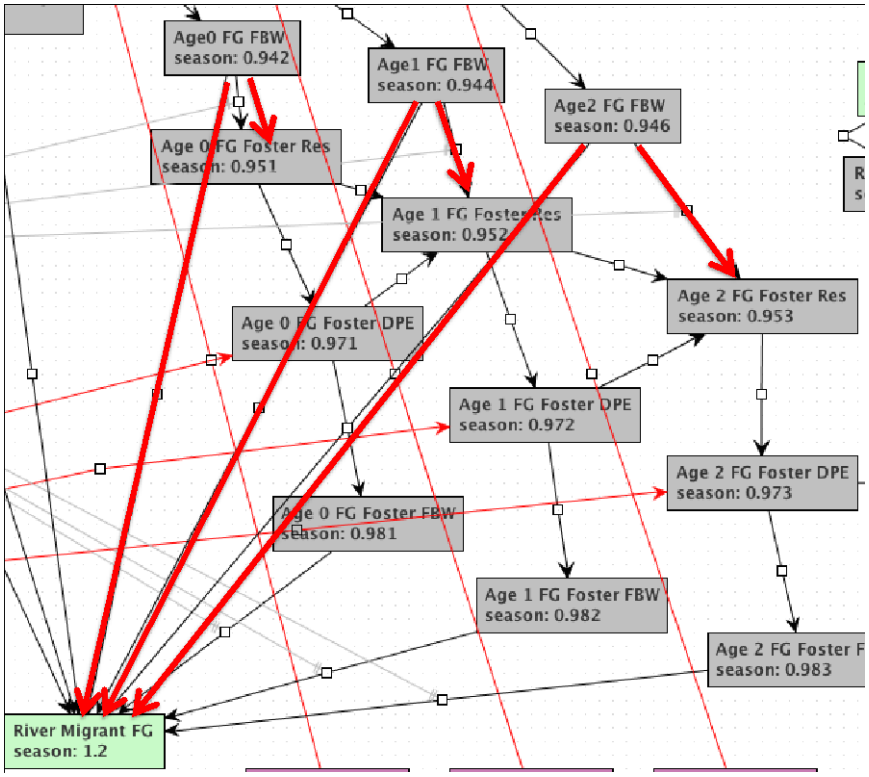
From	To	Proportion
Age0 FG DPE	Age0 FG FBW	Split influencer determined by DPE file
	Age1 FG	Split influencer determined by DPE file
Age1 FG DPE	Age1 FG FBW	Split influencer determined by DPE file
	Age2 FG	Split influencer determined by DPE file
Age2 FG DPE	Age2 FG FBW	Split influencer determined by DPE file
	Age2 + Resident	Split influencer determined by DPE file



Black arrows represent the split influence from dam passage efficiency data.

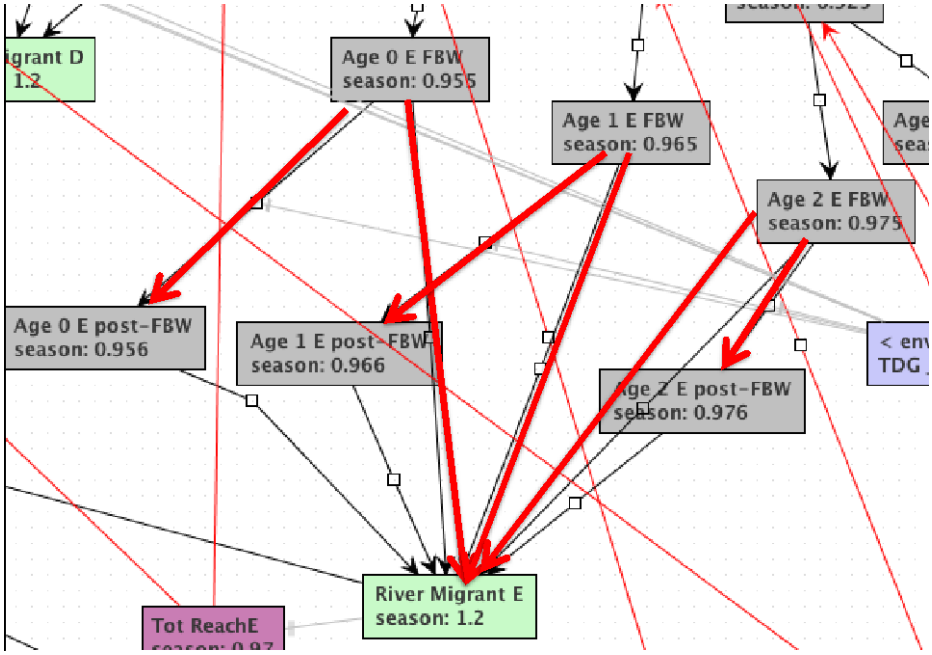
Proportion of individuals from Reach FG (above Green Peter) that bypass Green Peter Dam and are transported downstream of Foster Dam (River Migrant) or pass Green Peter Dam and enter Foster reservoir (Age 0 FG Foster Res, Age 1 FG Foster Res, and Age 2 FG Foster Res). When alternatives are being run that bypass fish around Green Peter Dam all fish (100%) of each age class are released downstream of Foster Dam and thus are not impacted by TDG.

From	To	Proportion
Age0 FG FBW	Age0 FG Foster Res	1
	River Migrant FG	0
Age1 FG FBW	Age1 FG Foster Res	1
	River Migrant FG	0
Age2 FG FBW	Age2 FG Foster Res	1
	River Migrant FG	0



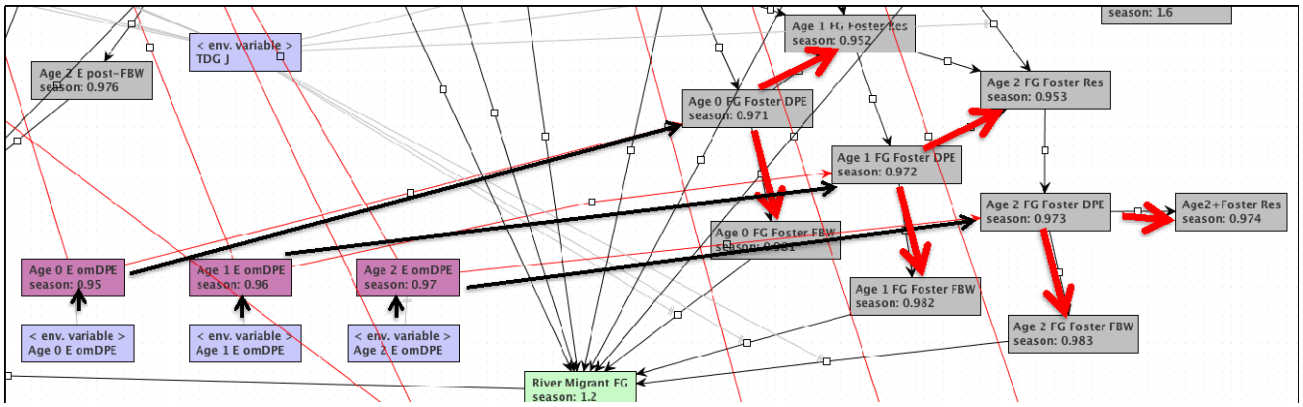
Proportion of individuals from Reach E (above Foster Dam) that bypass Foster Dam and are transported downstream of Foster Dam (River Migrant) below TDG influence or pass Foster Dam and are impacted by TDG (Age 0 post-FBW, Age 1 post-FBW, and Age 2 post-FBW). When alternatives are being run that bypass fish around Foster Dam all fish (100%) of each age class are released downstream of Foster Dam and thus are not impacted by TDG.

From	To	Proportion
Age0 E FBW	Age0 E post-FBW	1
	River Migrant FG	0
Age1 E FBW	Age1 E post-FBW	1
	River Migrant FG	0
Age2 E FBW	Age2 E post-FBW	1
	River Migrant FG	0



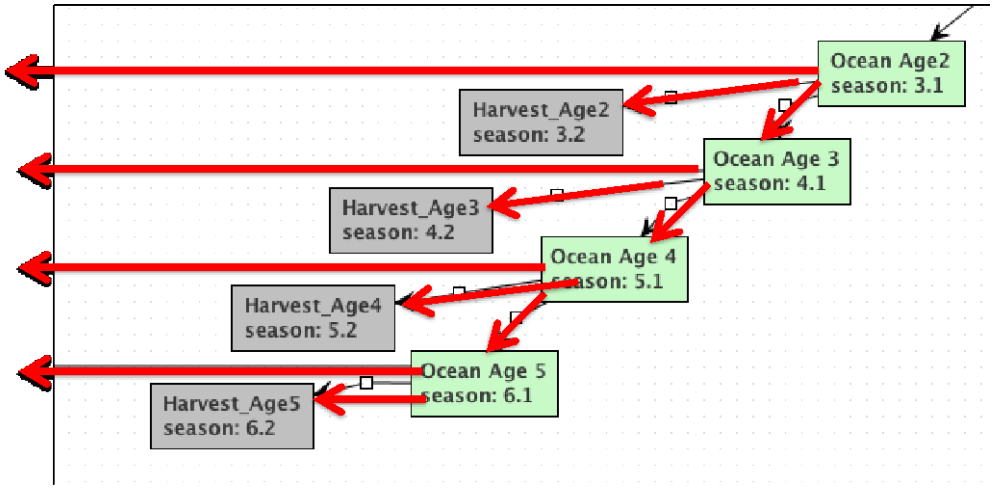
Proportion of individuals from Reach FG (above Green Peter Dam) that are in Foster reservoir and are available to pass Foster Dam or unavailable to pass and thus remain in the reservoir to become the next age class. These are the proportion of Age 0 individuals in Foster reservoir (Age0 FG Foster DPE) that are available to pass Foster Dam (Age0 FG Foster FBW) or unavailable to pass and thus remain in the reservoir to become Age 1 individuals (Age1 FG Foster Res), proportion of Age 1 individuals in Foster reservoir (Age1 Foster FG DPE) that are available to pass Foster Dam (Age1 FG Foster FBW) or unavailable to pass and thus remain in the reservoir and become Age 2 individuals (Age2 FG Foster Res), and proportion of Age 2 individuals in Foster reservoir (Age2 Foster FG DPE) that are available to pass Foster Dam (Age2 FG Foster FBW) or unavailable to pass, and are removed from the simulation (Age2 + Foster Res). These proportions use dam passage efficiency (DPE) data that were specific to particular dam project alternatives and were provided by USACE (Fish Benefits Workbooks User Guide 2014).

From	To	Proportion
Age0 FG Foster DPE	Age0 FG Foster FBW	Split influencer determined by DPE file
	Age1 FG Foster Res	Split influencer determined by DPE file
Age1 FG Foster DPE	Age1 FG Foster FBW	Split influencer determined by DPE file
	Age2 FG Foster Res	Split influencer determined by DPE file
Age2 FG Foster DPE	Age2 FG Foster FBW	Split influencer determined by DPE file
	Age2 + Foster Res	Split influencer determined by DPE file



Proportional splits of ocean adults (Ocean Age2, 3, 4, and 5) that stay in the ocean for another year, are harvested in the ocean, or return to freshwater.

From	To	Proportion
Ocean Age2	Returning First Time Spawners	0.0125
	Ocean Age 3	0.9375
	Harvest_Age2	0.05
Ocean Age3	Returning First Time Spawners	0.55
	Ocean Age 4	0.4
	Harvest_Age3	0.05
Ocean Age4	Returning First Time Spawners	0.85
	Ocean Age 5	0.1
	Harvest_Age4	0.05
Ocean Age5	Returning First Time Spawners	1
	Harvest_Age5	0



9.3. Datafiles

Most parameter values are scalars or are drawn from distributions according to parameters within SLAM, however there are stage transitions within the life-cycle model where survivals or splits come from datafiles. For example, dam passage survival and efficiency, enter into SLAM as a datafile. The following are the stages or stage transitions that call a datafile with survivals or splits.

9.3.1. Survivals

Stage at which datafile is located	Name of datafile	Name of series
Age0 E FBW	Foster_FBW_Alternatives_toSLAM-June 10 2014.csv	FD-Baseline FBW-Age0-146yr June 10 2014
Age1 E FBW	Foster_FBW_Alternatives_toSLAM-June 10 2014.csv	FD-Baseline FBW-Age1-146yr June 10 2014
Age2 E FBW	Foster_FBW_Alternatives_toSLAM-June 10 2014.csv	FD-Baseline FBW-Age2-146yr June 10 2014
Age0 FG FBW	GreenPeter_FBW_Alternatives_toSLAM-June 10 2014.csv	GP-Baseline FBW-Age0-146yr June 10 2014
Age1 FG FBW	GreenPeter_FBW_Alternatives_toSLAM-June 10 2014.csv	GP-Baseline FBW-Age1-146yr June 10 2014
Age2 FG FBW	GreenPeter_FBW_Alternatives_toSLAM-June 10 2014.csv	GP-Baseline FBW-Age2-146yr June 10 2014
Age 0 FG Foster FBW	Foster_FBW_Alternatives_toSLAM-June 10 2014.csv	FD-Baseline FBW-Age0-146yr June 10 2014
Age 1 FG Foster FBW	Foster_FBW_Alternatives_toSLAM-June 10 2014.csv	FD-Baseline FBW-Age1-146yr June 10 2014
Age 2 FG Foster FBW	Foster_FBW_Alternatives_toSLAM-June 10 2014.csv	FD-Baseline FBW-Age2-146yr June 10 2014
Kelts in Ocean	ChSOcean4thRt_modified_1_2013.csv	ChSAge2 x 2 (200yrs)
Smolt	EstuaryCurrent_modified_1_2013.csv	EstuaryHat50%UP x 2 (200yrs)
Ocean Age2	ChSOcean4thRt_modified_1_2013.csv	ChSAge2 x 2 (200yrs)
Ocean Age3	ChSOcean4thRt_modified_1_2013.csv	ChSAge3 x 2 (200yrs)
Ocean Age4	ChSOcean4thRt_modified_1_2013.csv	ChSAge4 x 2 (200yrs)
Ocean Age5	ChSOcean4thRt_modified_1_2013.csv	ChSAge5 x 2 (200yrs)
TDGJ	SSantiam_TDG_012413_modified 2014.csv	Baseline TDG-Foster-Juvenile (148yrs)
TDGA	SSantiam_TDG_012413_modified 2014.csv	Baseline TDG-Foster-Alevin (yolk sac fry) (148yrs)
Age 0 E omDPE	Foster_1-DPE_Alternatives_toSLAM-June 10 2014.csv	FD-Baseline 1-DPE-Age0-146yr June 10 2014
Age 1 E omDPE	Foster_1-DPE_Alternatives_toSLAM-June 10 2014.csv	FD-Baseline 1-DPE-Age1-146yr June 10 2014
Age 2 E omDPE	Foster_1-DPE_Alternatives_toSLAM-June 10 2014.csv	FD-Baseline 1-DPE-Age2-146yr June 10 2014
Age 0 FG omDPE	GreenPeter_1-DPE_Alternatives_toSLAM-June 10 2014.csv	GP-Baseline 1-DPE-Age0-146yr June 10 2014
Age 1 FG omDPE	GreenPeter_1-DPE_Alternatives_toSLAM-June 10 2014.csv	GP-Baseline 1-DPE-Age1-146yr June 10 2014
Age 2 FG omDPE	GreenPeter_1-DPE_Alternatives_toSLAM-June 10 2014.csv	GP-Baseline 1-DPE-Age2-146yr June 10 2014
Age 0 HoR Green Peter omDPE	Constant	0

USACE provided R2 Consultants, who in turn provided NWFSC, with the following SLAM datafiles; EstuaryCurrent, ChSOcean4thRt, and SSantiam_TDG. Each of the aforementioned files was expanded by NWFSC by repeating from the beginning, such that the files that were 74 years became 146 years, and those that were 100 years became 200 years. USACE provided Fish Benefits Workbooks datafiles that correspond to dam passage survival (e.g. Detroit_FBW_Alternatives_toSLAM.csv) and dam passage efficiency (e.g., Detroit_1-DPE_Alternatives_toSLAM.csv) (Fish Benefits Workbooks User Guide 2014).

9.3.2. Splits

Stage at which datafile is used	Name of datafile	Recruit stage datafile is app	Name of series
Age0 E	Age0 E & Age0 FG Foster Res.csv	Age1 E	Age1 E
		Age0 E DPE	Age0 E DPE
Age0 FG	Age0 FG.csv	Age1 FG	Age1 FG
		Age 0 FG DPE	Age 0 FG DPE
Age1 E	Age1 E & Age1 FG Foster Res.csv	Age2 E	Age2 E
		Age1 E DPE	Age1 E DPE
Age1 FG	Age1 FG.csv	Age2 FG	Age2 FG
		Age1 FG DPE	Age1 FG DPE
Age 0 FG Foster Res	Age0 E & Age0 FG Foster Res.csv	Age 0 Fg Foster DPE	Age 0 Fg Foster DPE
		Age 1 FG Foster Res	Age 1 FG Foster Res
Age 1 FG Foster Res	Age1 E & Age1 FG Foster Res.csv	Age 1 Fg Foster DPE	Age 1 Fg Foster DPE
		Age 2 FG Foster Res	Age 2 FG Foster Res

9.4. Dynamic Drivers and Influence Scripts

In some cases we used scripts to influence life stage transitions and splits. These were written in a Java-compatible syntax and are called groovy script. These gave us the ability to dynamically influence splits such as apportioning adults to natal reaches based on juvenile outmigrants four years earlier, or for applying the dam passage efficiency (DPE) to juveniles attempting to pass the dam. Below is a list of boxes where dynamic drivers are applied.

Box where dynamic driver is located	**Dynamic driver file name**	**What does dynamic driver do?**
ctr incr	ctr_incr.groovy	A counter to keep track of the year number being simulated.
%Virgin ABCDEFG	%Virgin.groovy	Calculates percent of virgin spawners in each Reach.
Tot Reach A, B, C, D, E, & F,G	Tot ReachABCDEFG.groovy	Calculates total number of juveniles that exit each Reach that is then used to calculate proportion of adults that return to each reach (see Split Influencer below).
Age0 FG omDPE	1-DPE.groovy	Calculates the proportion of fish that are available to pass dam. Based on Dam Passage Efficiency (DPE) provided by USACE.
Age1 FG omDPE	1-DPE.groovy	Calculates the proportion of fish that are available to pass dam. Based on Dam Passage Efficiency (DPE) provided by USACE.
Age2 FG omDPE	1-DPE.groovy	Calculates the proportion of fish that are available to pass dam. Based on Dam Passage Efficiency (DPE) provided by USACE.
Age 0 E omDPE	1-DPE.groovy	Calculates the proportion of fish that are available to pass dam. Based on Dam Passage Efficiency (DPE) provided by USACE.
Age 1 E omDPE	1-DPE.groovy	Calculates the proportion of fish that are available to pass dam. Based on Dam Passage Efficiency (DPE) provided by USACE.
Age 2 E omDPE	1-DPE.groovy	Calculates the proportion of fish that are available to pass dam. Based on Dam Passage Efficiency (DPE) provided by USACE.

Stage where influence script is located	Groovy script file name	What does script do?
Respawn Eggs Reach C	TDG.groovy	Calculates proportion of juveniles that survive the total dissolved gas.
Age0 C	TDG.groovy	Calculates proportion of juveniles that survive the total dissolved gas.
Age1 C	TDG.groovy	Calculates proportion of juveniles that survive the total dissolved gas.
Age2 C	TDG.groovy	Calculates proportion of juveniles that survive the total dissolved gas.
Age 0 E post-FBW	TDG.groovy	Calculates proportion of juveniles that survive the total dissolved gas.
Age 1 E post-FBW	TDG.groovy	Calculates proportion of juveniles that survive the total dissolved gas.
Age 2 E post-FBW	TDG.groovy	Calculates proportion of juveniles that survive the total dissolved gas.
Age 0 FG post-FBW	TDG.groovy	Calculates proportion of juveniles that survive the total dissolved gas.
Age 1 FG post-FBW	TDG.groovy	Calculates proportion of juveniles that survive the total dissolved gas.
Age 2 FG post-FBW	TDG.groovy	Calculates proportion of juveniles that survive the total dissolved gas.
River Migrant	TDG.groovy	Calculates proportion of juveniles that survive the total dissolved gas.

Stage where split influencer is located	Stage where groovy script is located	Groovy script file name	What does split influencer do?
Virgin Spawners to Trib	VirginAdult to ReachA	VirginAdult to ReachA.groovy	Calculates the proportion of virgin Adults that go to Reach A
Virgin Spawners to Trib	VirginAdult to ReachB	VirginAdult to ReachB.groovy	Calculates the proportion of virgin Adults that go to Reach B
Virgin Spawners to Trib	VirginAdult to ReachC	VirginAdult to ReachC.groovy	Calculates the proportion of virgin Adults that go to Reach C
Virgin Spawners to Trib	VirginAdult to ReachD	VirginAdult to ReachD.groovy	Calculates the proportion of virgin Adults that go to Reach D
Virgin Spawners to Trib	VirginAdult to ReachE	VirginAdult to ReachE.groovy	Calculates the proportion of virgin Adults that go to Reach E
Virgin Spawners to Trib	VirginAdult to ReachF	VirginAdult to ReachF.groovy	Calculates the proportion of virgin Adults that go to Reach F
Virgin Spawners to Trib	VirginAdult to ReachG	VirginAdult to ReachG.groovy	Calculates the proportion of virgin Adults that go to Reach G
Respawn to Trib	Respawn to ReachA	Respawn to ReachA.groovy	Calculates the proportion of respawners that go to Reach A
Respawn to Trib	Respawn to ReachB	Respawn to ReachB.groovy	Calculates the proportion of respawners that go to Reach B
Respawn to Trib	Respawn to ReachC	Respawn to ReachC.groovy	Calculates the proportion of respawners that go to Reach C
Respawn to Trib	Respawn to ReachD	Respawn to ReachD.groovy	Calculates the proportion of respawners that go to Reach D
Respawn to Trib	Respawn to ReachE	Respawn to ReachE.groovy	Calculates the proportion of respawners that go to Reach E
Respawn to Trib	Respawn to ReachF	Respawn to ReachF.groovy	Calculates the proportion of respawners that go to Reach F
Respawn to Trib	Respawn to ReachG	Respawn to ReachG.groovy	Calculates the proportion of respawners that go to Reach G

9.5. Initialization Values

When SLAM begins a simulation not all of the boxes are populated with fish. As a result, the first several simulated years can show large fluctuations in abundance and frequent extinctions. To reduce these fluctuations many of the boxes are initialized with some number of fish at the start of the model. The values used to initialize these boxes were taken from the 100th year in a previous baseline simulation.

Stage	Initialized
Returning First Time Spawners	19
Post Harvest	500
Respawn Post Harvest	20
Tot Respawn ABCDEFG	1
%Virgin ABCDEF	10
HoR Green Peter Fry	-
Age0 A	150
Age0 B	600
Age0 C	1100
Age0 D	600
Age0 E	1250
Age0 FG	0
Age 0 FG omDPE	0
Age1 A	200
Age1 B	600
Age1 C	1250
Age1 D	600
Age1 E	1250
Age1 FG	0
Age 1 FG omDPE	0
Age2 A	200
Age2 B	600
Age2 C	1250
Age2 D	600
Age2 E	1250
Age2 FG	0
Age 2 FG omDPE	0
Age 0 E omDPE	0
Age 1 E omDPE	0
Age 2 E omDPE	0
Tot ReachABCDEF	1000
River Migrant A	1000
River Migrant B	1000
River Migrant C	1000
River Migrant D	1000
River Migrant E	8000
River Migrant FG	5000
Kelts in Ocean	1000
Smolt	7000
Ocean Age2	1800
Ocean Age 3	1450
Ocean Age 4	500
Ocean Age 5	10

9.5.1. Model Demonstration & Alternative Scenarios

Below (Table 9.3) is a list of a set of the most recent alternatives selected by the USACE (Fish Benefit Workbook; received June 10, 2014) that represent various operational and structural modifications to Detroit Dam whose goal is to improve access to Reach D and E (above Detroit Dam). Each alternative was run in SLAM and estimates were produced of several variables including abundance of natural origin spawners and each life history strategy, and percent wild. Each alternative was run 500 times, and each run is 100 years long. We used 500 runs because output stabilized at this level. USACE provided datafiles of dam passage survival and efficiency, which were 73 years, and these files were duplicated to produce datafiles that were 146 years.

Table 9.3: List of alternatives run in the SLAM model of South Santiam River Steelhead salmon. Description of each alternative can be found in Appendix D.

	Foster Alternative Description	Green Peter Alternative Description	SLAM output name	Foster Dam Passage survival (average %)			Foster Dam 1-DPE (average %)			Green Peter Dam Passage survival (average %)			Green Peter Dam 1-DPE (average %)			Green Peter HoR	
				Fry	Sub-yr	Yrling	Fry	Sub-yr	Yrling	Fry	Sub-yr	Yrling	Fry	Sub-yr	Yrling	1-DPE (%)	Passage survival (%)
1	Baseline	Baseline	Baseline	89	82	75	40	40	40	51	41	36	48	55	55	0	0
2	Baseline	Fish Horn	FOS_Baseline-GPD_FishHorn	89	82	75	40	40	40	73	68	65	29	29	29	0	0
3	Baseline	Selective Withdrawal Str, Floating Screen Str	FOS_Baseline-GPD_SWS-FSS	89	82	75	40	40	40	92	87	89	29	29	29	0	0
4	Baseline	Selective Withdrawal Str - Only	FOS_Baseline-GPD_SWS	89	82	75	40	40	40	51	42	37	29	29	29	0	0
5	Baseline	Floating Surface Collector	FOS_Baseline-GPD_FSC	89	82	75	40	40	40	75	70	67	29	29	29	0	0
6	Baseline	HoR Opt 1: DPE: 30%; Passage Survival: 70%	FOS_Baseline-GPD_Baseline HoR1	89	82	75	40	40	40	51	41	36	48	55	55	70	70
7	Baseline	HoR Opt 2: DPE: 80%; Passage Survival: 90%	FOS_Baseline-GPD_Baseline HoR2	89	82	75	40	40	40	51	41	36	48	55	55	20	90
8	Continous Weir	Baseline	FOS_ContWeir-GPD_Baseline	89	83	76	20	19	19	51	41	36	48	55	55	0	0
9	Weir 860	Baseline	FOS_Weir860-GPD_Baseline	96	94	89	20	19	19	51	41	36	48	55	55	0	0
10	Fish Friendly Turbines	Baseline	FOS_FriendTurb-GPD_Baseline	92	92	91	40	40	40	51	41	36	48	55	55	0	0
11	Baseline w spill	Baseline	FOS_Baseline wSpill-GPD_Baseline	89	83	75	18	18	18	51	41	36	48	55	55	0	0
12	Weir 860	Fish Horn	FOS_Weir860-GPD_FishHorn	96	94	89	20	19	19	73	68	65	29	29	29	0	0
13	Fish Friendly Turbines	Selective Withdrawal Str, Floating Screen Str	FOS_FriendTurb-GPD_SWS-FSS	92	92	91	40	40	40	92	87	89	29	29	29	0	0
14	Fish Friendly Turbines	Selective Withdrawal Str - Only	FOS_FriendTurb-GPD_SWS	92	92	91	40	40	40	51	42	37	29	29	29	0	0
15	Continous Weir	Floating Surface Collector	FOS_ContWeir-GPD_FSC	89	83	76	20	19	19	75	70	67	29	29	29	0	0
16	Weir 860	Floating Surface Collector	FOS_Weir860-GPD_FSC	96	94	89	20	19	19	75	70	67	29	29	29	0	0
17	Fish Friendly Turbines	Floating Surface Collector	FOS_FriendTurb-GPD_FSC	92	92	91	40	40	40	75	70	67	29	29	29	0	0
18	Baseline w spill	Floating Surface Collector	FOS_Baseline wSPill-GPD_FSC	89	83	75	18	18	18	75	70	67	29	29	29	0	0

9.5.2. Parameter Variability

The following tables identify parameters that vary among years in each model run. In all the parameters listed below (except passage survival and estuary and ocean survival) values are randomly selected each model year from the specified distribution and these distributions and the parameters that define them do not vary among alternatives (Table 9.4). For any given alternative, passage survival values vary among years of a model run, but do not vary among the 500 model runs (passage survival values are taken from a datafile). Values of passage survival vary among alternatives (Table 9.5). For any given alternative, estuary and ocean survival values vary among years of a model run, but do not vary among the 500 model runs (estuary and ocean survival values are taken from a datafile). Values of estuary and ocean survival do not vary among alternatives (Table 9.6).

Table 9.4: Capacity and survival parameters whose values vary among years in each model run and vary among model runs.

Location in Life Cycle	From	To	Curve type	Capacity &/or Productivity	Distribution type	Mean	SD	Min	Max
Reach A mainstem Downstream of Lebanon	FTS Adults	FTS Eggs	Beverton-Holt	Capacity	Normal	50,000	10,000	25,000	250,000
Reach B tribs Downstream of Lebanon	FTS Adults	FTS Eggs	Beverton-Holt	Capacity	Normal	1,500,000	100,000	750,000	4,000,000
Reach C between Lebanon & Foster dams	FTS Adults	FTS Eggs	Beverton-Holt	Capacity	Normal	2,500,000	100,000	500,000	4,000,000
Reach D Wiley Creek	FTS Adults	FTS Eggs	Beverton-Holt	Capacity	Normal	1,500,000	100,000	750,000	2,500,000
Reach E upstream of Foster reservoir	FTS Adults	FTS Eggs	Beverton-Holt	Capacity	Normal	5,000,000	250,000	2,500,000	7,000,000
Reach F Quartzville Creek	FTS Adults	FTS Eggs	Beverton-Holt	Capacity	Normal	2,000,000	100,000	1,000,000	2,500,000
Reach G Middle Santiam River upstream of Green Peter Reservoir	FTS Adults	FTS Eggs	Beverton-Holt	Capacity	Normal	4,500,000	250,000	2,000,000	6,000,000
Reach A mainstem Downstream of Lebanon	Spawning Respawns	Respawn Eggs	Beverton-Holt	Capacity	Normal	50,000	10,000	25,000	250,000
Reach B tribs Downstream of Lebanon	Spawning Respawns	Respawn Eggs	Beverton-Holt	Capacity	Normal	1,500,000	100,000	750,000	2,500,000
Reach C between Lebanon & Foster dams	Spawning Respawns	Respawn Eggs	Beverton-Holt	Capacity	Normal	2,500,000	100,000	500,000	4,000,000
Reach D Wiley Creek	Spawning Respawns	Respawn Eggs	Beverton-Holt	Capacity	Normal	1,500,000	100,000	750,000	2,500,000
Reach E upstream of Foster reservoir	Spawning Respawns	Respawn Eggs	Beverton-Holt	Capacity	Normal	5,000,000	250,000	2,500,000	7,000,000
Reach F Quartzville Creek	Spawning Respawns	Respawn Eggs	Beverton-Holt	Capacity	Normal	2,000,000	100,000	1,000,000	2,500,000
Reach G Middle Santiam River upstream of Green Peter Reservoir	Spawning Respawns	Respawn Eggs	Beverton-Holt	Capacity	Normal	4,500,000	250,000	2,000,000	6,000,000
Reach F & G	Age0 FG	Age1 FG	Linear	Productivity	Triangular	0.2		0.1	0.3
Reach F & G	Age0 FG	Age0 FG DPE	Linear	Productivity	Triangular	0.3		0.2	0.4
Reach E	Age0 E	Age1 E	Linear	Productivity	Triangular	0.2		0.1	0.3
Reach E	Age0 E	Age0 E DPE	Linear	Productivity	Triangular	0.4		0.3	0.5
Reach FG	Age1 FG	Age2 FG	Linear	Productivity	Triangular	0.5		0.3	0.6
Reach FG	Age1 FG	Age1 E DPE	Linear	Productivity	Triangular	0.5		0.4	0.6
Reach E	Age1 E	Age2 E	Linear	Productivity	Triangular	0.5		0.4	0.6
Reach E	Age1 E	Age1 E DPE	Linear	Productivity	Triangular	0.5		0.4	0.6
Reach FG	Age2 FG	Age 2 FG DPE	Linear	Productivity	Triangular	0.9		0.8	1.0
Reach FG	Age2 E	Age 2 E DPE	Linear	Productivity	Triangular	0.9		0.8	1.0
Reach FG	Age 0 FG Foster Res	Age 0 FG Foster DPE	Linear	Productivity	Triangular	0.8		0.6	1.0
Reach FG	Age 0 FG Foster Res	Age 1 FG Foster Res	Linear	Productivity	Triangular	0.3		0.2	0.6
Reach FG	Age 1 FG Foster Res	Age 1 FG Foster DPE	Linear	Productivity	Triangular	0.8		0.6	1.0
Reach FG	Age 1 FG Foster Res	Age 2 FG Foster Res	Linear	Productivity	Triangular	0.8		0.6	1.0
Reach FG	Age 2 FG Foster Res	Age 2 FG Foster DPE	Linear	Productivity	Triangular	0.8		0.6	1.0

Table 9.5: Average, minimum, and maximum passage survival for each alternative and life history strategy. These values vary among years of a model run but do not vary among model runs.

FBW		Average Passage Survival			Min Passage Survival			Max Passage Survival		
Output File name	Alternative	Age0	Age1	Age2	Age0	Age1	Age2	Age0	Age1	Age2
Ch_FOS_1	Foster-Baseline	0.89	0.82	0.75	0.88	0.81	0.74	0.89	0.83	0.76
Ch_FOS_2	Foster-Continous Weir	0.89	0.83	0.76	0.89	0.82	0.75	0.90	0.85	0.77
Ch_FOS_3a	Foster-Weir 860	0.96	0.94	0.89	0.90	0.85	0.80	0.97	0.95	0.90
Ch_FOS_7	Foster-Fish Friendly Turbines	0.92	0.92	0.91	0.92	0.92	0.90	0.92	0.92	0.92
Ch_FOS_8	Foster-Baseline w spill	0.89	0.83	0.75	0.88	0.82	0.75	0.89	0.84	0.76
Ch_GPR_1	Green Peter-Baseline	0.51	0.41	0.36	0.50	0.40	0.35	0.53	0.45	0.40
Ch_GPR_2	Green Peter-Fish Horn	0.73	0.68	0.65	0.70	0.62	0.61	0.76	0.71	0.69
Ch_GPR_5	Green Peter-Selective Withdrawal Str, Floating Screen Str	0.92	0.87	0.89	0.89	0.85	0.86	0.94	0.90	0.92
Ch_GPR_6	Green Peter-Selective Withdrawal Str - Only	0.51	0.42	0.37	0.50	0.41	0.36	0.53	0.43	0.40
Ch_GPR_7	Green Peter-Floating Surface Collector	0.75	0.70	0.67	0.72	0.64	0.63	0.77	0.73	0.70

Table 9.6: Average, minimum, and maximum survival values during estuary and ocean stages. Age-specific time series of estuary and ocean survival were generated by ODFW, and incorporated into SLAM as datafiles.

Stage	Min	Average	Max
Estuary	0.44	0.48	0.51
Ocean 2yr olds	0.24	0.39	0.57
Ocean 3yr olds	0.31	0.51	0.74
Ocean 4yr olds	0.37	0.60	0.87
Ocean 5yr olds	0.42	0.68	0.99

9.5.3. SLAM Output and VSP Scores

For each alternative run in SLAM, four categories of model output are produced; abundance and productivity, age diversity, and spatial structure. For each of these categories we generate VSP scores, and then use the following equation to produce a Total VSP score:

$$Total\ VSP\ score = \frac{4(Abundance + Productivity) + Diversity + Spatial\ Structure}{6}$$

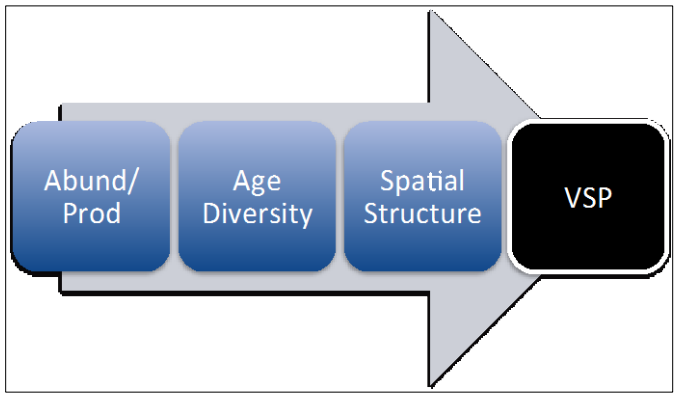


Figure 9.3: Representation of the three components (abundance and productivity, age diversity, and spatial structure) that comprise VSP score.

Abundance and Productivity

Under Baseline (i.e., current) conditions for South Santiam River, a median of 848 first-time and repeat spawners was estimated while the highest median of 3,947 individuals was associated with an alternative with Friendly Turbine (FriendTurb) at Foster Dam and Selective Withdrawal Structure with Floating Screen Structure (SWS-FSS) at Green Peter Dam (FOS-FriendTurb-GPD_SWS-FSS) (Table 9.3 and Figure 9.4).

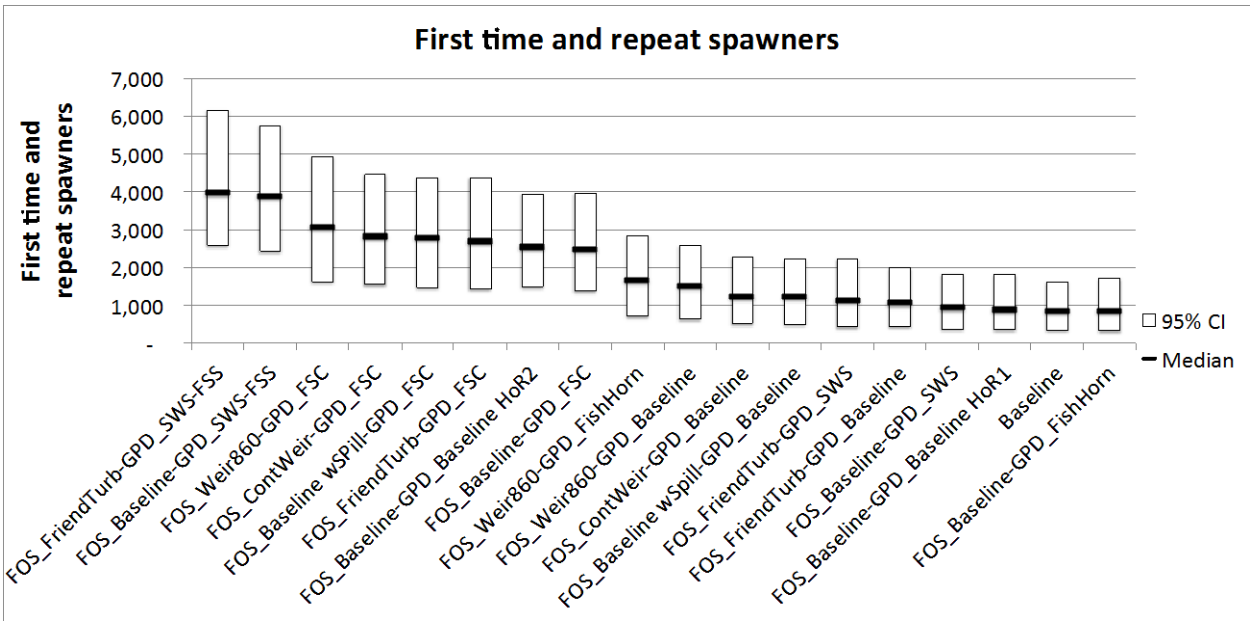


Figure 9.4: Abundance of first-time and repeat spawners among South Santiam River alternatives (see Table 9.3). Median and 95% confidence limits (line and box, respectively) were calculated from the 500 geomeans (1 per run) of abundance, each of which was for a 100-year period.

We estimated the probability quasi-exinction threshold (QET) for each alternative under the following conditions; critical abundance was set as 200 individuals, a four-year moving average was used over a 100-year period (from year 6 to year 105). We started QET calculation at year 6 because the model was fully initialized beyond this point and reflected system dynamics rather than the influences of starting values. Under Baseline (i.e., current) conditions, QET was estimated as 16% for South Santiam River, while QET was 0% for alternatives that included a Selective Withdrawal Structure and Floating Screen Structure at Green Peter Dam, Floating Surface Collector (FSC) at Green Peter Dam, and Head of Green Peter Reservoir collection (HoR2) (Figure 9.5).

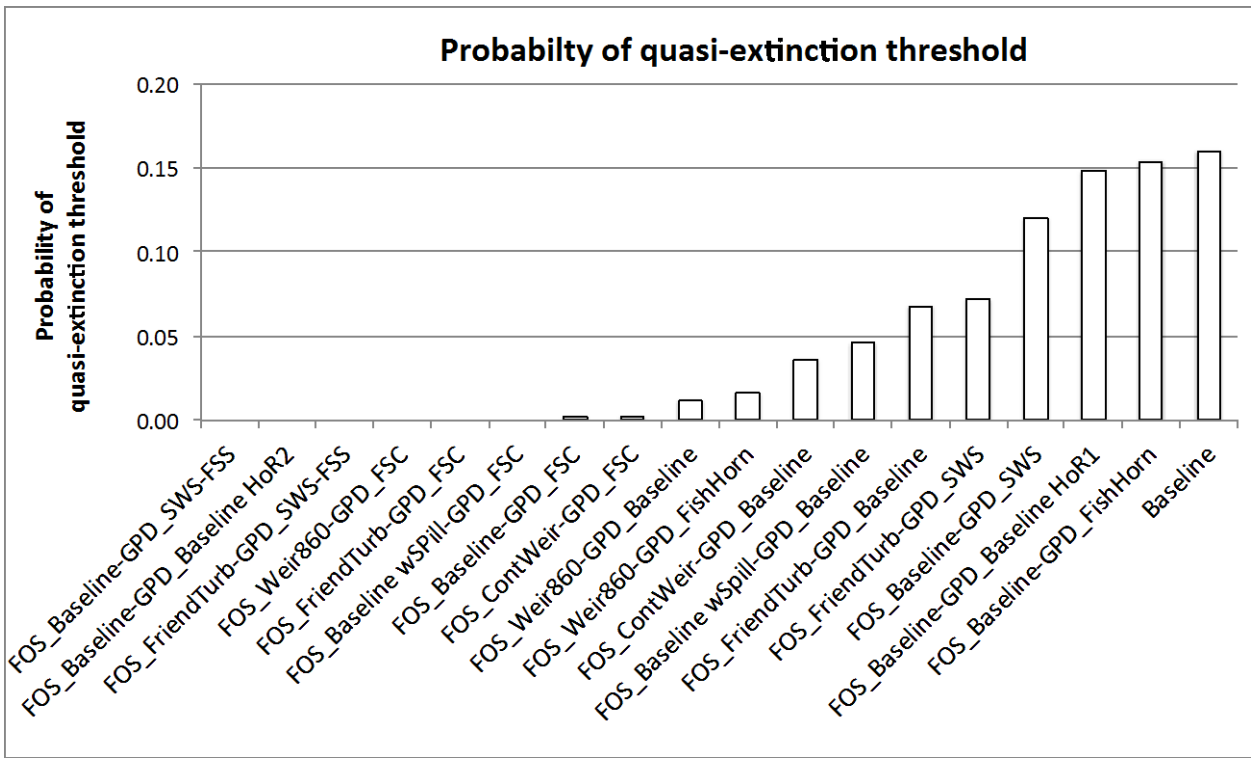


Figure 9.5: Probability of quasi-extinction among South Santiam River alternatives. The maximum value on the y-axis is 0.2 (instead of 1.0) to improve visibility of QET for several alternatives.

Based on a relationship between VSP score and abundance and productivity (see Chapter 3, Parameterization of VSP Criteria), the Baseline (i.e., current) conditions was given a median VSP score of 2.5, while seven alternatives had VSP scores greater than 3.9 (Figure 9.6).

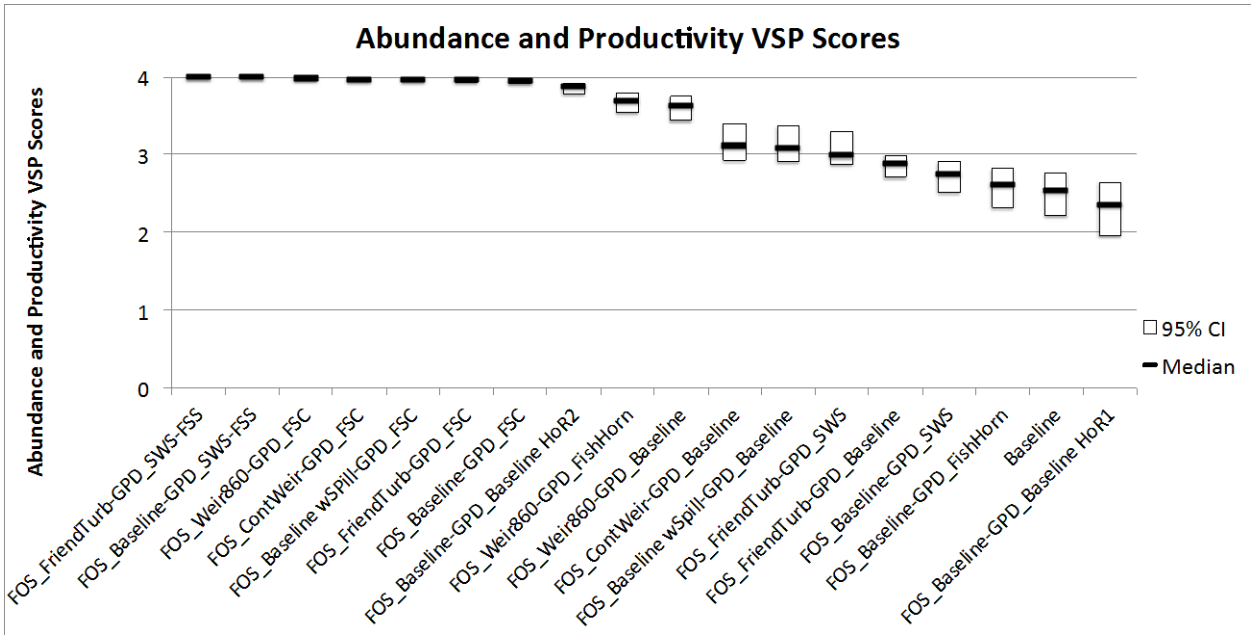


Figure 9.6: Abundance and Productivity VSP scores among South Santiam River alternatives.

Age Diversity

Age diversity was not calculated for the alternatives because the model structure for such calculations have not been developed and implemented in this iteration of SLAM. Therefore, all alternatives were given a VSP score of 3.0.

Spatial Structure

Spatial structure is a measure of population replacement in reaches above Foster and Green Peter dams. To assess replacement above Foster and Green Peter dams (i.e., Reach E, and FG) we used recruits per spawner, measured as returning spawners (i.e., first time spawners and spawning respawners) referenced to the spawning brood that produced them. According to age structure data the majority of spawning steelhead are age 4 and 5 (approximately 48% & 42%, respectively; Upper Willamette Recovery Plan 2011).

Table 9.4: Recruit-to-spawner ratio for steelhead in North and South Santiam rivers (see Chapter 3, Qualitative Spatial Considerations).

!	!	Reach!FG!(QC,MS)!		
!	!	<0.75!	0.75<x<0.95!	>0.95!
!	<0.75!	2.0!	2.33!	2.5!
Reach!E!(SSR)!	0.75<x<0.95!	2.33!	2.4!	3.17!
!	>0.95!	2.5!	3.17!	3.5!

$$RecruitE{:}\,SpawnerE = \frac{(Recruits\ in\ Reach\ E\ at\ time\ y + 2yrs * 0.65) + (Recruits\ in\ Reach\ E\ at\ time\ y + 3yrs * 0.35)}{Spawners\ in\ Reach\ E\ at\ time\ y}$$

$$RecruitFG{:}\,SpawnerFG = \frac{(Recruits\ in\ Reach\ FG\ at\ time\ y + 2yrs * 0.65) + (Recruits\ in\ Reach\ FG\ at\ time\ y + 3yrs * 0.35)}{Spawners\ in\ Reach\ FG\ at\ time\ y}$$

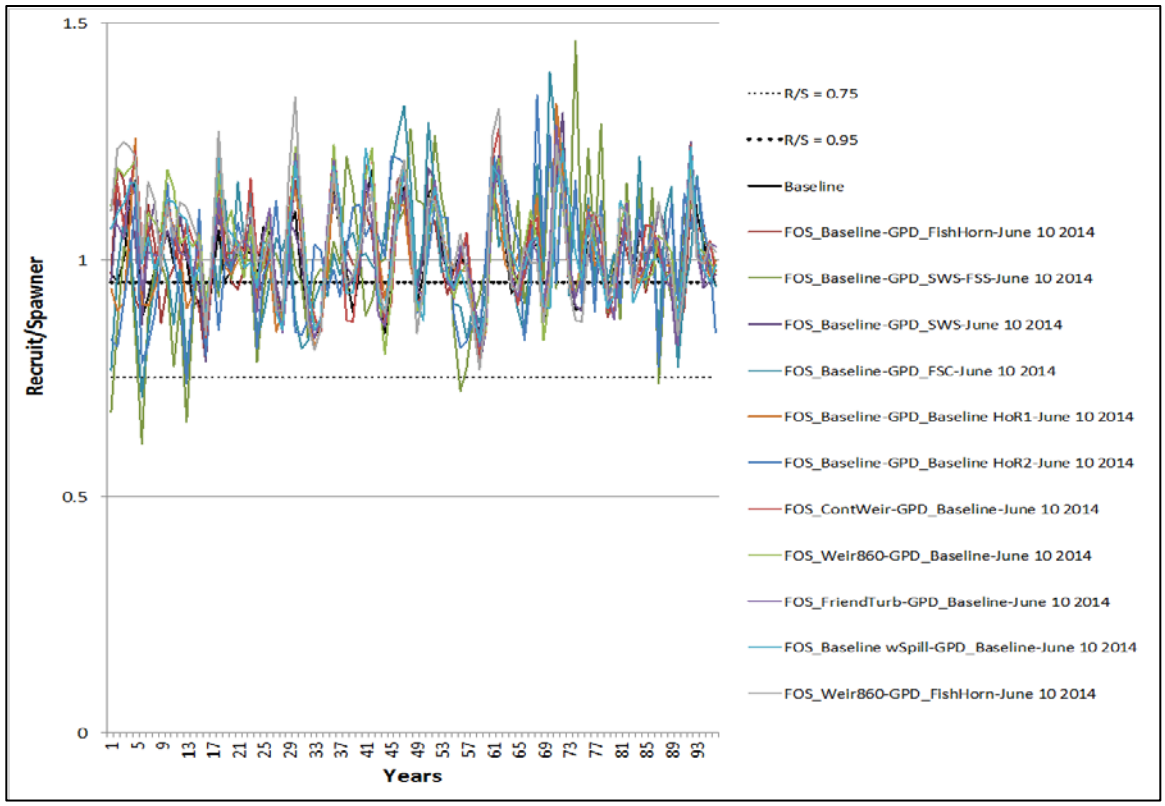


Figure 9.9: Times series of recruit-to-spawner ratio for each South Santiam River alternative. See text above for the equation used to calculate recruit-to-spawner ratio.

Under Baseline conditions the VSP score for spatial structure is 2.5, while the highest median score for three alternatives is 3.17 (FOS_Baseline-GPD_SWS, FOS_Weir860-GPD_FishHorn, and FOS_FriendTurb-GPD_SWS) (see Figure 9.12).

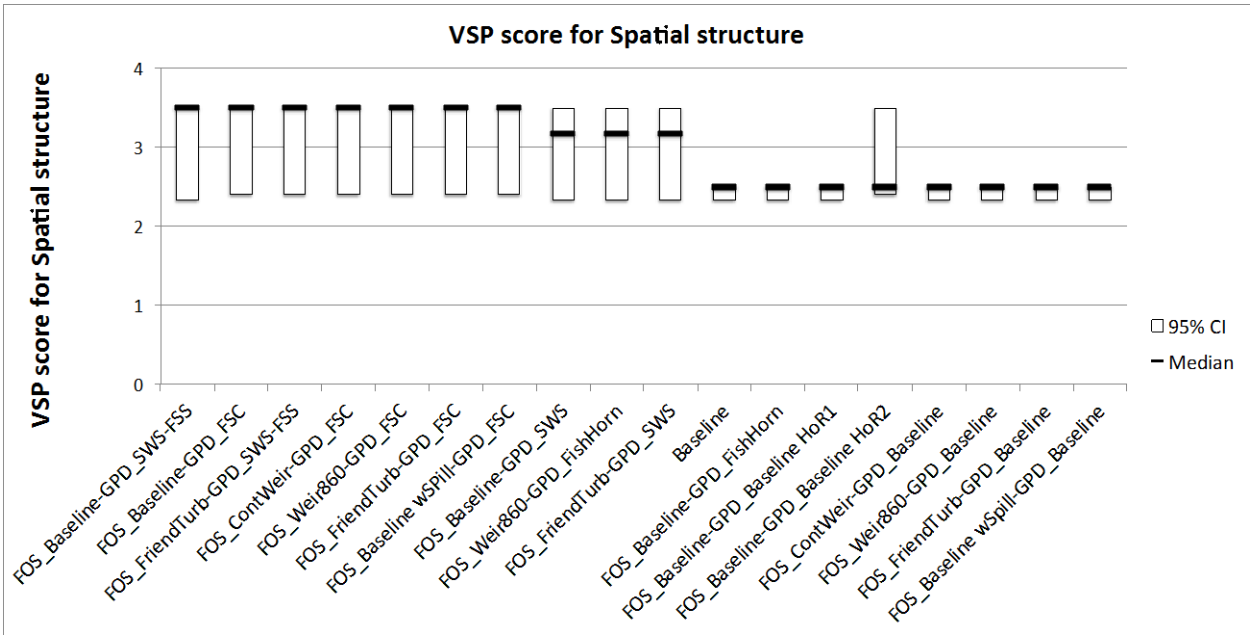


Figure 9.12: Spatial Structure VSP scores among South Santiam River alternatives. Median and standard deviation are shown (line and box, respectively), which were calculated using the median and standard deviation of recruit-to-spawner ratio.

Total VSP Score

To estimate the Total VSP score, we combined all the component VSP scores according to the following equation:

$$Total\ VSP\ score = \frac{4(Abundance + Productivity) + Diversity + Spatial\ Structure}{6}$$

Of the South Santiam River alternatives, seven produced the highest Total VSP Score of 3.7, while Baseline conditions yielded a score of 2.6 (Figure 9.13).

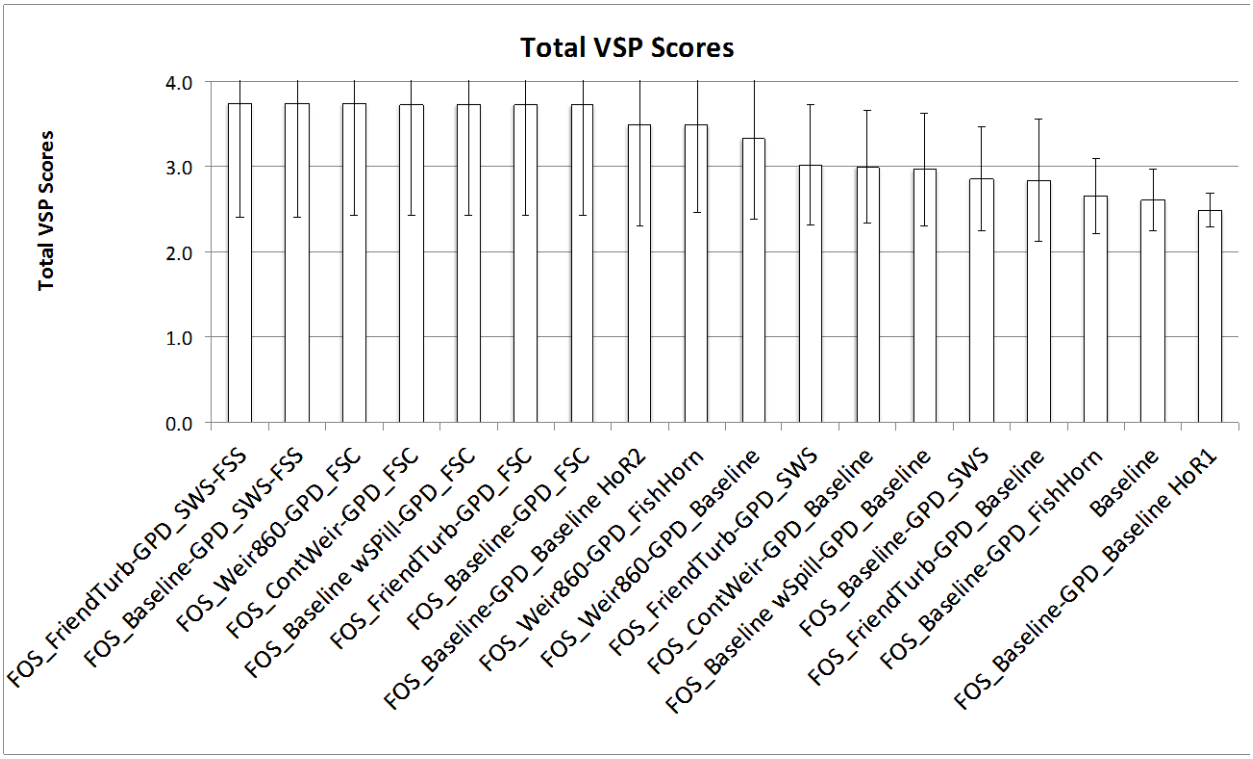


Figure 9.13: Total VSP scores among South Santiam alternatives. Whiskers denote +/- one standard deviation.

9.6. References

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CHAPTER 10. SENSITIVITY ANALYSIS OF WILLAMETTE RIVER LIFE CYCLE MODELS

10.1. Summary

We evaluated the sensitivity of life cycle models of six Upper Willamette River Chinook salmon and winter steelhead populations to ranges of parameter inputs across a selection of dam alternatives. Sensitivity analyses assisted in refinement of model and parameter assumptions, model structure, and an understanding of shifting parameter influence across a set of dam project and operational alternatives. Our analyses identified the relative importance of parameters with respect to other model parameters, and although some parameters may not appear to have been influential, it does not mean they were not important in the models. Rather, given the set of parameters chosen for evaluation, and given the ranges of parameter values being sampled, some parameters were more influential than others.

We tested sensitivities of the models with examination of two model output metrics for each alternative: natural origin spawner abundance, and the probability of falling below a quasi-extinction threshold of spawner abundance. The Chinook salmon life cycle models were most sensitive to the parameters describing the prespawning mortality functional relationship, and to juvenile reservoir survival, but not to parameters describing estuary/early ocean survival. Beyond the prespawning mortality influence, there were other parameters that exerted influence on model output. In the McKenzie Chinook salmon model, when we held dam passage survival fixed but decreased dam passage efficiency, parameters defining survival above Cougar Dam became less influential as the number of natural origin spawners returning to the basin relied more heavily on fish production below Cougar Dam. In the North Santiam Chinook salmon model, fry-subyearling reservoir survival and the proportion of fry available to pass Detroit Dam were influential parameters. In the South Santiam Chinook salmon life cycle model, reservoir survivals and fry splits into the juvenile life history trajectories were somewhat influential on spawner abundance and extinction risk. In the Middle Fork Chinook salmon model, parameters generally had more influence on extinction risk than on spawners and, depending on the alternative, parameter influence could sometimes be either positive or negative on extinction risk. The most influential parameter in both steelhead life cycle models was productivity of first-time spawners as measured by eggs per fish. For the North Santiam winter steelhead model, other influential parameters included capacity in reaches above Detroit Dam and fry splits into the juvenile life history trajectories. In the South Santiam steelhead model, additional parameters of influence included juvenile reservoir survival and productivity of respawning fish.

10.2. Background

The results of sensitivity analyses can help to gain a better understanding of the dynamics of a system, to understand model responses to its inputs, to test model and parameter assumptions, and help to formulate alternatives. Sensitivity analyses can also help inform decisions on how to prioritize research, monitoring, and evaluation efforts to get a better understanding of influential parameters and to improve a model's ability to simulate a system's dynamics. Sensitivity analysis is a combination of a process to assess parameter importance and an exploration of the uncertainty of the parameters themselves. Several of the SLAM life cycle models' parameters are specified with ranges set by minimum and maximum values with modes, or are drawn from a distribution defined by a set of parameters (i.e., mean and standard deviation). Sensitivity analyses allow for the exploration of the relative influence of parameters across a range of values for which we are

uncertain and others for which we are more certain but that vary. Comparing model outputs across a set of alternatives while keeping parameters fixed is a form of sensitivity, but by systematically varying parameters a much more detailed picture of parameter importance emerges, within and between alternatives.

Life cycle models with stochasticity and nonlinear and interacting factors require more robust sensitivity methods to ascertain parameter influence than the typical one-at-a-time parameter manipulations (sometimes referred to as "local" sensitivity analyses) that compare output to an average model outcome (McCarthy et al. 1995; Cross and Beissinger 2001). Manipulating multiple parameters simultaneously (i.e., "global" sensitivity analysis) provides an opportunity to evaluate complex models by looking at the relative parameter effect across a range of parameter values (Cross and Beissinger 2001). This method accounts for interactions among parameters because all parameters of interest are manipulated simultaneously. This is a common sensitivity procedure, and performance testing of this type of sensitivity analysis for complex models has shown it to be comparable with other model sensitivity methods (e.g., Hamby 1994, 1995). It has been applied to salmon life cycle models (e.g., Zabel et al. 2006; Crozier et al. 2008), and to population viability models for other species (e.g., Zeigler et al. 2013).

10.3. Methods

Our sensitivity analyses followed the methods of Zabel et al. (2006), which consisted of running the life cycle models multiple times with sets of parameter values chosen randomly for each model run, and then performing multiple regression analysis on the model input and resulting outputs to evaluate relative parameter influence (Cross and Beissinger 2001). SLAM has built-in capacity to conduct local, one-at-a-time, sensitivity analyses but there is no option for a global analysis. Thus, we recoded the SLAM life cycle models in R (R Core Team 2013; Fig. 10.1), which gave us the flexibility to conduct sensitivities of multiple parameters simultaneously. The R versions of the models were created to mirror the behavior of the SLAM models, and they used the same inputs and parameter values with the exception of estuary and ocean survival (see Chap. 3 for estuary and ocean components of the R versions of the life cycle models).

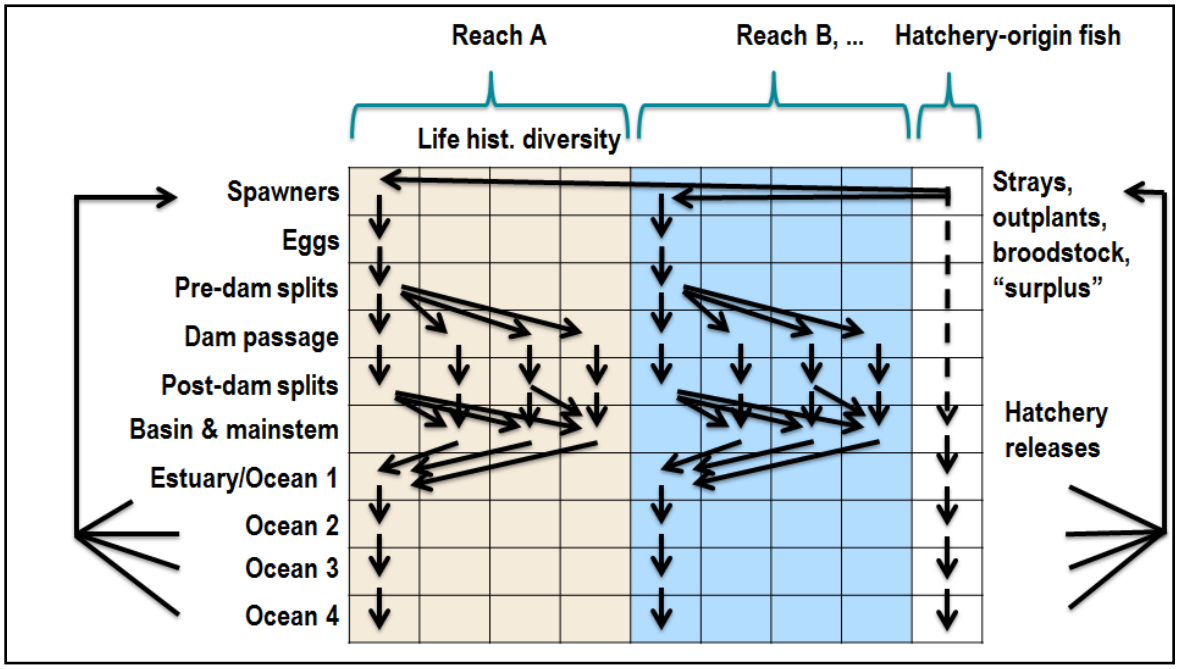


Figure 10.1: Idealized depiction of the matrix-type model structure of the R versions of the life cycle models.

The first step of the sensitivity analysis was to select a set of parameters for inclusion in the analyses, and an iterative process was used to select the parameter set. During the model construction process, some assumptions about the models and populations being modeled were re-evaluated and dam alternatives to be considered in the analyses changed, and we adapted the sensitivity analyses to accommodate these changes. Preliminary sensitivity analyses assisted in elimination of relatively non-influential parameters. Two criteria have driven the composition of parameter sets in the sensitivity process: (1) assessment of potentially influential parameters that would be directly affected by proposed alternatives on model responses (e.g., the importance of fish capacity above a dam as passage survival and passage efficiency changes from baseline conditions), and (2) uncertainty about a parameter value and its influence (in magnitude or direction) on model responses (e.g., fry splits into the different juvenile life history trajectories). What follows are sensitivity analyses that reflect the current state of the parameter selection process.

The sensitivity procedure consisted of repeatedly drawing a unique set of parameter values from within specified ranges for each model run of 100 years, and recording the model output. We tracked the median abundance of natural origin spawners (NORs) over the 100-year model run, and whether populations went extinct during each run of 100 years. An extinction event was defined as when any four year running mean of spawner counts within a run of 100 years fell below the quasi-extinction threshold level identified for that population (Chaps. 1 and 3), and we assigned a 1 or 0 to each run depending on whether it went extinct or not. We repeated this procedure 500 times (i.e., 500 runs of 100 years) for each of the alternatives to generate datasets for the sensitivity analyses. For each run of 100 years we held parameter values constant, the values of which we drew independently from each other from within their specified ranges according to a random uniform probability distribution. We chose random uniform draws within the ranges because data were insufficient to characterize their distributions (Cross and Beissinger 2001). The ranges of parameters spanned either their 95% confidence intervals if they were estimated from fitted relationships, from ranges in observed data or the literature, or, when information about constraining ranges was scarce, from the ranges established in several Willamette life cycle model parameter workshops (Chap. 3, and appendices).

Three-way proportional splits of juveniles among life history strategies (e.g., in the Chinook salmon life cycle models fry can follow either a spring subyearling, a fall subyearling, or a spring yearling life history pathway) were generated by sampling proportions according to a random uniform distribution within the specified ranges to generate vectors of three proportions that summed to 1.

For each model run, we kept track of the parameter values, resulting median spawners (natural origin spawners, NORs, in the case of Chinook salmon, and first-time plus repeat spawners in the case of steelhead) and extinction events to develop a dataset for the sensitivity analyses. We performed two types of regressions on the dataset. First, we regressed median spawners (dependent variable) as a function of the input parameter values (predictor variables). Second, to evaluate relative influence of parameters on pr(QET), we performed logistic regressions to relate extinction events to the parameter values. Regressing on median spawner abundance assessed model sensitivity to trends in spawner numbers, and logistic regression on extinction events assessed population persistence in response to the parameter sets.

After performing the regressions, we standardized the regression coefficients in two ways for comparison purposes. The relative importance of parameters for each dam and operational alternative was estimated by calculating standardized regression coefficients (coefficients divided

by their standard errors) for the predictor variables (Cross and Beissinger 2001). To make direct comparisons across the coefficients more easily interpretable we further standardized them by dividing each standardized coefficient by the absolute value of the largest standardized coefficient value (Crozier et al. 2008). The sign of the standardized coefficients (+ or −) indicated the influence of each parameter on median spawners or extinction (positive or negative), and the most influential parameter within an alternative had an absolute value of 1. This procedure was repeated for each of the alternatives.

Evaluation of the influence of juvenile life history trajectory splits required those parameters to be transformed prior to the regressions to assess their relative influence. Multicollinearity issues arise when including all proportions that sum to 1 in a multiple linear regression, in the case of three proportions any two will be an exact predictor of the third. We used an alternative log-ratio transformation (Aitchison 1997) to achieve independence of predictors derived from the splits. For example, the predictors of the three-way juvenile life history splits for Chinook salmon were: log(prop. spring subyearlings)/log(prop. spring yearlings) and log(prop. fall subyearlings)/log(prop. spring yearlings) (Fig. 10.2).

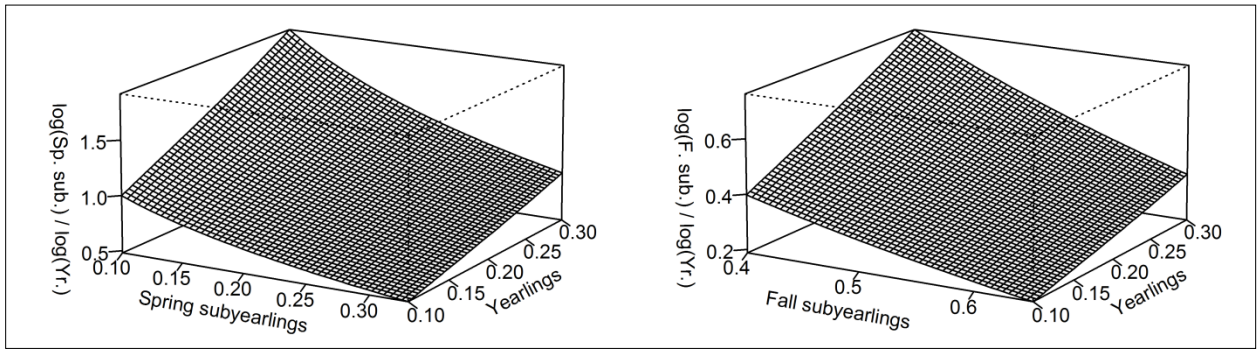


Figure 10.2: Alternative log ratio transformations of juvenile Chinook salmon fry rearing to particular juvenile life history trajectories (proportional splits and alternative log ratio transformations for the McKenzie Chinook salmon parameter ranges shown here) according to splitting rules that were included in analyses of relative influence.

10.4. Results

The prespawning mortality parameters consistently stood out as influential within and across most all of the alternatives evaluated in all of the Chinook salmon life cycle models. Also, in the alternatives that put fish above dams and increased passage survivals and dam passage efficiencies relative to baseline conditions, juvenile reservoir survivals and proportions of certain life history types passing dams generally became relatively more influential. One of the main structural differences between the SLAM and R versions of the life cycle models was estuary and ocean survival, and in the sensitivity analyses these parameters were generally not as influential relative to other parameters.

It should be noted that although some parameters appeared to have little influence (their relative influence across alternatives was near zero), it does not mean that they were not important in the life cycle model. Rather, given the parameters selected for inclusion in the analyses and within the ranges from which their values were sampled, those parameters were relatively less influential than the others.

10.5. Chinook Salmon

10.5.1. McKenzie River Chinook salmon

For the McKenzie River Chinook salmon life cycle model, we evaluated parameters that described the prespawning mortality functional relationship, fish production above Cougar Dam, survival of fry below Cougar Dam, proportions of juveniles available to pass Cougar Dam, juvenile reservoir survival, juvenile life history splits, and the parameters associated with estuary and early ocean survival (Table 10.1).

Prespawning mortality was generally highly influential across alternatives (Figures 10.3-10.4). Egg-fry survival under baseline conditions and in the drawdownRO alternative was more influential to pr(QET) than to median spawner abundance (Figure 10.3). In general, egg-fry survival across the alternatives had a bigger impact on pr(QET) than on median abundance. Fry-subyearling reservoir survival was more influential on median abundance than on pr(QET). As dam passage survival and efficiency improved from baseline conditions, fry-subyearling reservoir survival increased in influence as the importance of fish production from reaches above the dam increased (Figure 10.3).

Table 10.1: Inputs and parameters included in the McKenzie River Chinook salmon life cycle model sensitivity analysis. The ranges for the terms associated with prespawning mortality and estuary/early ocean survivals were 95% confidence intervals around those estimated parameters.

Aspect of life cycle	Input or parameter	Label	Range or 95% C.I.
Prespawning mortality	β_0 (intercept)	psm.beta0	(-13.5, -5.7)
	$\beta_{percent_wild}$	psm.wild	(-4.6, -0.2)
	$\beta_{temperature}$	psm.temp	(0.3, 0.8)
Fish capacity (eggs) above Cougar Dam	μ_{reach_C}	cap.mean.C	(15m, 19m)
Egg-fry survival below Cougar Dam	Survival, Reach B	B.egg.fry	(0.30, 0.50)
Fry available to pass Cougar Dam	Proportion	CGR.prop.fry.passing	(0.03, 0.10)
Fry-subyearling reservoir survival	Survival	CGR.fry.sub.res.surv	(0.15, 0.35)
Subyearlings available to pass Cougar Dam	Proportion	CGR.prop.subs.passing	(0.75, 1.0)
Subyearling-yearling reservoir survival	Survival	CGR.sub.yr.res.surv	(0.40, 0.90)
Post-Cougar Dam splits, subyearlings remaining as subyearling migrants	Proportion	post.CGR.subs.split	(0.60, 0.70)
Post-Cougar Dam splits, fry to spring subyearling, fall subyearling, and spring yearlings	Proportion	fry.spsub.div.year, fry.fallsub.div.year	Sp.subs (0.10, 0.33) Fall.subs (0.40, 0.65) Yearlings (0.10, 0.30)
Estuary/early ocean survival	β_0 (intercept)	beta0	(-4.35, -3.92)
	$\beta_{Up.May}$	Up.May	(-0.67, -0.22)
	$\beta_{Up.Sept}$	Up.Sept	(-0.43, 0.03)
	$\beta_{PDO.May}$	PDO.May	(-0.84, -0.37)

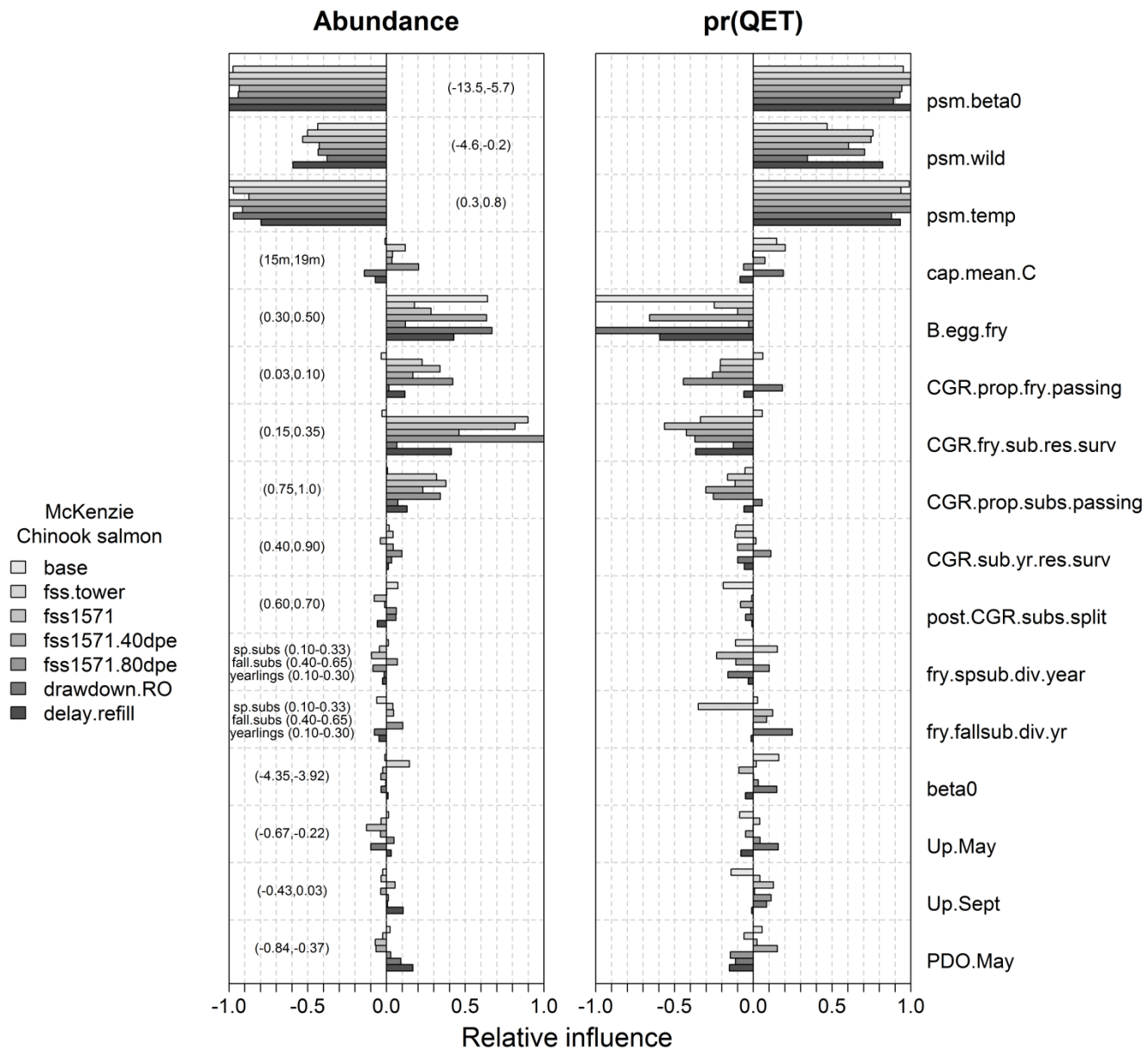


Figure 10.3: Sensitivity analysis of the McKenzie Chinook salmon life cycle model median NOR abundance and pr(QET) for a range of alternatives: base = baseline conditions; fss.tower = floating screen structure with tower; fss1571 = floating screen structure above 1571 ft; fss1571.40dpe = floating screen structure above 1571 ft with 40% dam passage efficiency; fss1571.80dpe = floating screen structure above 1571 ft with 80% dam passage efficiency; drawdownRO = drawdown to 1500 ft for 2 weeks in December, RO priority fry; delay.refill = delay refill until June 15th, RO priority fry. Parameter ranges (Table 10.1) are in parentheses.

10.5.2. North Santiam River Chinook salmon

We evaluated a similar set of parameters for the North Santiam Chinook salmon life cycle model sensitivity analysis (Table 10.2) as for the McKenzie model, and we examined relative parameter importance across a range of dam passage alternatives. Parameters included those defining the prespawning mortality functional relationship, fish production above Detroit Dam, egg-fry survival below Detroit and Big Cliff Dams, proportions of juveniles available to pass Detroit Dam, juvenile reservoir survival, juvenile life history splits, and parameters associated with estuary and early

ocean survival. Among the alternatives we evaluated, prespawning mortality parameters were among the most influential (Figures 10.4 – 10.5). Fry-subyearling reservoir survival was also among the most influential parameters. The proportion of fry available to pass Detroit Dam was somewhat influential in spite of the fact that in the sensitivity analyses the proportion of fry available to pass Detroit Dam ranged from only 1% to up to 15% of fry in the reservoir (Table 10.2). Capacity above Detroit Dam was not relatively influential. Egg-fry survival below Detroit and Big Cliff Dams was not as important among the alternatives evaluated. This was in contrast to sensitivity results for the McKenzie model, where egg-fry survival below Cougar Dam was more influential relative to other parameters.

Under baseline conditions, fry-subyearling reservoir survival was highly influential on extinction events, but less influential on median NORs. However, as dam passage survival and efficiency improves, this input became generally less influential to extinction risk and more influential on median NORs.

Table 10.2: Inputs and parameters included in the North Santiam River Chinook salmon life cycle model sensitivity analysis. The ranges for the terms associated with prespawning mortality and estuary and early ocean survivals were 95% confidence intervals around those estimated parameters.

Aspect of life cycle	Input or parameter	Label	Range or 95% C.I.
Prespawning mortality	β_0 (intercept)	psm.beta0	(-13.5, -5.7)
	$\beta_{\text{percent_wild}}$	psm.wild	(-4.6, -0.2)
	$\beta_{\text{temperature}}$	psm.temp	(0.3, 0.8)
Fish capacity (eggs) above Detroit Dam	$\mu_{\text{reach_D}}$	D.cap.mean	(4m, 8m)
	$\mu_{\text{reach_E}}$	E.cap.mean	(10.5m, 14.5m)
Egg-fry survival below Detroit and Big Cliff Dams	Survival, reaches B and F	BandF.egg.fry	(0.448, 0.486)
Fry available to pass Detroit Dam	Proportion	DET.prop.fry.passing	(0.01, 0.15)
Fry-subyearling reservoir survival	Survival	DET.fry.sub.res.surv	(0.10, 0.40)
Subyearlings available to pass Detroit Dam	Proportion	DET.prop.subs.passing	(0.75, 0.90)
Subyearling-yearling reservoir survival	Survival	DET.sub.yr.res.surv	(0.40, 0.70)
Post-Detroit Dam splits, subyearlings remaining as subyearling migrants	Proportion	post.DET.subs.split	(0.60, 0.85)
Post-Detroit Dam splits, fall subyearling, and spring yearlings	Proportion	fry.spsub.div.year, fry.fallsub.div.yr	Sp sub (0.20, 0.50) Fall sub (0.40, 0.60) Sp yearling (0.10,0.20)
Estuary/early ocean survival	β_0 (intercept)	beta0	(-4.63, -3.91)
	$\beta_{\text{Up.May}}$	Up.May	(-0.62, 0.13)
	$\beta_{\text{PDO.May}}$	PDO.May	(-0.90, -0.14)

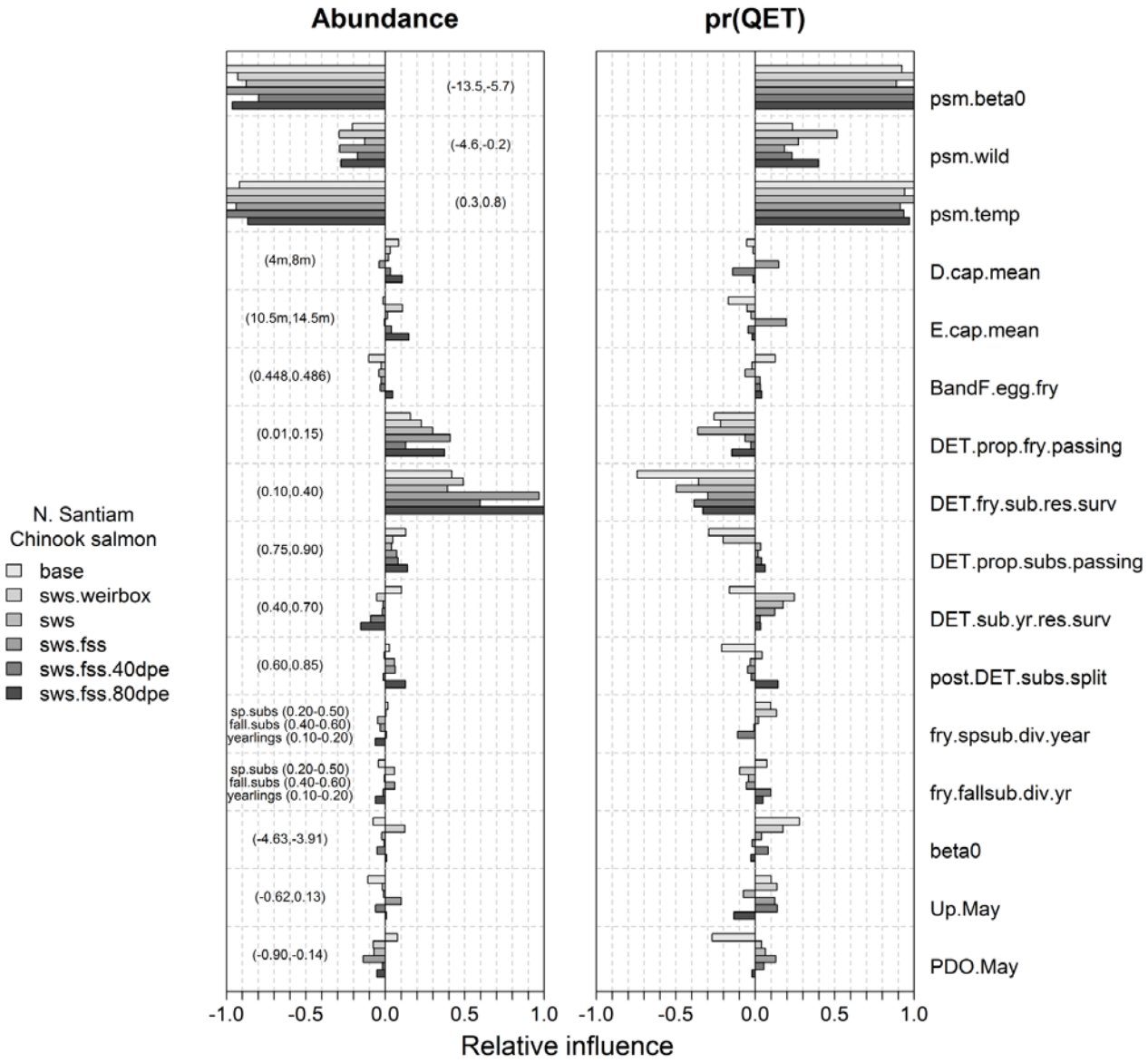


Figure 10.4: Sensitivity analysis of the North Santiam Chinook salmon life cycle model for a range of alternatives: base = baseline conditions; sws.weirbox = selective withdrawal structure with weirbox; sws = selective withdrawal structure; sws.fss = selective withdrawal structure with floating screen structure; sws.fss.40dpe = selective withdrawal structure with floating screen structure 40% dam passage efficiency (DPE); sws.fss.80dpe = selective withdrawal structure with floating screen structure 80% DPE. Parameter ranges (Table 10.2) are in parentheses.

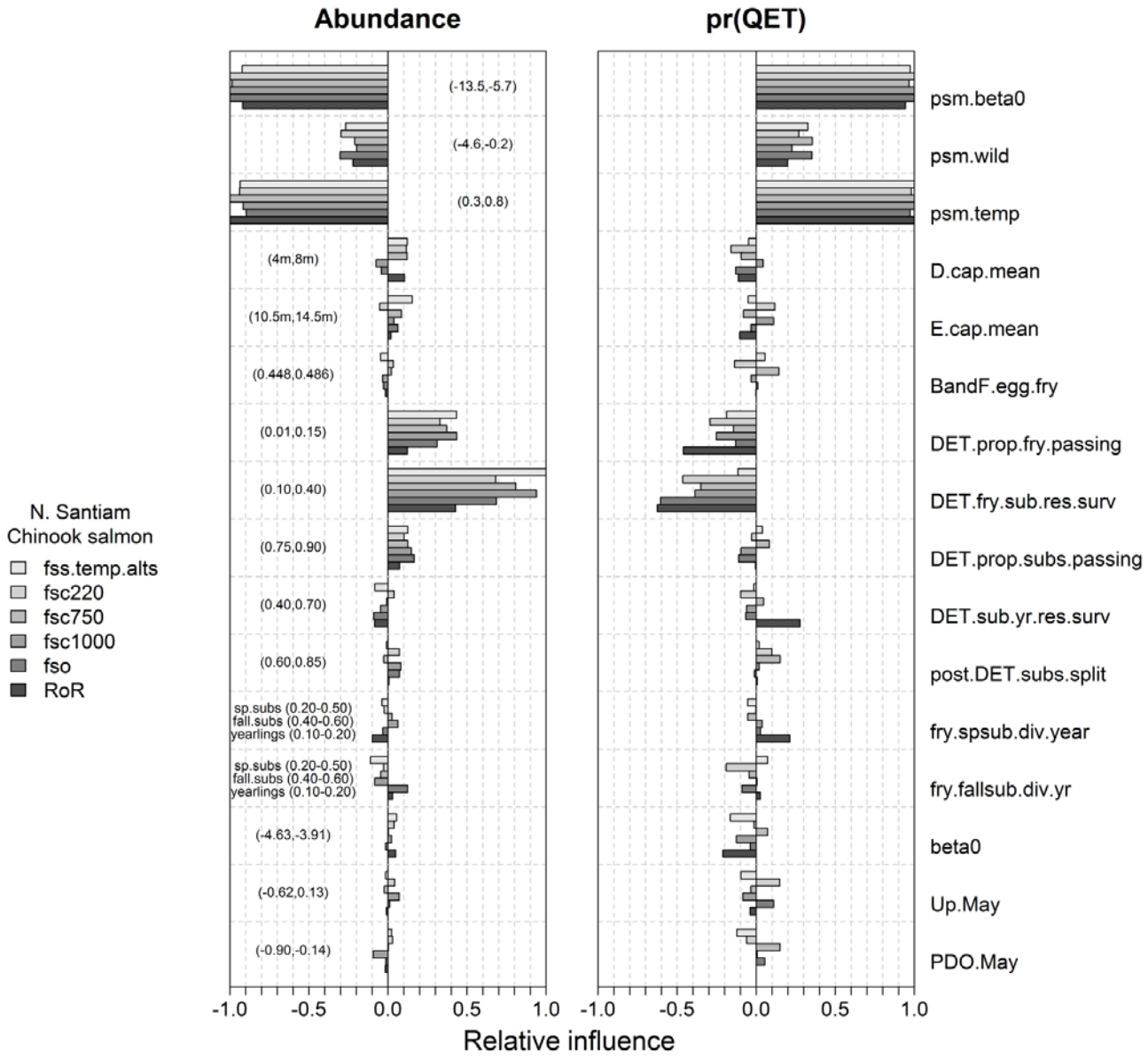


Figure 10.5: Sensitivity analysis of the North Santiam Chinook salmon life cycle model for a range of alternatives: fss.temp.alts = floating screen structure with temperature alternatives; fscXXX = floating surface collector at 220, 750, and 1000 cfs collection flows; fso = floating surface outlet (glory hole); RoR = run of river. Parameter ranges (Table 10.2) are in parentheses.

10.5.3. South Santiam River Chinook salmon

The South Santiam Chinook salmon population life cycle model sensitivity analysis included evaluation of parameters accounting for two dams, Green Peter Dam and Foster Dam, and their two reservoirs, which increased the number of parameters and inputs (Table 10.3) relative to the McKenzie and North Santiam populations' models. Egg capacities in the three reaches above dams were evaluated, along with juvenile life history splits and survivals for the two reservoirs. As in the previous models, the parameters associated with prespawning mortality were generally the most influential across all alternatives evaluated, both for median NOR abundance and extinction risk (Figures 10.6 – 10.7).

Table 10.3: Inputs and parameters included in the South Santiam River Chinook salmon life cycle model sensitivity analysis (GP = Green Peter Dam; FOS = Foster Dam). The ranges for the terms associated with prespawning mortality and estuary and early ocean survivals were 95% confidence intervals around those estimated parameters.

Aspect of life cycle	Input or parameter	Label	Range or 95% C.I.
Prespawning mortality	β_0 (intercept)	psm.beta0	(-13.5, -5.7)
	$\beta_{\text{percent_wild}}$	psm.wild	(-4.6, -0.2)
	$\beta_{\text{temperature}}$	psm.temp	(0.3, 0.8)
Fish capacity (eggs) above Foster Dam	$\mu_{\text{reach_E}}$	cap.mean.E	(5m, 9m)
Fish capacity (eggs) above Green Peter Dam	$\mu_{\text{reach_F}}$	cap.mean.F	(1m, 3m)
Fish capacity (eggs) above Green Peter Dam	$\mu_{\text{reach_G}}$	cap.mean.G	(2.5m, 6.5m)
Fry available to pass dam	Proportion	GP.prop.fry.passing	(0.01,0.05)
		FOS.prop.fry.passing	(0.60, 0.90)
Fry-subyearling reservoir survival	Survival	GP.fry.sub.res.surv	(0.10, 0.40)
		FOS.fry.sub.res.surv	(0.10, 0.40)
Subyearlings available to pass dam	Proportion	GP.prop.subs.passing	(0.75, 0.90)
		FOS.prop.subs.passing	(0.80,1.0)
Subyearling-yearling reservoir survival	Survival	GP.sub.yr.res.surv	(0.35, 0.70)
		FOS.sub.yr.res.surv	(0.35,0.80)
Post-Foster Dam splits, subyearlings remaining as subyearling migrants	Proportion	post.FOS.subs.split	(0.70, 0.80)
Post-Foster Dam splits, fry fall subyearling, and spring yearlings	Proportion	fry.spsub.div.year, fry.fallsub.div.yr	Sp sub (0.20, 0.50) Fall sub (0.20, 0.60) Sp yearling (0.10,0.20)
Estuary/early ocean survival	β_0 (intercept)	beta0	(-4.76, -3.90)
	$\beta_{\text{Up.Sept}}$	Up.Sept	(-0.944, -0.044)
	$\beta_{\text{PDO.Apr}}$	PDO.Apr	(-0.961, -0.061)

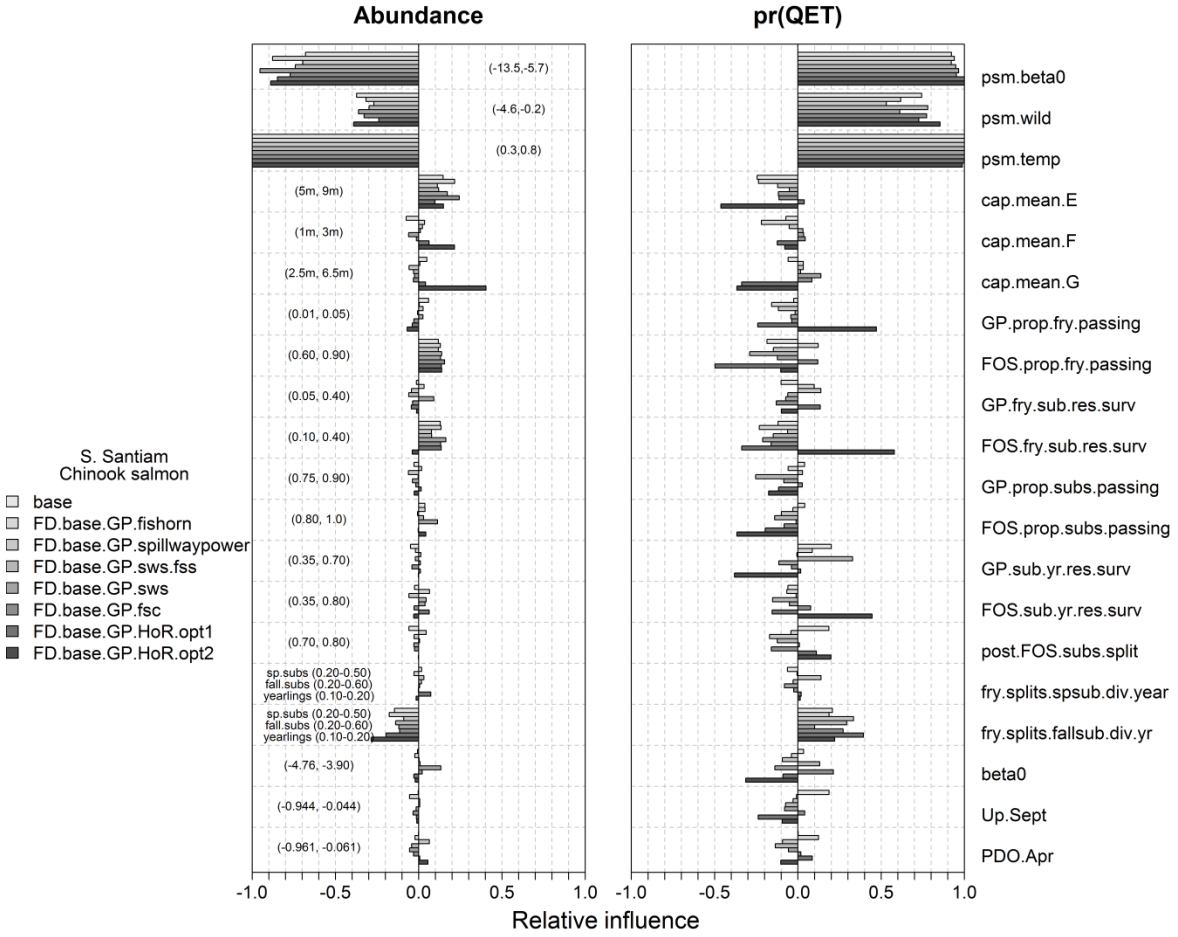


Figure 10.6: Sensitivity analysis of the South Santiam Chinook salmon life cycle model for a range of alternatives: base = baseline conditions at both Green Peter and Foster dams; FD.base.GP.fishorn = Foster baseline with the fish horn alternative at Green Peter; FD.base.GP.spillwaypower = Foster baseline with Green Peter operated with the spillway and powerhouse; FD.base.GP.sws.fss = Foster Dam baseline with Green Peter selective withdrawal structure and floating screen structure; FD.base.GP.sws = Foster Dam at baseline with Green Peter selective withdrawal structure; FD.base.GP.fsc = Foster Dam baseline with Green Peter floating surface collector; FD.base.GP.HoR.optX = Foster Dam baseline with Green Peter head of reservoir fry trapping, options 1 and 2. Parameter ranges (Table 10.3) are in parentheses.

Parameter sensitivities for the head of reservoir option 2 fry trapping alternative in general did not follow the patterns for the other alternatives. Median NOR counts were the highest for this alternative, and extinction risk as measured by the number of extinction events was the lowest. Reservoir survivals in Foster, the proportion of fry passing Green Peter, and egg capacity in Reach E (above Foster but below Green Peter) were relatively more influential on the few extinction events that occurred in this head of reservoir trapping alternative. However, egg capacity in Reach G, above Green Peter Dam, had some relative influence in both head of reservoir alternatives on the low extinction risk, but only the head of reservoir fry trapping option 2 alternative had the strongest positive influence on NORs and on lowered extinction risk. The proportion of fry below the dams moving into either fall subyearling or spring yearling juvenile life history strategy was associated with an increasing extinction risk.

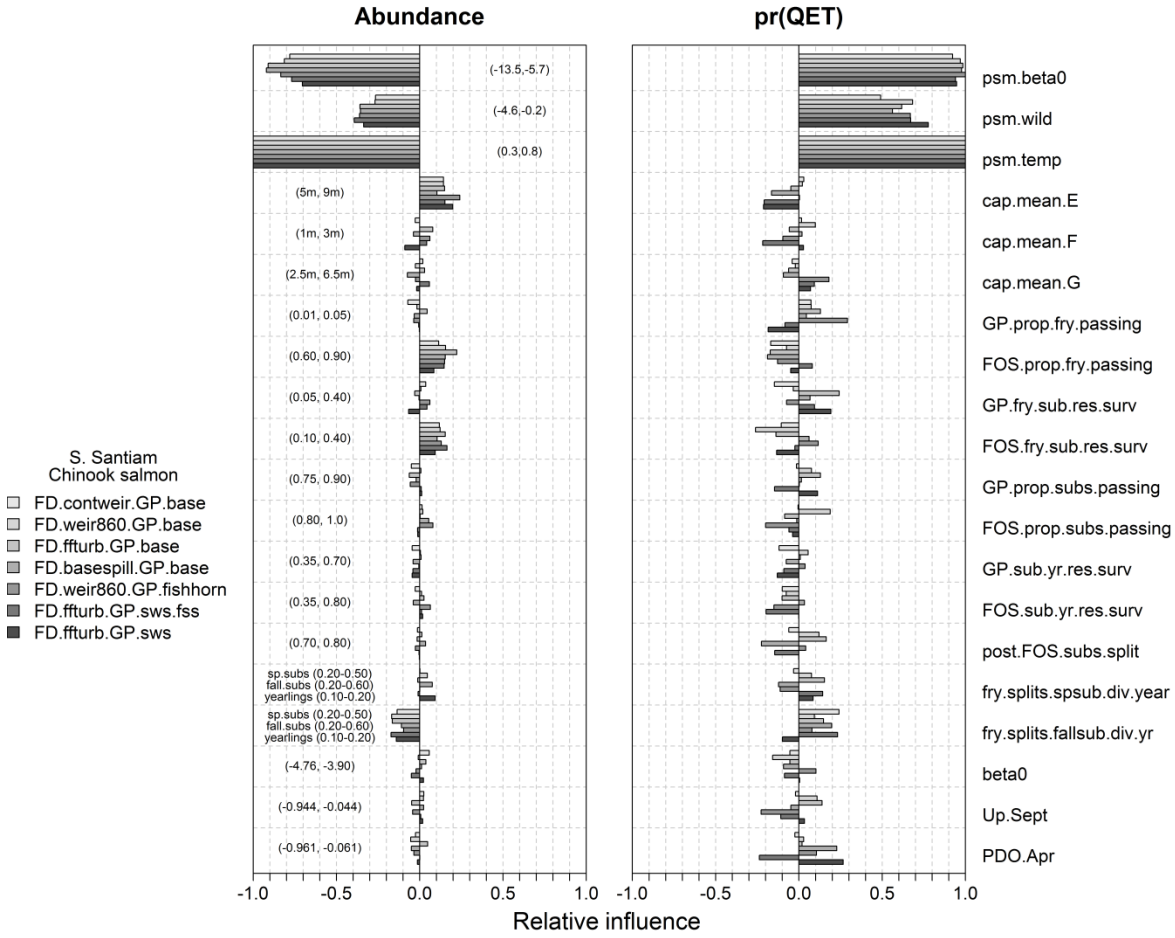


Figure 10.7: Sensitivity analysis of the South Santiam Chinook salmon life cycle model for a range of alternatives: FD.contweir.GP.base = Green Peter baseline with continuous weir at Foster Dam; FD.weir860.GP.base = Green Peter baseline with weir at 860 cfs; FD.ffturb.GP.base = Green Peter baseline with a fish friendly turbine at Foster Dam; FD.basespill.GP.base = Green Peter baseline with spill at baseline at Foster Dam; FD.weir860.GP.fishhorn = Foster Dam with a weir at 860 cfs and Green Peter Dam fish horns; FD.ffturb.GP.sws.fss = Foster Dam with fish friendly turbines and Green Peter Dam with a selective withdrawal structure and floating screen structure; FD.ffturb.GP.sws = Foster Dam with fish friendly turbines and Green Peter with a selective withdrawal structure. Parameter ranges (Table 10.3) are in parentheses.

10.5.4. Middle Fork Willamette River Chinook salmon

The Middle Fork Willamette River population life cycle model sensitivity analysis included evaluation of parameters associated with three dam projects, Fall Creek Dam, the Lookout Point Dam/Dexter Dam complex, and Hills Creek Dam (Table 10.4). The parameters associated with the prespawning mortality functional relationship were the most influential parameters across the alternatives (Figures 10.8 – 10.10). Besides the prespawning parameters, influence of other parameters on median NORs was relatively minor and no parameters other than those for prespawning mortality were strong influencers on median NORs.

Table 10.4: Inputs and parameters included in the Middle Fork Willamette River Chinook salmon life cycle model sensitivity analysis (HCR = Hills Creek Dam; LOP = Lookout Point Dam/Dexter Dam complex; FCR = Fall Creek Dam). The ranges for the terms associated with prespawning mortality and estuary and early ocean survivals were 95% confidence intervals around those estimated parameters.

Aspect of life cycle	Input or parameter	Label	Range or 95% C.I.
Prespawning mortality	β_0 (intercept)	psm.beta0	(-13.5, -5.7)
	$\beta_{percent_wild}$	psm.wild	(-4.6, -0.2)
	$\beta_{temperature}$	psm.temp	(0.3, 0.8)
Fish capacity (eggs) above Fall Creek Dam	μ_{reach_E}	cap.mean.C	(1m, 3m)
Fish capacity (eggs) above Lookout Point Dam	μ_{reach_F}	cap.mean.D	(17m, 25.5m)
Fish capacity (eggs) above Hills Creek Dam	μ_{reach_G}	cap.mean.E	(7m, 13m)
Fry available to pass dam	Proportion	HCR.prop.fry.passing	(0.03, 0.05)
		LOP.prop.fry.passing	(0.05, 0.15)
		FCR.prop.fry.passing	(0.75, 1.0)
Fry-subyearling reservoir survival	Survival	HCR.fry.sub.res.surv	(0.15, 0.35)
		LOP.fry.sub.res.surv	(0.10, 0.40)
		FCR.fry.sub.res.surv	(0.20, 0.45)
Subyearlings available to pass dam	Proportion	HCR.prop.subs.passing	(0.70, 0.95)
		LOP.prop.subs.passing	(0.70, 0.95)
		FCR.prop.subs.passing	(0.95, 1.0)
Subyearling-yearling reservoir survival	Survival	HCR.sub.yr.res.surv	(0.40, 0.90)
		LOP.sub.yr.res.surv	(0.40, 0.90)
		FCR.sub.yr.res.surv	(0.35, 0.80)
Post-dam splits, subyearlings remaining as subyearling migrants	Proportion	post.dam.subs.split.LOP	(0.70, 0.80)
		post.dam.subs.split.FCR	(0.85, 1.0)
Post-dam splits, fry to: spring subyearling/yearling; fall subyearling/spring yearling	Proportion	fry.splits.spsub.div.yr.FCR, fry.splits.fallsubs.div.yr.FCR	Sp sub (0.15, 0.35) Fall sub (0.40, 0.65) Sp yearling (0.10,0.30)
		fry.splits.spsub.div.yr.LOP, fry.splits.fallsubs.div.yr.LOP	Sp sub (0.15, 0.33) Fall sub (0.40, 0.65) Sp yearling (0.10, 0.30)
Fall Creek Dam passage survival	Survival	FCR.mean.passage.survival	(0.75, 0.95)
Estuary/early ocean survival	β_0 (intercept)	beta0	(-4.03, -3.59)
	$\beta_{Up.Sept}$	Up.Sept	(-0.59, -0.096)
	$\beta_{PDO.Apr}$	PDO.June	(-0.64, -0.14)

The pattern of parameter influence on pr(QET) was more complex. Across all the alternatives evaluated, pr(QET) in the sensitivity analyses was relatively high. Parameters were either positively or negatively influential on pr(QET) for one or a set of alternatives, and then typically neutral or minimally influential for the other alternatives. Under baseline conditions at Lookout Point and Dexter dams and with the selective withdrawal structure alternative for Hills Creek Dam, fry-subyearling survival in the reservoir above Hills Creek Dam in the range we sampled had a negative influence on pr(QET). However, fry-subyearling reservoir survival above Lookout Point Dam under these same conditions had a positive influence on pr(QET). Also, below Lookout Point and Dexter dams the ratio of fry splits into the proportion of subyearlings divided by the proportion of spring yearlings had a negative influence on extinction risk (i.e., a higher the ratio was related to a higher extinction risk), whereas this same parameter under LOP/DEX baseline conditions but with a selective withdrawal structure in combination with a floating screen structure alternative at Hills Creek Dam had a positive influence on extinction risk (i.e., a higher ratio was related to a lower extinction risk; Figure 10.9).

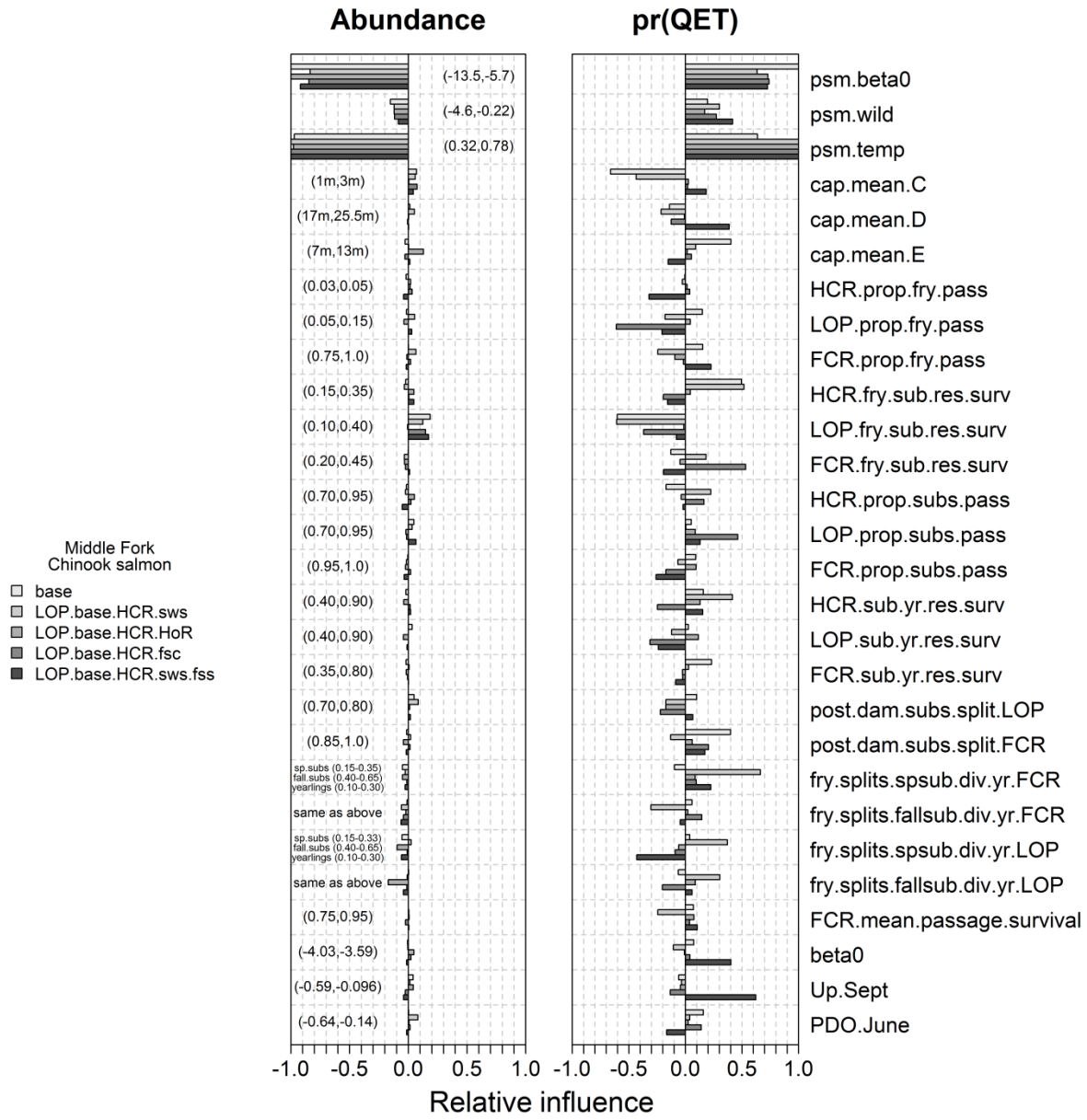


Figure 10.8: Sensitivity analysis of the Middle Fork Chinook salmon life cycle model for a range of alternatives: base = baseline conditions at Hills Creek and Lookout Point dams; LOP.base.HCR.sws = baseline at Lookout Point Dam and selective withdrawal structure at Hills Creek Dam; LOP.base.HCR.HoR = baseline at Lookout Point Dam and fry trapped at the head of the Hills Creek Dam reservoir; LOP.base.HCR.fsc = baseline at Lookout Point Dam and floating surface collector at Hills Creek Dam; LOP.base.HCR.sws.fss = baseline at Lookout Point and a selective withdrawal structure with floating screen structure at Hills Creek Dam. Parameter ranges (Table 10.4) are in parentheses.

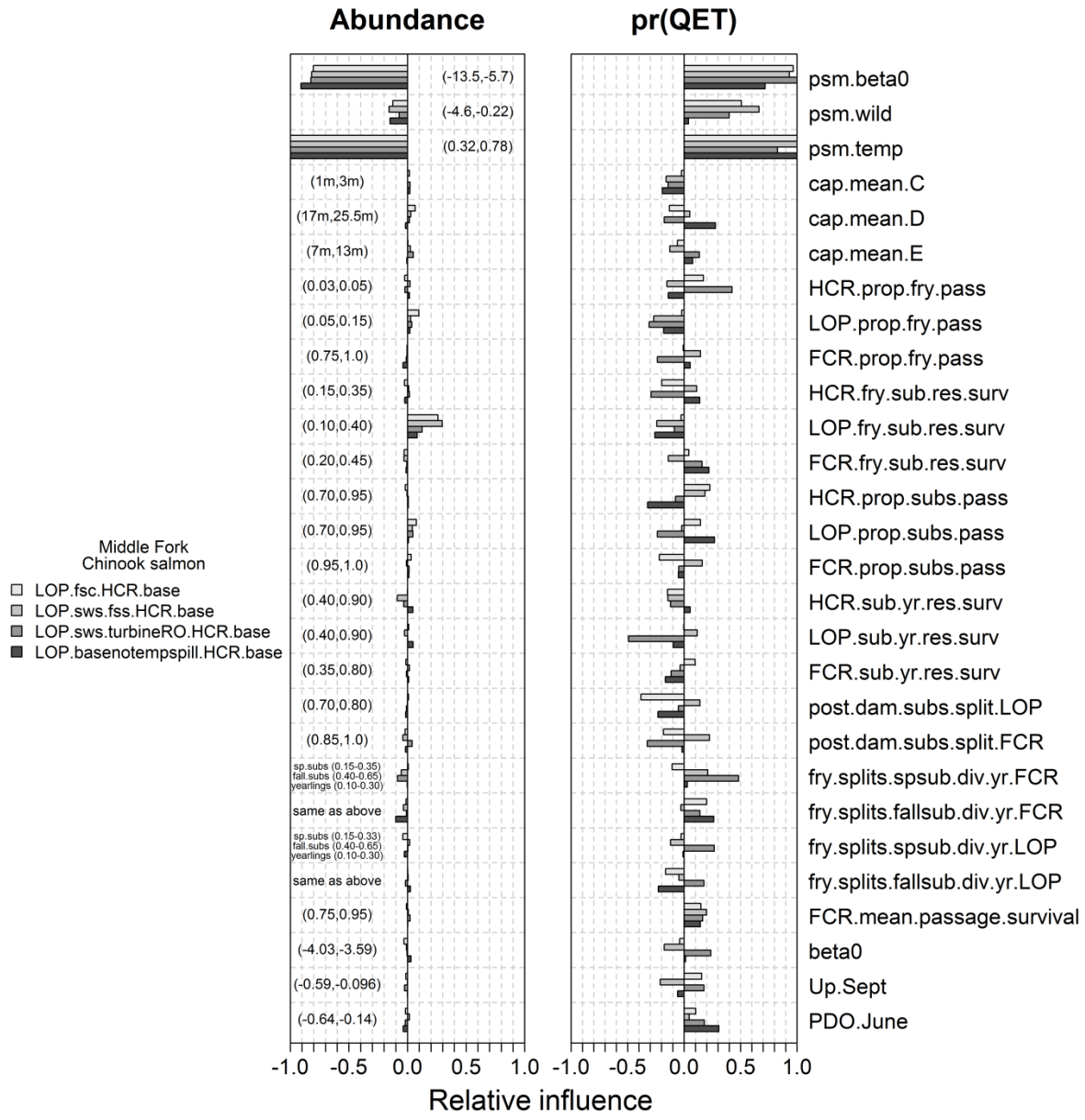


Figure 10.9: Sensitivity analysis of the Middle Fork Chinook salmon life cycle model for a range of alternatives: LOP.fsc.HCR.base = baseline at Hills Creek Dam and floating surface collector at Lookout Point; LOP.sws.fss.HCR.base = baseline at Hills Creek Dam and selective withdrawal structure and floating screen structure at Lookout Point Dam; LOP.sws.turbineRO.HCR.base = baseline at Hills Creek Dam and selective withdrawal structure and turbine/RO at Lookout Point Dam; LOP.basenotempspill.HCR.base = baseline at Hills Creek Dam and baseline with no temperature spill at Lookout Point Dam. Parameter ranges (Table 10.4) are in parentheses.

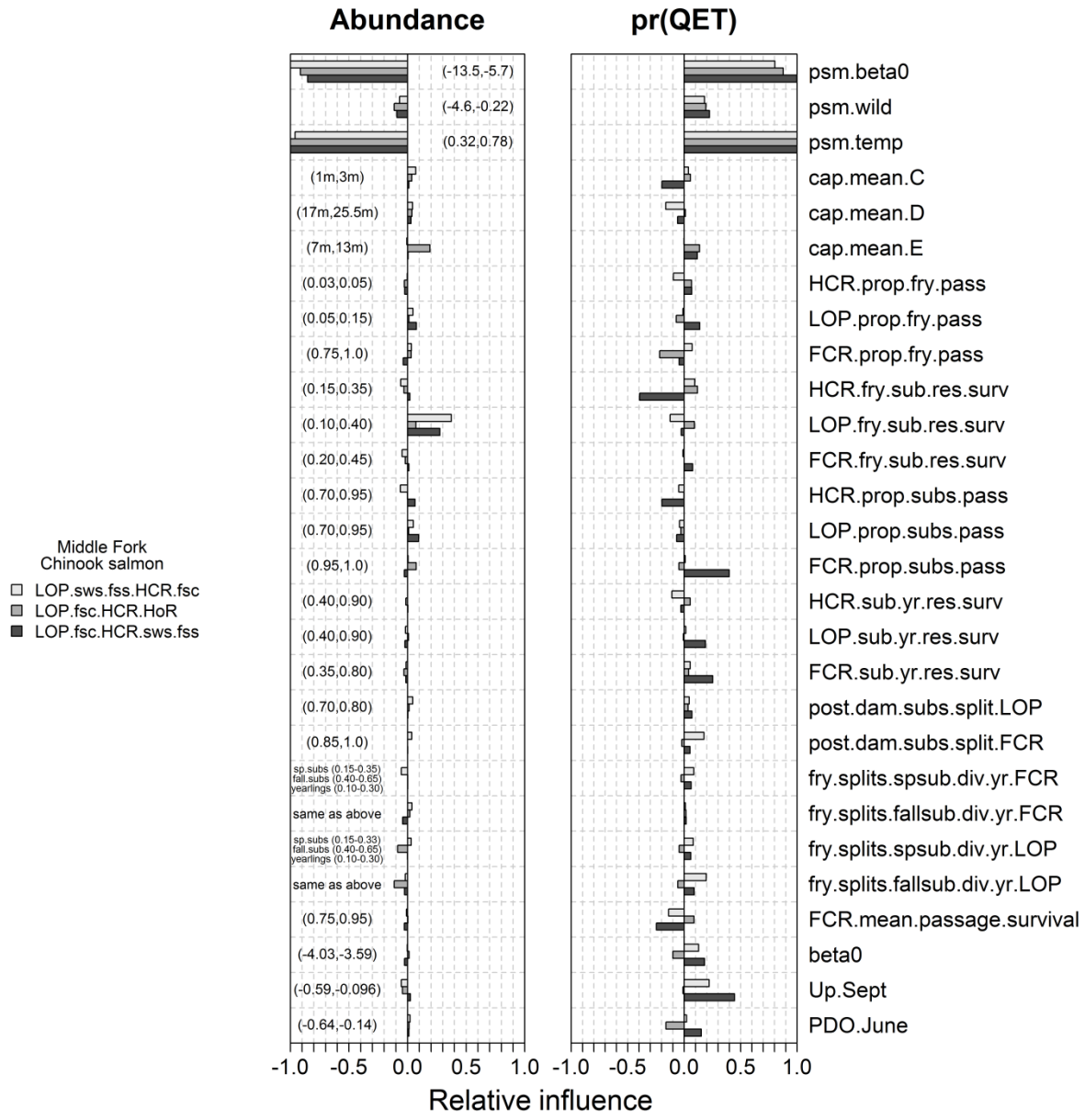


Figure 10.10: Sensitivity analysis of the Middle Fork Chinook salmon life cycle model for a range of alternatives: LOP.sws.fss.HCR.fsc = selective withdrawal structure with floating screen structure at Lookout Point Dam and floating surface collector at Hills Creek Dam; LOP.fsc.HCR.HoR = floating surface collector at Lookout Point and fry trapping at the head of Hills Creek reservoir; LOP.fsc.HCR.sws.fss = floating surface collector at Lookout Point and selective withdrawal structure with floating screen structure at Hills Creek Dam. Parameter ranges (Table 10.4) are in parentheses.

10.6. Steelhead

10.6.1. North Santiam River winter steelhead

In the steelhead life cycle model sensitivity analyses we evaluated a similar set of parameters with inclusion of a few different parameters. There was no prespawning mortality functional relationship for the steelhead models, given their spawn timing characteristics prespawning temperatures are not a limiting factor. We included parameters for the estuary and early ocean

functional relationship we developed for Clackamas River winter steelhead (Chap. 3) which we then applied in the North Santiam winter steelhead life cycle model (Table 10.5). In the steelhead models' sensitivity analyses we included a parameter defining productivity of first-time and repeat spawners, the number of eggs per fish.

Table 10.5: Inputs and parameters included in the North Santiam River winter steelhead life cycle model sensitivity analysis (DET = Detroit Dam). The ranges for the terms associated with estuary and early ocean survivals (upwelling, PDO index, and mean of monthly summer Willamette River flow at Salem) were 95% confidence intervals around those estimated parameters.

Aspect of life cycle	Input or parameter	Label	Range or 95% C.I.
Fish capacity (eggs) above Detroit Dam	μ_{reach_D}	D.cap.mean	(2.5m, 7.5m)
	μ_{reach_E}	E.cap.mean	(4m, 12m)
Egg capacity variability multiplier	Multiplier (1 + value)	cap.variability	(0, 0.478)
Productivity (# of eggs) of first-time and repeat spawners	Eggs	prod.firstspawn	(1100, 2100)
		prod.respawn	(2200, 5400)
Above Detroit Dam, fry splits to Age0, Age1, and Age2	Proportion	DE.frysplit.Age0.Age2, DE.frysplit.Age1.Age2	Fry-Age0 (0.60, 0.80) Fry-Age1 (0.08, 0.12) Fry-Age2 (0.15, 0.22)
Survival of Age0 in Detroit reservoir	Survival	Age0.reservoir	(0.30, 0.50)
Age0 available to pass Detroit Dam	Proportion	Age0.availpass	(0.70, 0.90)
Age0-Age1 reservoir survival	Survival	Age0.Age1.res.surv	(0.10, 0.30)
Age1 reservoir survival	Survival	Age1.Reservoir	(0.40, 0.60)
Age1 available to pass Detroit Dam	Proportion	Age1.availpass	(0.90, 1.0)
Age1-Age2 reservoir survival	Survival	Age1.Age2.res.surv	(0.40, 0.60)
Age2 reservoir survival	Survival	Age2.reservoir	(0.80, 0.95)
Post-Detroit Dam splits, subyearlings remaining as subyearling migrants	Proportion	post.DET.subs.split	(0.60, 0.85)
Post-Detroit Dam splits, fry-spring subyearling split/yearling split	Proportion	fry.spsub.div.year	Sp sub (0.20, 0.50) Fall sub (0.40, 0.60) Sp yearling (0.10,0.20)
Post-Detroit Dam splits, fry-fall subyearling split/yearling split	Proportion	Fry.fallsub.div.yr	Sp sub (0.20, 0.50) Fall sub (0.40, 0.60) Sp yearling (0.10,0.20)
Estuary/early ocean survival	β_0 (intercept)	beta0	(-2.62, -2.11)
	$\beta_{Up.May}$	Up.Sept	(-0.59, -0.06)
	$\beta_{PDO.May}$	PDO.May	(-0.66, -0.12)
	$\beta_{flow_July\text{-}Sept}$	Flow.JulSept	(0.12, 0.65)

Productivity, capacity and juvenile life history splits were included among the top influential parameters in the model outputs. The model's outputs were most sensitive to the productivity of first-spawning adults across nearly all of alternatives we evaluated (Figure 10.11). Egg capacity in reaches D and E (above Detroit Dam) was relatively more influential as dam passage survival and efficiency increased from baseline conditions. The added variability to the capacity parameters exerted some influence in two alternatives, floating surface collector at 1000 cfs and the floating surface outlet (glory hole). Productivity of respawners was also relatively influential to both median spawners and extinction risk. The numbers of respawners was low relative to first-time spawners, however the upper end of the range in productivity of respawners was high relative to first-time spawners which contributed to this parameter's influence. Splits of fry apportioned to age0, age1, and age2 life history trajectories were also influential. The ratio of fry splits to age0/age2 became relatively more influential as conditions moved from baseline to alternative scenarios of increased dam passage and efficiency.

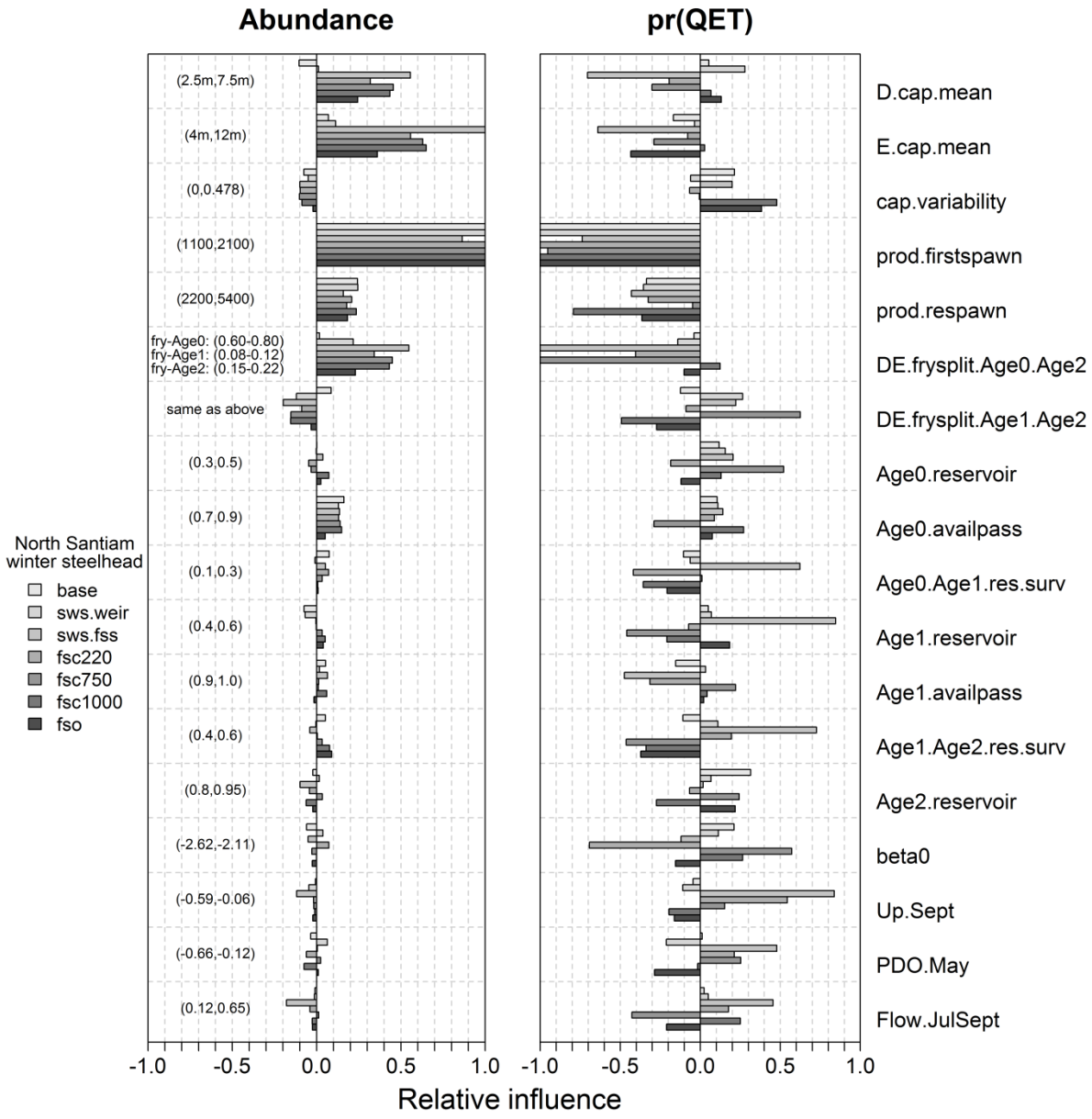


Figure 10.11: Sensitivity analysis of the North Santiam winter steelhead life cycle model for a range of alternatives: base = baseline conditions; sws.weir = selective withdrawal structure with fish weir; sws.fss = selective withdrawal structure with floating screen structure; fscXXX = floating surface collector at 220, 750, and 1000 cfs; fso = floating surface outlet (glory hole). Parameter ranges (Table 10.5) are in parentheses.

Many parameters exerted conflicting influence on pr(QET) across the alternatives evaluated, much like what we observed in the Middle Fork Chinook salmon life cycle model sensitivity analysis. However, it should be noted that extinction risk as estimated by the North Santiam winter steelhead life cycle model was relatively low across the alternatives evaluated, thus parameters that had a deleterious influence on pr(QET) were identified in a context where extinction events were rare. Fry splits into age1 and age2, reservoir survivals, and estuary and early ocean parameters frequently had alternating influence on pr(QET).

10.6.2. South Santiam River winter steelhead

The South Santiam winter steelhead life cycle model sensitivity analysis included more parameters than for the North Santiam steelhead analysis to take into consideration the additional dams and their associated reservoirs (Table 10.6). This sensitivity analysis included evaluation of fish productivity (eggs per fish) and many combinations of alternatives.

Table 10.6: Inputs and parameters included in the South Santiam River winter steelhead life cycle model sensitivity analysis (GP = Green Peter Dam; FOS = Foster Dam). The ranges for the terms associated with estuary and early ocean survivals (upwelling, PDO index, and mean of mean monthly summer Willamette River flows at Salem, OR) were 95% confidence intervals around those estimated parameters.

Aspect of life cycle	Input or parameter	Label	Range or 95% C.I.
Fish capacity (eggs) above Foster Dam	μ_{reach_E}	cap.mean.E	(3m, 6m)
Fish capacity (eggs) above Green Peter Dam	μ_{reach_F}	cap.mean.F	(1.5m, 2m)
Fish capacity (eggs) above Green Peter Dam	μ_{reach_G}	cap.mean.G	(3m, 5m)
Egg capacity variability multiplier	Multiplier (1 + value)	cap.variability	(0, 0.478)
Productivity (# of eggs) of first-time and repeat spawners	Eggs	prod.firstspawn	(1100, 2100)
		prod.respawn	(2200, 5400)
Above Foster and Green Peter dams, fry splits to Age0, Age1, and Age2	Proportion	E.frysplit.Age0.Age2, E.frysplit.Age1.Age2, FG.frysplit.Age0.Age2, FG.frysplit.Age1.Age2	Fry-Age0 (0.70, 0.95) Fry-Age1 (0.06, 0.15) Fry-Age2 (0.0, 0.05)
Age0 Green Peter Reservoir survival	Survival	GP.Age0.reservoir	(0.20, 0.40)
Age0 available to pass Green Peter Dam	Proportion	GP.Age0.availpass	(0.65, 0.85)
Age0 to Age1 Green Peter reservoir survival	Survival	GP.Age0.Age1.res.surv	(0.05, 0.25)
Age1 Green Peter reservoir survival	Survival	GP.Age1.Reservoir	(0.40, 0.60)
Age1 available to pass Green Peter Dam	Proportion	GP.Age1.availpass	(0.90, 1.0)
Age1 – Age2 Green Peter reservoir survival	Survival	GP.Age1.Age2.res.surv	(0.30, 0.60)
Age2 survival in Green Peter reservoir	Survival	GP.Age1.reservoir	(0.80, 0.95)
Age0 Foster Reservoir survival	Survival	FOS.Age0.reservoir	(0.20, 0.40)
Age0 available to pass Foster Dam	Proportion	FOS.Age0.availpass	(0.90, 1.0)
Age0 to Age1 Foster reservoir survival	Survival	FOS.Age0.Age1.res.surv	(0.10, 0.30)
Age1 Foster reservoir survival	Survival	FOS.Age1.Reservoir	(0.40, 0.60)
Age1 available to pass Foster Dam	Proportion	FOS.Age1.availpass	(0.90, 1.0)
Age1 – Age2 Foster reservoir survival	Survival	FOS.Age1.Age2.res.surv	(0.40, 0.60)
Age2 survival in Foster reservoir	Survival	FOS.Age1.reservoir	(0.80, 0.95)
Estuary/early ocean survival	β_0 (intercept)	beta0	(-2.62, -2.11)
	$\beta_{Up.May}$	Up.Sept	(-0.59, -0.06)
	$\beta_{PDO.May}$	PDO.May	(-0.66, -0.12)
	$\beta_{flow_July\text{-}Sept}$	Flow.JulSept	(0.12, 0.65)

As with the North Santiam life cycle model for winter steelhead, this model's output was most influenced by productivity of first-time spawners across all alternatives (Figures 10.12 – 10.14). Survival of age0 fish in Foster reservoir and productivity of respawning fish were somewhat influential across the alternatives. In the head of reservoir juvenile trapping option 2 alternative, egg capacity in reach E was very influential to a reduction in extinction risk but was not as influential on spawner abundance (Figure 10.11). No other reaches across the other alternatives we

evaluated influenced spawner abundance or extinction risk as much as Reach E (above Foster Dam and reservoir) under this scenario.

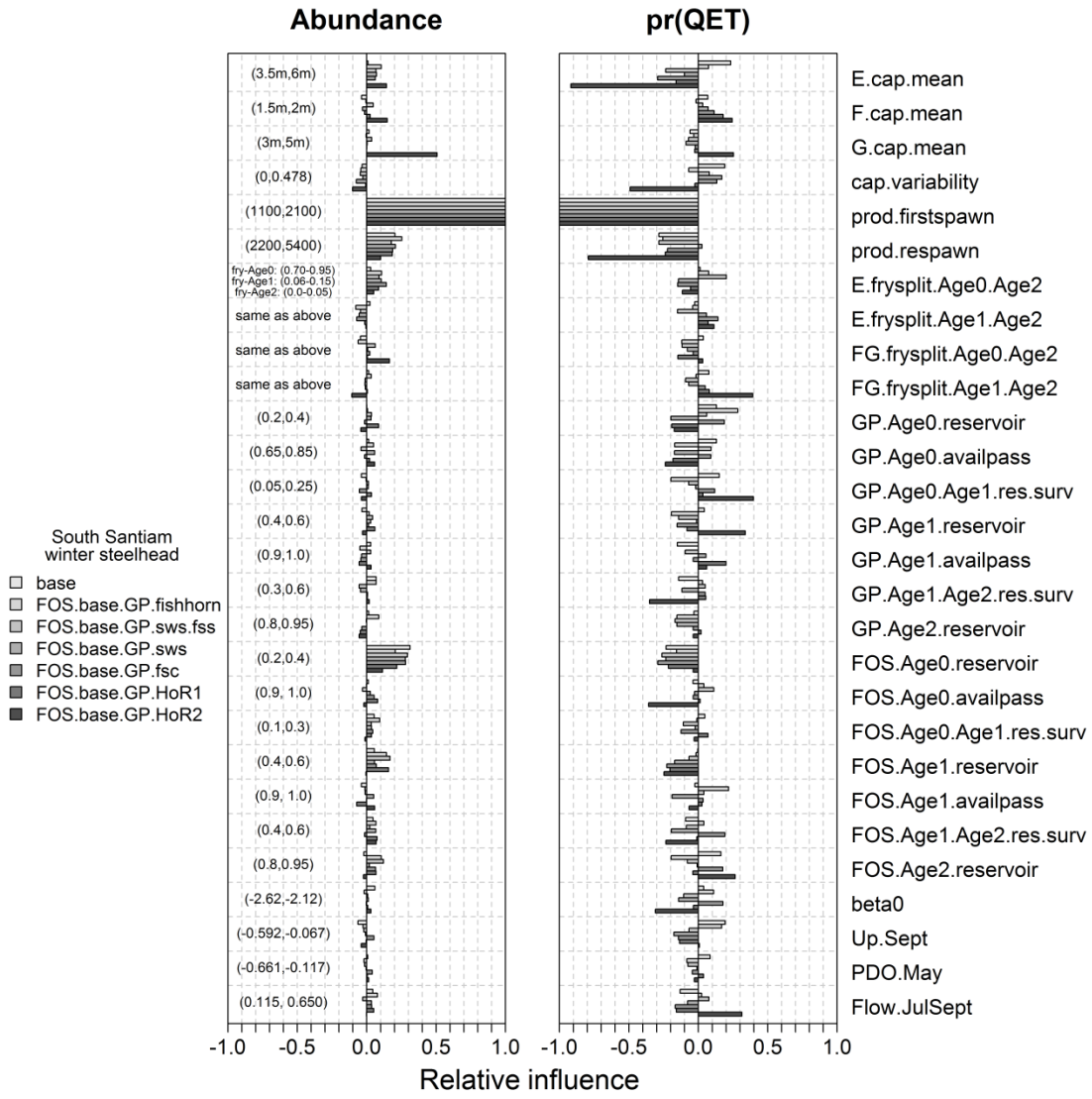


Figure 10.12: Sensitivity analysis of the South Santiam winter steelhead life cycle model for a range of alternatives: base = baseline conditions at both Green Peter and Foster dams; FD.base.GP.fishorn = Foster baseline with the fish horn alternative at Green Peter; FD.base.GP.sws.fss = Foster Dam baseline with Green Peter selective withdrawal structure and floating screen structure; FD.base.GP.sws = Foster Dam at baseline with Green Peter selective withdrawal structure; FD.base.GP.fsc = Foster Dam baseline with Green Peter floating surface collector; FD.base.GP.HoR.optX = Foster Dam baseline with Green Peter head of reservoir fry trapping, options 1 and 2. Parameter ranges (Table 10.6) are in parentheses.

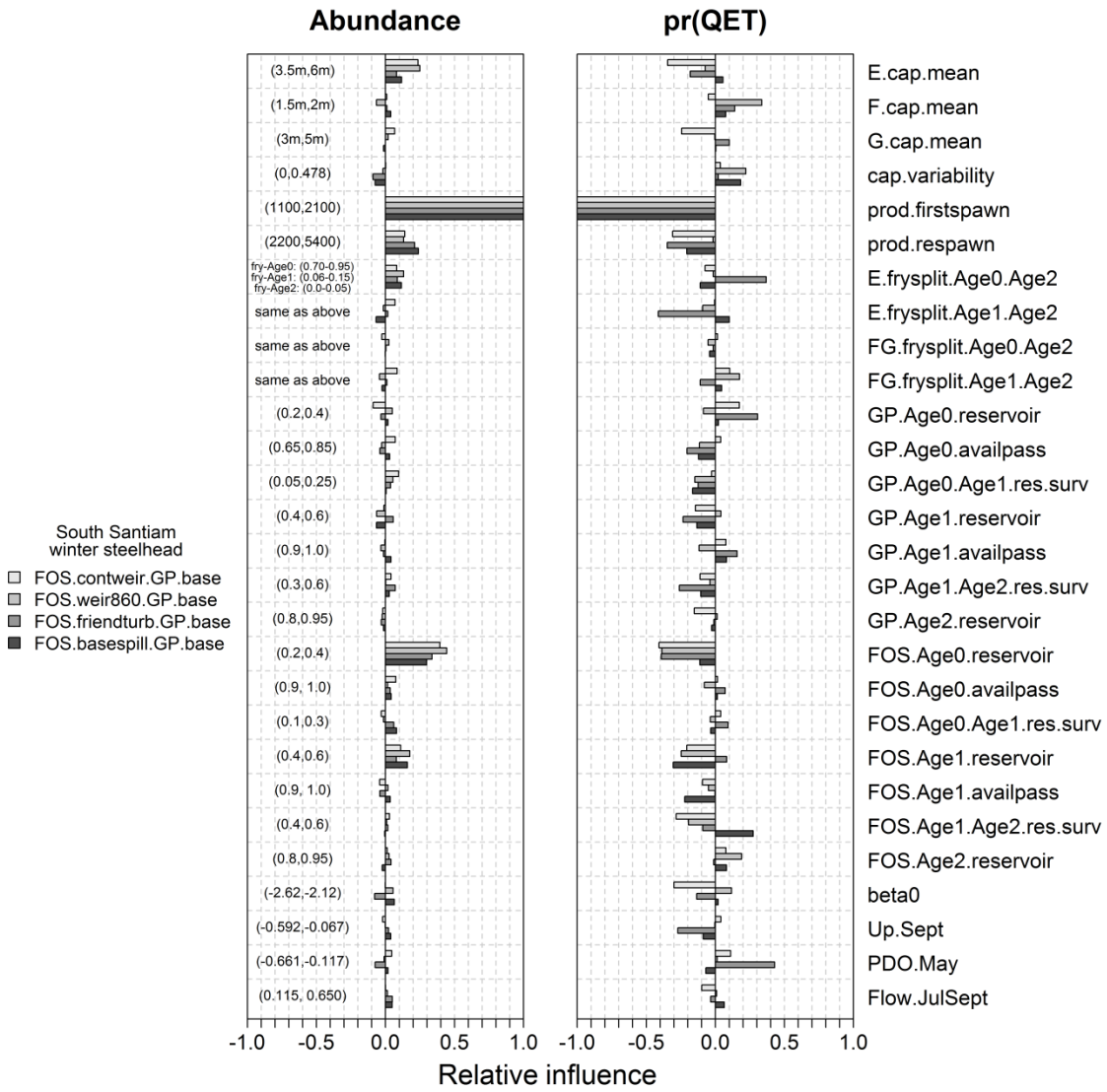


Figure 10.13: Sensitivity analysis of the South Santiam winter steelhead life cycle model for a range of alternatives: FD.contweir.GP.base = Green Peter baseline with continuous weir at Foster Dam; FD.weir860.GP.base = Green Peter baseline with weir at 860 cfs; FD.friendturb.GP.base = Green Peter baseline with a fish friendly turbine at Foster Dam; FD.basespill.GP.base = Green Peter baseline with spill at baseline at Foster Dam. Parameter ranges (Table 10.6) are in parentheses.

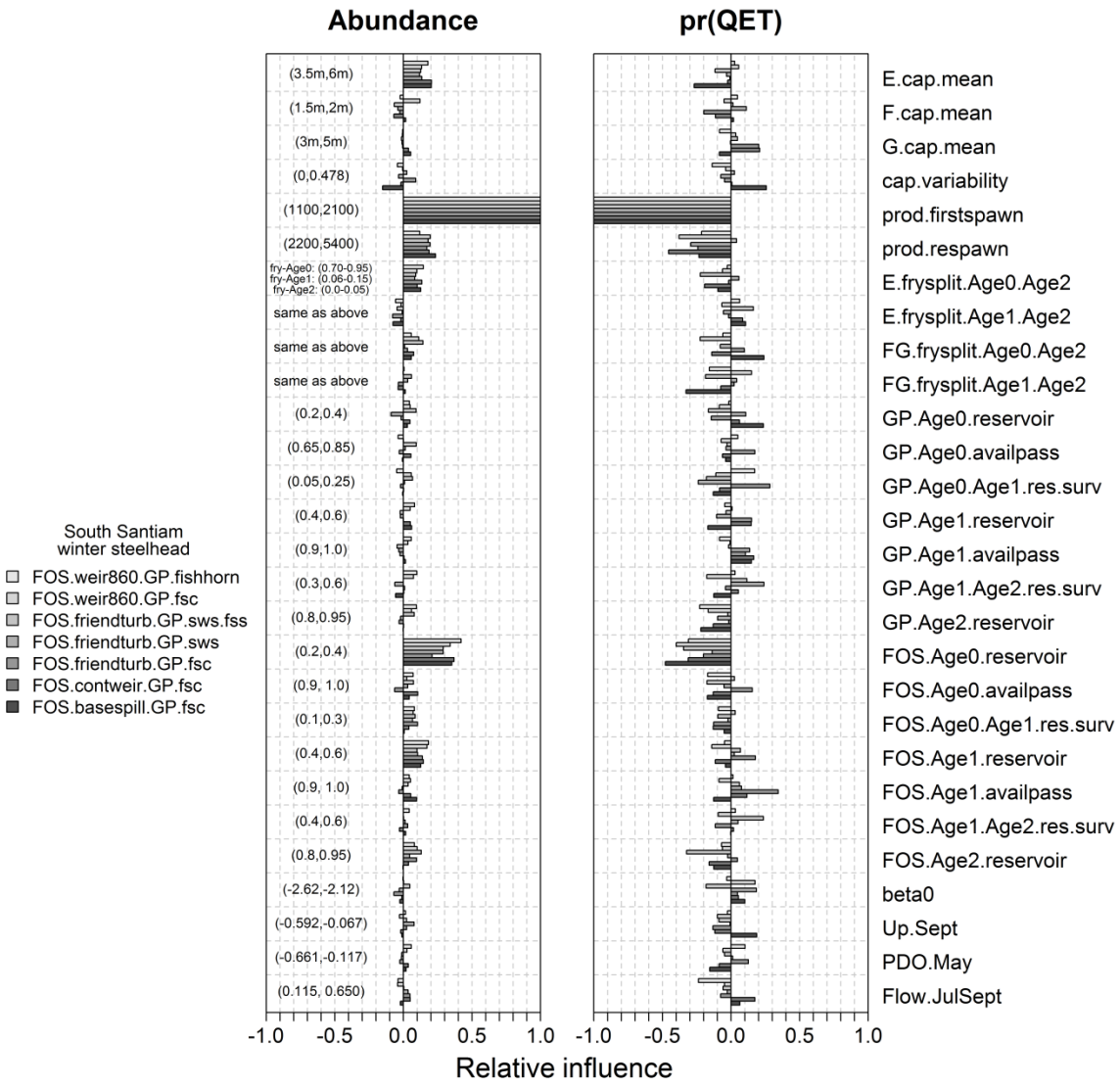


Figure 10.14: Sensitivity analysis of the South Santiam winter steelhead life cycle model for a range of alternatives: FD.weir860.GP.fishhorn = Foster Dam with a weir at 860 cfs and Green Peter Dam fish horns; FD.friendturb.GP.sws.fss = Foster Dam with fish friendly turbines and Green Peter Dam with a selective withdrawal structure and floating screen structure; FD.friendturb.GP.sws = Foster Dam with fish friendly turbines and Green Peter with a selective withdrawal structure; FD.friendturb.GP.fsc = Foster Dam with fish friendly turbine and Green Peter Dam with a floating surface collector; FD.contweir.GP.fsc = Foster Dam with continuous weir and Green Peter Dam with a floating surface collector; FD.basespill.GP.fsc = Foster Dam baseline with spill and Green Peter Dam with floating surface collector. Parameter ranges (Table 10.6) are in parentheses.

Similar to the North Santiam winter steelhead life cycle model, parameters exerted conflicting influence on pr(QET) across the alternatives evaluated. It should be noted that extinction risk as estimated by the South Santiam life cycle model was relatively low across the alternatives evaluated, thus those parameters with some relative deleterious influence on pr(QET) in a few alternatives were identified in a context where extinction events were rare. Fry splits, reservoir survivals, and some of the estuary and early ocean parameters frequently had alternating influence on pr(QET) (Figures 10.10 – 10.12).

10.7. References

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