Abundance, Distribution, Diversity and Survival of Adult Spring Chinook Salmon in the Upper Willamette River: 2015 and 2016

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Contents

List of Tables

List of Figures

Section 1: Introduction

The National Marine Fisheries Service (NMFS) listed spring Chinook salmon *Oncorhynchus tshawytscha* and winter steelhead *O. mykiss* in the upper Willamette River Evolutionarily Significant Unit (ESU) as threatened under the Endangered Species Act (ESA; NMFS 1999a; NMFS 1999b). As a result, any actions taken or funded by a federal agency in the ESU must be evaluated to assess whether they are likely to jeopardize threatened and endangered species, or result in the destruction or impairment of critical habitat. Several hatcheries produce and release hatchery salmonids in the upper Willamette Basin (Figure 1), which may impact wild populations of listed species. All hatcheries are operated by the Oregon Department of Fish and Wildlife (ODFW) and are funded (50–100%) by the U.S. Army Corps of Engineers (USACE) with ODFW funding up to 50%.

The 2011 Recovery plan identifies impaired productivity and diversity due to hatchery fish interbreeding with wild fish on the spawning grounds as a limiting factor for spring Chinook and winter steelhead in the North and South Santiam, and competition from hatchery summer steelhead is an additional limiting factor for recovery of winter steelhead in the North and South Santiam. Potential risks of artificial propagation programs have been widely debated (e.g. Kostow and Zhou 2006; Levin and Williams 2002). Risks include disease transfer, competition for food and spawning sites, increased predation, increased incidental mortality from harvest, loss of genetic variability, genetic drift, and domestication (Steward and Bjornn 1990; Hard et al. 1992; Cuenco et al. 1993; Busack and Currens 1995, and Waples 1999). Hatcheries can also bolster spawner abundance—a critical consideration for those populations on the verge of extirpation—by providing a genetic reserve, and by providing marine-derived nutrients to streams (Steward and Bjornn 1990; Cuenco et al. 1993). Recent work, however, has shown that some hatchery fish tend to have lower reproductive success than wild fish even when broodstocks are largely comprised of wild fish (Araki et al. 2007) and productivity parameters are depressed when large numbers of hatchery salmonids mix with wild fish (Chilcote et al. 2012). However, reproductive success studies focused specifically on spring Chinook salmon yielded conflicting results with some suggesting lower reproductive success for hatchery

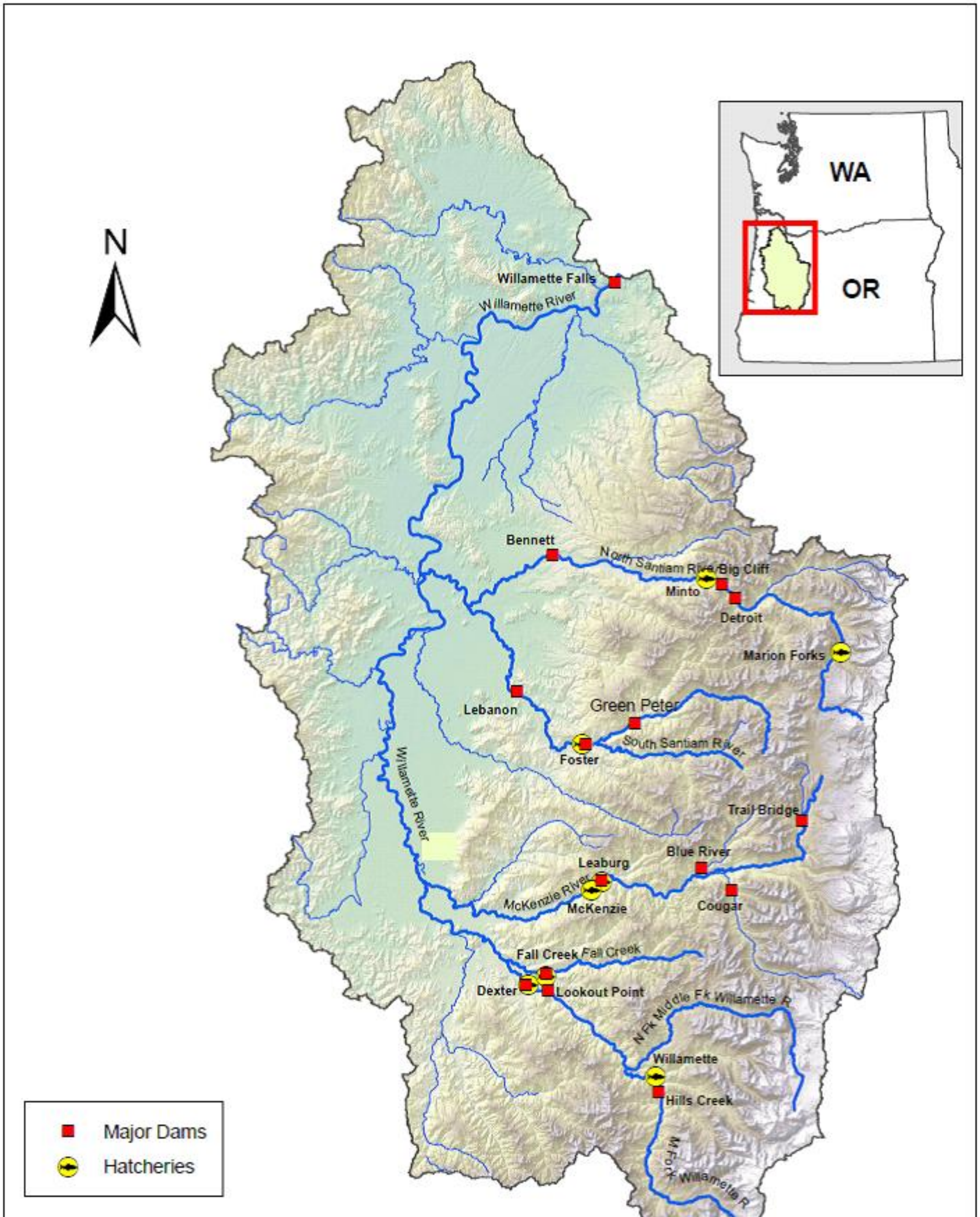

Figure 1. The Willamette Basin with major dams, hatcheries, and fish collection facilities.

Chinook salmon (Williamson et al. 2010), especially males (Sard et al. 2015), and others showing little difference between hatchery- and natural-origin fish (Hess et al. 2012).

The objective of this project is to conduct baseline monitoring of returning adult fish and to evaluate the potential effects of hatchery programs on naturally spawning populations of spring Chinook salmon and winter steelhead in the upper Willamette River basin. Restoration of spring Chinook salmon under the ESA and the implementation of ODFW's Native Fish Conservation Policy require monitoring the number of hatchery and wild fish that comprise the spawning populations in the Willamette Basin. The Willamette Project Biological Opinion identified the need to reduce hatchery fish spawning in the wild to "the lowest extent possible (0–10%)" (NOAA 2008).

In the Willamette Basin upstream of Willamette Falls (Figure 1), there are four distinct spring Chinook salmon hatchery programs (North Santiam [Stock 21], South Santiam [Stock 24], McKenzie [Stock 23], and Middle Fork Willamette [Stock 22]) that are managed as integrated programs meant to provide ESA conservation benefits, and to help meet harvest objectives consistent with survival and recovery of the Upper Willamette River Evolutionary Significant Unit (ESU).· Hatchery stocks, as well as all naturally-spawned spring Chinook salmon in the Upper Willamette Basin, are included in the ESU.

The Upper Willamette Summer Steelhead Hatchery Program is managed to provide fish for sport fisheries and to replace loss of fisheries caused by habitat and passage loss/degradation in the Willamette Basin and other lower Columbia River basins. The hatchery program currently includes annual smolt releases into the North Santiam, South Santiam, McKenzie, and Middle Fork Willamette rivers. Lack of access to historical habitat and degradation of remaining habitat below the dams, especially in the North and South Santiam (the "core" populations) are the key limiting factors shared between winter steelhead and spring Chinook salmon (NOAA/NMFS 2008). In addition, summer steelhead are not native to the Willamette Basin upstream of Willamette Falls and a third, unique, limiting factor is the potential for competition, predation and genetic introgression from out-of-ESU hatchery fish interacting with and spawning in the wild with the native winter-run (ODFW/NMFS 2011). Summer steelhead were first introduced to the South Santiam River to mitigate for lost winter steelhead production in areas inundated by

Foster and Green Peter reservoirs. The scope of work actually directed towards evaluating risks posed by summer steelhead is much smaller than that directed towards issues faced by spring Chinook. In particular, while some abundance data are available given the existing video monitoring at Willamette Falls and both Bennett dams in the North Santiam basin, fine-scale information on spawner abundance and distribution throughout the DPS is not.

Some work that has occurred focused upon interactions between hatchery- and natural-origin steelhead in the upper Willamette. For example, genetic analyses on steelhead describing genetic structure in the upper Willamette (Van Doornik and Teel 2012) and levels of introgression between summer- and winter-run steelhead (Johnson et al. 2015; Van Doornik et al. 2015) have occurred. McMichael et al. (2013) conducted research on ecological interactions between winter- and summer-run steelhead in the South Santiam subbasin. Jepson et al. (2015) described migration patterns of adult winter- and summer-run steelhead from Willamette Falls (Oregon City) to their final destinations and used those data to estimate run size, spatial overlap, and temporal overlap in natal streams in the Upper Willamette.

Other steelhead work focused on the potential for reintroduction of steelhead above project dams. For example, Beeman and Adams (2015) used active tagging to study downstream passage of juvenile steelhead in the North Santiam subbasin and Hughes et al. (2016) performed similar work in the South Santiam subbasin. Johnson et al. (2016) used passive tagging to evaluate steelhead passage from releases above and below Detroit Reservoir. Romer et al. (2016) reported on juvenile steelhead migration into and out of Willamette reservoirs. Finally, Noakes et al. (2015) have developed procedures for rearing wild-broodstock steelhead that seems likely to contribute to using the hatchery programs to reintroduce steelhead above, in particular, Detroit Dam in the North Santiam.

This report fulfills requirements under Task Orders W9127N-12-2-0004-4009 and W9127N-10-2-0008-0036 covering activities of May 2015–September 2017, that were implemented by ODFW on behalf of the Corps to assist with meeting requirements of the reasonable and prudent alternatives (RPAs) and measures prescribed in the Willamette Project Biological Opinion (BiOp) of July 2008 (NOAA/NMFS 2008). The Corps provided funding to continue ongoing monitoring activities and initiate long-term planning. The conceptual relationship between spring

Chinook salmon prioritized objectives (Peven and Keefe 2010), RPAs, and work tasks is depicted in Figure 2. The conceptual framework provided in Figure 2 combines objectives for monitoring compliance with BiOp RPA's that can be broadly categorized as belonging to either mitigation goals or conservation goals. Mitigation goals relate to characteristics of the hatchery programs such as species, numbers, size, location, and timing of fish released from hatcheries as well as harvest rates for returning adults. Conservation goals relate to, especially, undesirable escapement of hatchery-origin fish into natural spawning areas as well as intentional transport of natural- and hatchery-origin fish into (usually) spawning areas blocked by high-head dams. The conservation goals associated with escapement of hatchery-origin adults relate to primarily increasing natural origin abundance through outplanting, while minimizing genetic risks posed by the hatchery programs and, secondarily, potential but poorly understood ecological risks such as density-dependent disease risks to wild fish. Also, while harvest rates are clearly associated with mitigation goals, the existence of active fisheries with comingled natural- and hatchery-origin fish means some natural-origin fish will die from hook-and-release mortality, an issue better related to conservation concerns. Additional conservation issues are associated with potential ecological interactions between juvenile natural- and hatchery-origin fish. Research into ecological interactions at juvenile life history stages is not specifically part of the existing monitoring program but the issue is discussed as part of the long-term planning efforts noted above. Appendix 1 provides material on the various metrics associated with conservation and mitigation goals.

The ultimate goal of ODFW's Hatchery Research, Monitoring and Evaluation (HRME) program is to inform decisions on operation of the USACE Willamette Valley Hatchery Mitigation Program so that mitigation goals are met while minimizing negative impacts on naturally-produced, listed species, thereby promoting their conservation and recovery. Progress towards the ultimate goal will follow achievement of three overarching objectives:

1. Develop and maintain hatchery broodstocks to meet harvest goals and assist with implementation of the Upper Willamette Conservation and Recovery Plan for Chinook Salmon and Steelhead, while complying with the existing genetic guidelines (Hatchery Genetic Management Plans);

2. Rear and release high quality hatchery fish to minimize impacts on naturally-produced fish and promote conservation and recovery of listed species;

3. Manage adult returns to minimize impacts on naturally-produced populations and to aid in recovery goals.

Additional work supported by the hatchery program relates specifically to reintroduction of adult salmonids above projects. The objectives for that work are to:

1. Provide information on spawning distribution, abundance, origin (hatchery vs. wild), and pre-spawning mortality for adult Chinook salmon upstream of Detroit, Foster, Cougar, Fall Creek, Lookout Point and Hills Creek reservoirs. We will summarize adult Chinook and steelhead annual abundance for hatchery and natural origin returns for each population of concern, based on results from the carcass and redd surveys, adult trap counts, video counts, and other data as they become available (e.g. radiotelemetry, genetic sampling, etc.). This objective is intended to achieve the basic evaluation needs associated with a number of project concepts to "determine the effects of release date, outplanting site, and handling and transport protocols" on reproductive performance of outplanted Chinook above projects dams. Importantly, achieving this objective will also inform the ongoing and proposed work associated with direct measurement of reproductive fitness based on an adult to adult pedigree approach.

2. Use the data acquired under Objective 1 in combination with results from other ongoing and proposed work to assess relationships among characteristics of the spawning population and other relevant variables and to provide recommendations for conducting outplanting operations to support spawning success and use of quality habitat by spawners. This objective is intended to contribute to achieving APH-09-04 SYS-2, i.e. "provide recommendations on management of adult UWR Chinook."

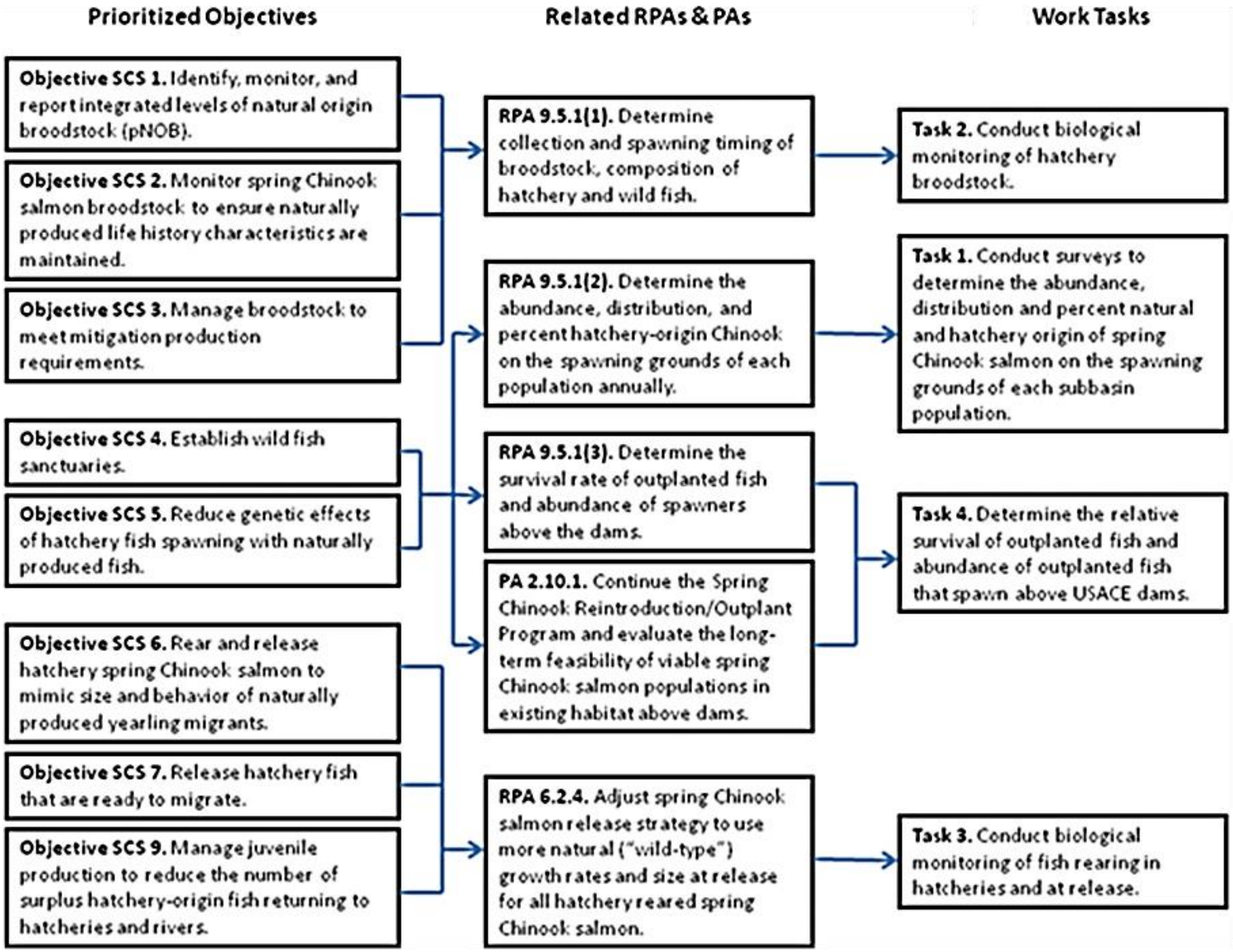

Figure 2. Relationship between Prioritized Objectives, Reasonable and Prudent Alternatives (RPAs), Proposed Actions (PAs), and Work Tasks conducted for spring Chinook hatchery programs in the Upper Willamette Basin.

Section 1.1 Tasks

Task 1. Conduct surveys to determine the abundance, distribution and origin (hatchery or naturally produced) of spring Chinook salmon on the spawning grounds of each subbasin population (objectives addressed: SCS 4 and SCS 5).

The purpose of this task is to describe the abundance, distribution, and composition (i.e., hatchery vs. natural origin fish) of adult spring Chinook salmon returning to spawn in Upper Willamette Basin tributaries. This task aims to describe, at varying spatial scales (Appendix 2), the population of adult returns with respect to: run size and timing, numbers of natural and hatchery origin fish collected for broodstock and outplanting, peak spawning dates, redd distribution and density, estimated natural spawner abundance, the proportion of hatchery origin fish on spawning grounds (pHOS), pre-spawning mortality (PSM) on spawning grounds, the age structure of the natural spawning population, hatchery stray rates, and harvest rates. To accomplish this, we employed a variety of data collection methods, such as monitoring the number of adipose fin-clipped and unclipped adults arriving at dams and fish collection facilities, tracking the fate and disposition of fish entering traps and transported to hatcheries, conducting redd and carcass surveys on spawning grounds, sampling carcasses that were spawned at hatcheries, and compiling fish recapture data from the Regional Mark Information System (RMIS) and the ODFW CWT release and recovery database (CWT-Fish). Ultimately, the intent is to determine if mitigation goals have been met for harvest, broodstock, and conservation (reintroduction/outplanting). Establishing useful numeric goals for abundance and disposition of returning hatchery adults, goals that are agreed upon by the managers and Action Agencies, is an important process that is ongoing.

The spawning ground surveys conducted as part of Task 1 are aimed at characterizing the naturally-spawning population in accessible stream reaches downstream of USACE dams. Similar spawning ground surveys were conducted above these dams as well but are included under Task 4 as described below. This separation has been made to specifically monitor and evaluate outplanting efforts in stream reaches blocked by dams and the potential of these reaches to serve for reintroduction purposes and as sanctuaries for wild fish populations. Comparisons of estimated spawning population parameters (e.g., peak redd counts, redd densities, pHOS, and PSM) between spawning areas downstream and upstream of USACE dams are a useful tool for identifying reaches with relatively greater habitat potential and for evaluating hatchery management practices. Such comparisons are also addressed under Task 4.

Task 2. Conduct biological monitoring of hatchery broodstock (objectives addressed: SCS 1, SCS 2, and SCS 3).

The purpose of this task is to obtain estimates of origin (hatchery, wild, strays), body size, age structure, run timing, and spawn timing of hatchery broodstock. The intent is to ensure that broodstock collected and spawned in each hatchery program adequately meet mitigation, conservation, and recovery goals, and comply with existing guidelines being developed in each Hatchery Genetic Management Plan (HGMP).

Task 3. Conduct biological monitoring of fish rearing in hatcheries and at release (objectives addressed: SCS 6, SCS 7, and SCS 9).

This task involves monitoring of fish performance both in-hatchery (survival, growth) and post-release (migratory performance; smolt-adult return [SAR]) and includes monitoring of timing and number of juveniles released by species and stock for each hatchery.

Task 4. Estimate the relative survival of outplanted fish and abundance of outplanted fish that spawn above USACE dams (objectives addressed: SCS 4 and SCS 5).

The purpose of this task is to monitor and evaluate outplanting efforts in each of the four major Upper Willamette River subbasins. As mentioned above, the components of this task include: conducting spawning ground surveys in reaches where fish have been outplanted; collecting data on spawning population parameters (e.g., peak redd counts, redd densities, pHOS, and PSM); and analysis of spawning population parameters at varying spatial scales (Appendix 2). In addition, genetic sampling of outplanted fish is conducted in support of ongoing parentage studies at several projects, and a study on the genetic diversity of the Willamette spring Chinook salmon populations (Johnson and Friesen 2014).

It is very clear that monitoring the performance and fate of NORs passed above high head dams is a priority. However, even when only HORs are passed, it seems likely that monitoring their performance and fate will ultimately inform how and when NORs might be passed where that is not already occurring (South Santiam and Fall Creek).

Section 1.2 Spring Chinook Salmon Production Program Goals

Section 1.2.1: Broodstock Collection and pNOB Goals

The intent of broodstock collection protocols at the UWR hatcheries is to sequester enough broodstock to ensure enough adults to support all mitigation and conservation requirements (e.g. harvestable fish, broodstock for the next generation, fish for outplanting, etc.) while also ensuring that the fish taken for broodstock are phenotypically similar to naturally-produced fish (e.g. run timing, spawn timing, age structure, etc.).

Adult collection began in May and occurred into October at all facilities. Collection protocols varied by hatchery program. In the North Santiam subbasin, broodstock were collected at the Minto Fish Collection Facility. In the South Santiam subbasin collection occurred at the Foster Fish Collection Facility. In the McKenzie subbasin hatchery fish volunteered to the ladder on site at the hatchery. In the Middle Fork Willamette subbasin fish were captured at the Dexter Dam trap and transported by truck to the Willamette Hatchery further upstream. At capture adults are generally anesthetized with CO_2 or Aqui-S to facilitate handling.

Spawning protocols were relatively uniform across hatcheries whereby adults were crowded, anesthetized, and checked for ripeness. Unripe fish were returned to holding areas and ripe fish were killed and bled. Eggs were removed from females into spawning buckets and fertilized using a 1:1 sex ratio.

Once the subbasin HGMP's are approved (anticipated spring 2018), incorporation of natural-origin fish into the broodstocks will occur at 5% or more per year.

Section 1.2.2: Outplanting and pHOS Protocols and Goals

Outplanting protocols varied widely throughout the subbasins. When the outplant goal is focused on disposition of hatchery-origin fish (as in the North Santiam and Middle Fork Willamette subbasins), outplanting generally begins relatively early in the run when it becomes apparent that the run size will be adequate to provide sufficient broodstock, and ends late. Exceptions exist at the McKenzie Hatchery and Dexter Trap when ongoing research projects require outplants at specific times either to test a particular practice (Dexter trap: early outplants) or to achieve specific escapement goals (McKenzie Hatchery: outplanting above Cougar Dam). When outplanting is focused upon the disposition of unclipped fish (South Santiam River, Fall Creek and, ideally, the Cougar Dam trap in the South Fork McKenzie River) then outplanting begins and ends with the capture of the first and last unclipped adult fish.

In the North Santiam River outplanted fish (hatchery-origin, predominantly) were captured at Minto and trucked to the Breitenbush and North Santiam arms of Detroit Reservoir. On the South Santiam River only unclipped fish captured at the Foster Dam trap were outplanted at locations ranging from near the head of reservoir to multiple locations further upstream. On the McKenzie River outplants from the McKenzie Hatchery were exclusively adipose-clipped fish taken to the South Fork McKenzie River to complement mostly unclipped fish transported from the Cougar Dam adult trap in support of a research project evaluating productivity of hatchery- and natural-origin spawners (Banks et al. 2014). Outplanting in the Middle Fork Willamette subbasin includes releases at several locations. Adult fish from Dexter Dam trap are outplanted into the Middle Fork Willamette above Hills Creek Dam to support recovery efforts for bull trout *Salvelinus confluentus*, and into Little Fall Creek, a tributary entering Fall Creek and the Middle Fork Willamette River below Dexter Dam. Adults from both the Dexter trap and Willamette Hatchery are also outplanted in the North Fork Middle Fork Willamette River above Lookout Point Reservoir in various locations to support ongoing research into causes of prespawning mortality (Schreck et al. 2014; Mann et al. 2012). Finally, natural-origin adult Spring Chinook and other native fish species captured at the Fall Creek Dam trap are outplanted by USACE biologists above Fall Creek Reservoir and ODFW conducts spawning ground surveys to continue collaborative recovery efforts there.

Section 1.2.3: Marking and Tagging of Hatchery Chinook Salmon

Adult hatchery fish are identified using a combination of marks that were applied to the juveniles prior to release. All hatchery-origin Chinook salmon receive adipose fin clips and a secondary thermal otolith mark. In addition, a portion of the juvenile hatchery Chinook salmon are released with coded-wire tags (CWTs). Specific information on CWT releases from RMIS is available online at http://www.rmpc.org/. On average, 687,000 CWT spring Chinook salmon are released into the basin annually (Shaun Clements, ODFW, pers. comm.) with more than 100,000 tagged fish typically released from each hatchery.

Section 1.3 Willamette River Escapement

Escapement estimates are obtained by a combination of video counts and spawning ground surveys. Counts of clipped and unclipped Chinook salmon and steelhead trout (and other species) are obtained as fish enter the Upper Willamette River (at Willamette Falls) and at two other locations in subbasins (Bennett dams on the North Santiam River, and Leaburg Dam on the McKenzie River).

Section 2: Methods

Section 2.1 Estimating Spawner Parameters: Distribution, Abundance, and Proportion of Hatchery- and Natural-Origin Chinook Salmon

Section 2.1.1: Monitoring Adult Returns

The majority of the spring Chinook salmon adults that pass Willamette Falls enter the North Santiam, South Santiam, McKenzie, and Middle Fork Willamette subbasins to spawn. Returns specific to each subbasin were monitored through spawning surveys and at fish ladders or collection facilities in each of these four subbasins. Depending on management objectives for each of the subbasin hatchery programs, fish captured at collection facilities were retained for broodstock, outplanted above USACE dams, recycled downstream for additional angling opportunities, sold to offset costs of fish transport, donated to tribes, or used for stream enrichment.

2.1.1.1 Spawner Surveys: We surveyed four major eastside tributaries (North Santiam, South Santiam, McKenzie, and Middle Fork Willamette rivers) in the Willamette Basin upstream of Willamette Falls (Figure 1) by boat and on foot to count spring Chinook salmon carcasses and redds following established protocols (Boydstun and McDonald 2005; Schroeder et al. 2007; Gallagher et al. 2007; Kenaston et al. 2009; Cannon et al. 2010). We counted redds from late August through October to encompass the peak times of spawning based on data from surveys conducted in past years. Detailed maps of the subbasins are provided in the Results section and descriptions of the reaches are provided in Appendix 3.

For boat surveys we used rafts with elevated viewing towers on large river sections. On some river sections the raft stayed on one side of the river (with the other bank covered simultaneously with another raft or on subsequent surveys) over the entire length of the section to count redds, whereas on other sections the raft crossed the river to count redds on both sides. Similar techniques were used on medium-sized rivers except that we used small rafts with viewing platforms lacking elevated towers. In tributary reaches that were inaccessible to walking surveys we used inflatable kayaks. All boat surveys were conducted in a downstream direction except that a small number of reaches required paddling or rowing upstream a short distance (<100 m) when the only boat launch site was below a reach break that could not be safely passed.

For walking surveys, a stream was classified as "medium" if the surveyor had to cross the stream to observe areas on the other side, or "small" if the surveyor could observe both sides of the stream without crossing (Schroeder et al. 2005). Observers counted redds and attempted to record global positioning system (GPS) coordinates for each redd in a river section. If a GPS signal could not be obtained at a particular location, the redd was still counted. All walking surveys were conducted in a downstream direction except in a few instances when a surveyor completed a section and had the opportunity to assist a partner in a reach by surveying upstream.

2.1.1.2 Carcass Sampling*:* During spawning surveys all carcasses that could be recovered by hand or with long-handled gaffs were examined for adipose fin clips to determine the proportion of hatchery fish on spawning grounds. We measured carcasses (cm fork length; FL), determined sex, and estimated the proportion of remaining eggs in female fish to document pre-spawning mortality (details in section 2.1.2.5, below). Carcasses in water too deep to permit recovery or too degraded to permit inspection were recorded as unprocessable. We collected otoliths from processable carcasses without fin-clips to differentiate unclipped hatchery fish from naturally-produced fish using results from otolith analyses performed by the Washington Department of Fish and Wildlife Otolith Laboratory (*see Proportion of Hatchery Spawners,* below). We used hand-held detectors manufactured by Northwest Marine Technology, Inc. (Tumwater, WA) to determine if carcasses with or without adipose fin clips had CWTs. Fish with CWTs and without fin clips might simply be mis-clipped fish, fish with regenerated adipose fins, or fish from "double-index release groups" (intentionally released without a fin clip for fishery management purposes). We collected the snouts of tagged fish and put them in plastic bags with individually numbered labels. Tags were removed and identified at the ODFW Clackamas Fish Identification Laboratory to establish the origin of tagged fish.

2.1.1.3 Monitoring Fish Passage at Bennett and Leaburg Dams*:* We used underwater video cameras to monitor net upstream movement of salmon, steelhead and other fish species through ladders at the Bennett dams on the North Santiam River and Leaburg Dam on the McKenzie River (Figure 1). The video equipment uses software (FishTick, SalmonSoft, Inc., Portland, OR) that automatically scans and records fish movement and creates video files from these images. The captured video images were reviewed and species, presence or absence of an adipose fin clip, direction of movement (upstream or downstream) were noted so that the net upstream movement of spring Chinook salmon and steelhead trout by presumed hatchery or wild origin could be estimated. Other fish including coho salmon *O. kisutch*, lamprey *Entophenus* and *Lampetra* spp., and bull trout were also counted. Counts of clipped and unclipped Chinook salmon were later adjusted using otolith data to get estimates of actual hatchery- and natural-origin fish above the counting stations. We attempted to operate the video systems continuously throughout the migration season. On the rare occasions when a video system failed we estimated the number of fish that may have passed during these outages based on simple linear extrapolation of fish counts recorded during the time when the video equipment was operating normally, generally on the same day.

2.1.1.3.1 Video Monitoring at Bennett Dams: Passage of spring Chinook salmon (and other species) occurred at both Upper and Lower Bennett dams. The video monitoring system at upper Bennett Dam operated continuously and, at Lower Bennett Dam, the system operated from April through December in both 2015 and 2016. Calibration of counts at the Bennett dams to account for fallback (decreasing apparent abundance upstream) or fallback followed by re-ascension (increasing apparent abundance) has not occurred but because of work performed at Leaburg Dam (described below) we think that the video records are reasonably accurate indices of upstream migration of anadromous salmonids.

2.1.1.3.2 Video Monitoring at Leaburg Dam: Passage of spring Chinook salmon through the two fishways at Leaburg Dam was continuously monitored with video recording equipment. We recorded fish passage at both the left-bank and right-bank fish ladders. Comparisons of estimated numbers of spawners based on redd count expansion to numbers of fish counted at Leaburg dam are in most years in very close agreement (see Figure 6, for example).

2.1.1.4 Monitoring Harvest*:* Harvest estimates were obtained by summarizing ODFW online harvest reports available at http://www.dfw.state.or.us/resources/fishing/sportcatch.asp .

Section 2.1.2: Data Analysis

2.1.2.1 Peak Redd Counts and Peak Redd Densities*:* The peak redd count is the maximum number of redds observed in each survey section over the course of the survey season and represents an estimate of the total number of redds constructed by Chinook salmon in each section. When redd counts differed between initial surveys and resurveys conducted to evaluate variability in redd counts (described below), the resurvey counts were used to replace the initial counts. Peak redd densities were calculated by dividing the peak redd count by the length (km) of each section.

2.1.2.2 Spawn Timing*:* We compared spawn timing of naturally-spawning fish and broodstock spawned in the hatcheries. The intent of the work was to determine if the spawn timing in the hatchery differed from the average spawn timing in the river in recent years. We estimated peak spawning of naturally spawning fish by fitting a sigmoid curve to the cumulative redd counts over time for multiple years in each subbasin. The date associated with the inflection point on the fitted sigmoid curve was assumed to represent the average date of the maximum rate of redd construction in each subbasin; that is, average peak spawn timing. We then compared the average spawn timing in the rivers to the spawn timing in the hatcheries. Average spawn timing in the hatcheries was calculated as the weighted mean date of spawning, weighted by the number of broodstock spawned on each spawn date.

2.1.2.3 Spawner Abundance Estimates*:* We used the peak count expansion method described below to estimate total spawner abundance. We made the three following assumptions: 1) that the peak redd count in any reach of interest adequately reflected the relative abundance of fish that spawned in that reach; 2) each redd was constructed by one female; and 3) each female spawned with 1.5 males (Gallagher et al. 2007; Boydstun and McDonald 2005).

A spawner abundance estimate (A) derived from the peak count expansion method was calculated by the following equations:

$A = F_{spawn} + M_{spawn}$, where

F_{spawn} = number of spawning females = $Redd_{peak}/Redd_{female}$;

$Redd_{peak}$ = peak redd count, and $Redd_{female}$ = number of redds/spawning female = 1, and

M_{spawn} = number of spawning males = $F_{spawn} \times 1.5$.

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We then parsed the total spawner abundance estimate into hatchery and wild spawning cohorts by using the pHOS estimates derived from carcass sampling with adjustments based upon otolith analyses. Clearly there is a large effect that this string of assumptions has on the accuracy of the estimates of spawner abundance, and there are no estimates of precision associated with redd count expansions. The values for spawner abundance and redd count expansion should therefore be used with caution.

***2.1.2.4 Proportion of Hatchery Spawners**:* We combined counts of clipped and unclipped fish wherever they were encountered (at video counting stations, during spawner surveys, and during monitoring of adult fish entering hatchery traps) with validation of hatchery or wild origin from otolith data to derive the proportion of hatchery spawners (pHOS) at various spatial scales. The spatial scales included basin-wide, by subbasin, above and below dams, and, in some cases, by river reach. To differentiate between hatchery and wild Chinook salmon and to implement a selective fishery, all hatchery spring Chinook salmon in the Willamette basin, beginning with the 1997 brood year, have been marked with adipose fin clips, CWTs, or both. Also, thermal marks were (and are) induced in the otoliths of all hatchery Chinook salmon released in the basin to provide an additional mark for identifying unclipped hatchery fish. Some juvenile Chinook salmon are inadvertently released without a fin clip at a rate that varies by hatchery and by brood year (Schroeder et al. 2005). However, the percentage of unclipped fish in hatchery releases has decreased in recent years with the implementation of automated fin-clipping systems. Other factors that contribute to the return of unclipped hatchery fish include the release of unclipped hatchery fish with CWTs (double-index), and natural regeneration of partially clipped adipose fins.

We estimated the proportion of natural-origin (wild) and hatchery-origin fish by adjusting counts of clipped and unclipped carcasses after examining otoliths collected from the unclipped carcasses recovered on the spawning grounds. We collected samples from adult spring Chinook salmon carcasses without fin clips on spawning grounds (North and South Santiam, McKenzie, and Middle Fork Willamette rivers). Otoliths were collected and placed into individually numbered vials. The samples were subsequently sent to the otolith laboratory operated by Washington Department of Fish and Wildlife for analysis of thermal marks. The reach-specific proportion of hatchery origin spawners (pHOS) was derived from the counts of fin-clipped fish (AD), unclipped thermally-marked fish (UTM) and total count of fish examined (TOT) using the equation:

pHOS = [AD + UTM]/TOT).

The reach-specific pHOS estimates were then applied to the reach-specific spawner abundance estimates and the products summed to yield subbasin-wide pHOS estimates weighted by spawner abundance (reach-specific redd counts).

In future years, after HGMPs are approved and natural-origin fish can be incorporated into brood, we will also use the otoliths to adjust estimates of the proportion of natural-origin brood (pNOB) by using the counts of non-thermally-marked unclipped broodstock ($WILD_B$), and the total number of broodstock (TOT_B) using the following equation:

$pNOB = WILD_B/TOT_B$.

2.1.2.5 Pre-spawning Mortality*:* We surveyed major tributaries of the Willamette basin, both above and below project dams, by boat and on foot to estimate pre-spawning mortality (PSM) based on the proportion of unspawned female salmon carcasses observed. Female carcasses with intact or relatively intact skeins (i.e. greater than 50% eggs remaining) were considered unspawned. The 50% threshold is arbitrary but in practical terms virtually all female carcasses had either essentially no eggs remaining or completely intact skeins. The surveys were conducted in a manner identical to the spawner surveys (described above) but began in the summer prior to any spawning to permit observation of any early mortality that occurred as salmon reached spawning tributaries. Female carcasses were also checked for spawning success during the regular spawning surveys and redd counts through early October so that pre-spawning mortality could be assessed over the entire run. For every female salmon carcass that could be recovered during the pre-spawning and spawning surveys the gut cavity was cut open to visually judge the relative abundance of eggs. We then calculated PSM by dividing the number of unspawned female carcasses by the total number of female carcasses where spawning status was observed. For the purpose of discussion in this document we arbitrarily categorize PSM as “low”, “moderate”, and “high” when estimates were <20%, 20% to 50%, and >50%, respectively.

***2.1.2.6 Straying of Hatchery Fish**:* In the Willamette basin a “stray” is defined as any hatchery fish that does not return to its hatchery of origin and either spawns naturally or is encountered at another hatchery. In addition to estimating pHOS (described above) in each subbasin we estimated the contribution to pHOS of strays from outside the subbasin into which the juveniles were originally released.

We used handheld tag detectors to check for CWTs in carcasses recovered during surveys. Snouts were removed from carcasses with CWTs, tagged, bagged, and frozen for later processing. Frozen snouts were delivered to ODFW’s Clackamas Fish Identification Laboratory, where the wire was extracted and decimal codes read to identify the hatchery stock and release site.

Section 2.2: Reintroduction Efforts

We intercepted salmon designated for outplanting (and broodstock collection, fish sales, fish donation, and stream enrichment) at adult fish traps at the left (south) bank ladder of the Leaburg Dam, Dexter Dam, Foster fish collection facility (FCF) and the Minto FCF. Biological data (fork length, sex, scales, presence of tags or fin clips) and specimens (otoliths [from lethally sampled fish], DNA) were collected. The count of adult fish outplanted above project dams was used as the initial basis for adult abundance above dams, modified by estimates of abundance, PSM, and distribution based on spawner surveys (described below).

We collected biological samples and data (sex, DNA sample, fin clips, date, outplant location) from all Chinook salmon that were outplanted. We subsampled outplanted fish for FL and scales at a rate intended to yield a sample size of approximately 100 fish.

Section 2.3: Broodstock Sampling

2.3.1 Collection, Spawn Timing, Composition, and Disposition of Broodstock: Traps are operated for each of the Willamette spring Chinook salmon hatcheries to collect broodstock.

Chinook salmon are also trapped at Leaburg Dam and Leaburg Hatchery and then transported to McKenzie River Hatchery. Disposition of collected salmon is determined at each hatchery by presence or absence of an adipose fin clip and recorded. At each hatchery on each spawning date samplers recorded number of fish spawned by sex, length of broodstock, and obtained samples from fish as required (scales, otoliths, DNA, CWTs).

Section 2.4: Within-Hatchery Monitoring

2.4.1 Adult Monitoring*:* The bulk of within-hatchery monitoring involved tracking the fate and disposition of adult fish at each hatchery or FCF. The data were acquired by a combination of (1) direct sampling by HRME staff at each hatchery during outplanting and spawning activities, (2) queries of the data provided by the hatchery managers to the Hatchery Management Information System (HMIS), and (3) interviews with the hatchery managers to verify portions of the data that were provided to HMIS.

2.4.2 Juvenile Monitoring*:* We obtained summaries of the number of fish released, rearing locations, release locations and size at release for both summer-run steelhead and Chinook salmon by querying HMIS for those data. We also queried RMIS to obtain information on Chinook salmon liberation dates and release locations for CWT fish from Willamette hatcheries. Steelhead have not been released with CWTs since the 1980s.

Other juvenile monitoring involved compiling hatchery records for size distributions and tag retention data for fish just prior to release.

Section 3: Results

Section 3.1: Abundance, Distribution, Spawn Timing and Composition of Naturally Spawning Adult Spring Chinook Salmon

Section 3.1.1 Adult Returns:

In 2015 the total count of spring Chinook salmon ascending Willamette Falls (Table 1) was 53,088 (51,046 adults and 2,042 jacks). Of the adults, 42,098 were adipose-clipped and 8,948 were unmarked. Of the jacks, 1,561 were adipose-clipped and 481 were unmarked. The run at Willamette Falls was dominated by hatchery returns, with an estimated 82% of the 2015 run originating from Willamette hatcheries based on observed adipose mark rates (available online at http://www.dfw.state.or.us/fish/fish_counts/willamette%20falls.asp).

In 2016 the total count of spring Chinook salmon ascending Willamette Falls (Table 1) was 32,478 (30,317 adults and 2,161 jacks). Of the adults, 23,686 were adipose-clipped and 6,631 were unmarked. Of the jacks, 1,770 were adipose-clipped and 391 were unmarked. The run at Willamette Falls was dominated by hatchery returns, with an estimated 78% of the 2016 run originating from Willamette hatcheries based on observed adipose mark rates (available online at http://www.dfw.state.or.us/fish/fish_counts/willamette%20falls.asp).

Spring Chinook salmon adults and jacks were collected at Upper Willamette Basin facilities beginning in late May or early June at all facilities, and concluding in early September through early October at the North Santiam, South Santiam, McKenzie, and Dexter facilities.

Table 1. Number of fish passing Willamette Falls by month, 2015 (top) and 2016 (bottom). CHS – spring Chinook salmon; STS = summer steelhead; STW = winter steelhead; CHF = fall Chinook salmon; Mk = finmarked (adipose clipped); Nm = non-finmarked; JK = jack.

	CHS				STS		STW		CHF				Coho Salmon			
2015 Month	Adult Mk	Adult Nm	JK Mk	JK Nm	STS Mk	STS Nm	STW Mk	STW Nm	Adult Mk	Adult Nm	JK Mk	JK Nm	Adult Mk	Adult NM	JK Mk	JK Nm
Jan	0	0	0	0	0	0	2	792	0	0	0	0	0	1	0	0
Feb	0	0	0	0	0	0	12	1,351	0	0	0	0	0	0	0	0
Mar	175	71	0	0	137	0	0	1,047	0	0	0	0	0	0	0	0
Apr	14,422	3,018	332	89	430	0	0	750	0	0	0	0	0	0	0	0
May	22,180	4,324	941	302	1,226	0	0	293	0	0	0	0	0	0	0	0
Jun	4,605	1,210	253	75	705	87	0	0	0	0	0	0	0	0	0	0
Jul	563	236	22	9	99	13	0	0	0	0	0	0	0	0	0	0
Aug	153	89	13	6	164	13	0	0	70	53	7	4	3	2	14	0
Sep	0	0	0	0	691	98	0	0	213	1,024	52	400	19	427	45	440
Oct	0	0	0	0	154	71	0	0	23	1,517	11	540	1	1,672	3	373
Nov	0	0	0	0	0	0	18	59	0	1	0	0	0	377	0	36
Dec	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0
Total	42,098	8,948	1,561	481	3,606	282	32	4,292	306	2,595	70	944	23	2,479	62	849

2016 Month	Adult Mk	Adult Nm	JK Mk	JK Nm	STS Mk	STS Nm	STW Mk	STW Nm	Adult Mk	Adult Nm	JK Mk	JK Nm	Adult Mk	Adult NM	JK Mk	JK Nm
Jan	0	0	0	0	0	0	80	1,029	0	0	0	0	0	0	0	0
Feb	2	0	0	0	0	0	144	1,526	0	0	0	0	0	0	0	0
Mar	30	5	0	0	234	0	0	1,388	0	0	0	0	0	0	0	0
Apr	3,150	1,023	47	4	1,175	0	0	895	0	0	0	0	0	0	0	0
May	10,037	2,593	682	150	7,176	0	0	577	0	0	0	0	0	0	0	0
Jun	7,620	2,043	752	159	8,375	332	0	0	0	0	0	0	0	0	0	0
Jul	2,781	833	268	52	3,452	157	0	0	0	0	0	0	0	0	0	0
Aug	66	134	21	26	231	47	0	0	19	25	10	7	1	0	2	0
Sep	0	0	0	0	348	94	0	0	71	661	18	160	12	1,355	23	1,403
Oct	0	0	0	0	59	52	0	0	0	265	0	27	3	1,136	0	520
Nov	0	0	0	0	0	0	5	24	0	0	0	0	1	50	0	43
Dec	0	0	0	0	0	0	0	103	0	0	0	0	0	1	0	0
Total	23,686	6,631	1,770	391	21,050	682	229	5,542	90	951	28	194	17	2,542	25	1,966

Section 3.1.2 Redd Counts, Redd Distribution, and Spawn Timing:

We used a combination of spawning ground surveys, hatchery records, and dam counts to derive indices of spawner density and estimates of run-size and spawner abundance for hatchery- and natural-origin Chinook salmon in the four basins of interest. Redd density data are provided in Table 2. Figures 3 and 4 provide spawner abundance estimates over time based on redd count expansion for surveys below and above dams, respectively. For all years, the pooled reaches are generally bounded by points where some measure of control of fish movement exists, such as at traps or dams. In some cases the pooled reaches represent particular tributary streams where special surveys were conducted (e.g. Little Fall Creek in the Middle Fork Willamette). A description of how survey reaches were pooled for which metrics is presented in Appendix 2.

North Santiam River: In 2015 the North Santiam River was surveyed beginning 6 July and ending 12 November. Spawner escapement and pHOS estimates are presented in Figure 3. Redd construction was first observed August 31. Peak redd counts were obtained between 16 September and 8 October, depending on the particular river reach surveyed. Reach-specific peak redd counts and timing of peak counts are presented in Table 3. As in previous years, redd density below Minto was highest in the section between the Bennett and Minto dams. Within that reach the highest redd counts were observed immediately below Minto Dam in close association with the Minto Fish Collection Facility. The river reach between Minto and Big Cliff dams was surveyed in 2015, but because of river conditions and related safety issues only two surveys were conducted, both near the end of the spawning season. Therefore, while the redd counts are probably useful for inferring spawner abundance in that reach, carcass recoveries do not permit a direct estimate of PSM because no carcasses were recovered early in the season when PSM would likely have occurred. We estimated that for 2008-2014 the average spawn timing in the North Santiam River was September 28 (Figure 5).

In 2016 the North Santiam River was surveyed beginning 6 July and ending 12 October. Spawner escapement and pHOS estimates is presented in Figure 5. Redd construction was first observed August 24. Peak redd counts were obtained between September 18 and October 6, depending on the particular river reach surveyed. Reach-specific peak redd counts and timing are presented in Table 7. As in previous years, redd density below Minto was highest in the section between the Bennett and Minto dams. Within that reach the highest redd counts were observed immediately below Minto Dam in close association with the Minto Fish Collection Facility. The river reach between Minto and Big Cliff dams was surveyed in 2016, but because of river conditions and related safety issues only two surveys were conducted, both near the end of the spawning season. Therefore, while the redd counts are probably useful for inferring spawner abundance in that reach, carcass recoveries do not permit a direct estimate of PSM because no carcasses were recovered early in the season when PSM would likely have occurred. We estimated that for 2008-2014 the average spawn timing in the North Santiam River was 28 September (Figure 5).

South Santiam River: In 2015, the South Santiam River was surveyed beginning 1 July and ending 8 October. Redd construction was first observed September 4, and peak redd counts were obtained between 17 September and 24 September, depending on the particular river reach surveyed (Table 4). As in previous years, the redd density in 2015 was highest in the section between the town of Lebanon and Foster Dam. Within that reach the highest redd densities were observed immediately below Foster Dam, near the South Santiam Hatchery. We estimated that the average spawn timing in the South Santiam River was 23 September (Figure 5).

In 2016, the South Santiam River was surveyed beginning 6 July and ending 11 October. Redd construction was first observed September 6, and peak redd counts were obtained between 13 September and 4 October, depending on the particular river reach surveyed (Table 8). As in previous years, the redd density in 2016 was highest in the section between the town of Lebanon and Foster Dam. Within that reach the highest redd densities were observed immediately adjacent to and below Foster Dam, near the South Santiam Hatchery. We estimated that the average spawn timing in the South Santiam River was 23 September (Figure 5).

Table 2. Current and recent historical redd densities in comparable spawning reaches.

Section	Redds/km														
	2002	2003	2004	2005	2006	2007	2008	2009	2010	2011	2012	2013[a]	2014	2015	2016
Minto to Bennett	6.3	14.9	6.1	5.7	4.8	9.7	2.9	5.2	8.2	12.2	11.9	7.5	11.3	5.2	6.9
Below Bennetts	0.8	0.5	0.8	0.7	0.5	0.5	0.1	0.9	1.5	0.8	0.2	0.0	0.2	0.0	0.1
LNS	1.1	1.2	1.9	2.3	1.4	2.4	3.9	1.0	2.2	2.0	1.7	0.7	0.0	0.8	1.0
Above Detroit	--	--	--	--	--	2.7	--	1.8	8.4	0.4	1.3	4.5	3.3	4.9	8.1
Foster – Pleasant Valley	121.5	82.5	46.9	70.4	64.3	58.1	25.1	59.9	92.6	68.5	60.1	48.9	71.9	56.7	153.6
Pleasant Valley – Waterloo	0.8	1.0	2.1	1.4	2.7	3.9	1.7	3.1	7.0	2.9	0.6	1.0	2.0	1.7	5.5
Lebanon - Mouth	2.3	0.7	0.1	0.0	0.7	--	--	--	0.5	0.1	0.0	--	0.0	0.0	0.0
Above Foster Dam	--	--	--	--	--	4.8	4.1	2.6	4.6	7.1	6.8	2.9	1.9	5.3	4.9
Below Leaburg Dam	12.0	17.8	10.3	7.8	7.5	14.7	24.5	17.4	27.4	22.9	25.7	7.8	19.5	15.6	18.8
Leaburg - SF McKenzie	8.0	10.2	9.7	4.3	3.9	11.1	5.4	4.8	12.1	10.6	6.1	3.5	7.6	12.6	11.5
S. Fork below Cougar Dam	16.5	13.0	21.6	13.1	13.0	24.1	12.8	10.4	7.9	14.6	10.2	5.5	9.1	10.1	14.5
S. Fork above Cougar Dam	--	--	--	--	--	--	--	--	6.8	8.4	8.9	5.2	8.8	4.9	10.5
Above S. Fork Confluence	9.3	10.1	12.6	12.9	7.1	7.0	5.0	4.9	10.1	10.9	5.4	5.6	4.1	9.7	8.7
Below Dexter	3.1	0.7	0.4	0.4	5.3	0.4	6.4	1.7	1.0	4.7	3.6	0.6	0.0	0.0	0.0
Fall Creek	6.6	3.1	6.6	5.0	8.3	1.1	3.5	1.4	--	2.2	2.2	0.5	0.9	1.5	3.8
Little Fall Creek	--	--	--	--	--	--	--	--	--	2.5	1.4	1.0	1.1	0.0	0.0
NF MF Willamette	--	--	--	--	--	--	--	6.2		1.6	6.5	6.7	4.4	9.2	--
MF Will. Above Hills Cr. Dam	--	--	--	--	--	--	--	--	--	--	15.6	4.6	1.8	3.3	--

[a] A severe storm event late in the 2013 spawning season may have compromised the estimate of peak redd counts. Values may be biased low.

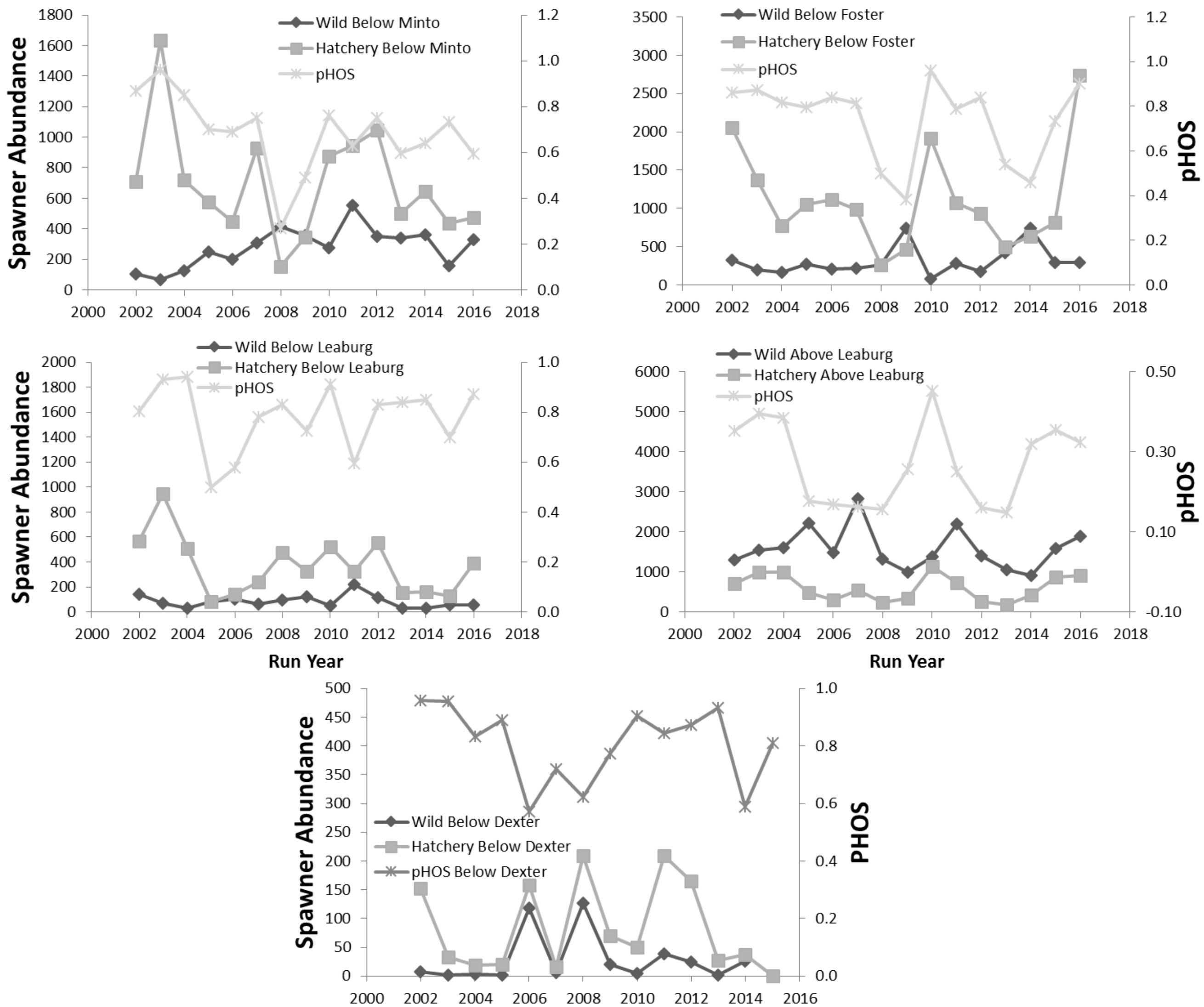

Figure 3. Spawner abundance estimates based on redd count expansion and pHOS estimates based on carcass recoveries for reaches below dams through 2016. Note variable y-axes.

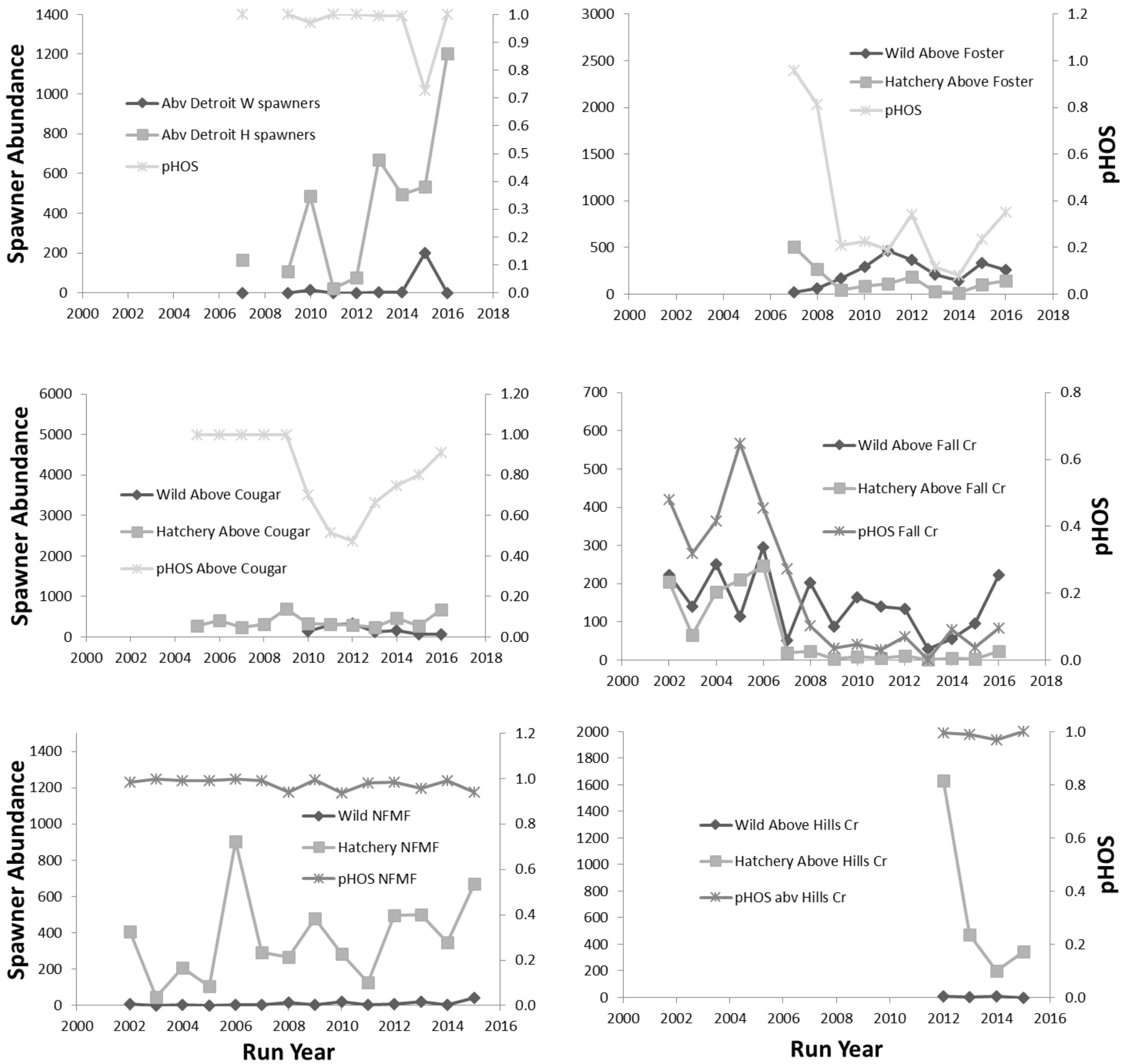

Figure 4. Spawner abundance estimates based on redd count expansion and pHOS estimates based on carcass recoveries for reaches above dams through 2016. Surveys above dams on the North Fork Middle Fork and Middle Fork above Hills Creek were conducted in 2015 but not in 2016. Note variable y-axes.

Table 3. Peak redd counts, date peak count was recorded, and number of surveys conducted by survey section in the North Santiam subbasin, 2015. LB and RB indicate left and right bank counts.

Subbasin	Survey Section	Peak Redd Count	Date of Peak Count	Number of Surveys
North Santiam	Minto Dam to Packsaddle	11	9/21	12
	Packsaddle to Gate's Br	89	9/21 LB, 10/5 RB	14
	Gate's Br to Mill City	51	9/28 LB, 9/21 RB	14
	Mill City to Fisherman's Bend	38	10/5 LB, 9/21 RB	13
	Fisherman's Bend to Mehama	5	9/28 RB	14
	Mehama to Powerlines	0	N/A	11
	Powerlines to Upper Bennett	0	N/A	11
	Upper Bennett to Stayton	0	N/A	12
	Lower Bennett to Stayton	NOT	SURVEYED	
	Stayton to Shelburn	0	N/A	11
	Shelburn to Green's Br	0	N/A	4
	Green's Br to Mouth	2	11/12	2
North Santiam Above Detroit	Parish Lake Road to Straight Cr	0	N/A	5
	Straight Cr to Bugaboo	0	N/A	5
	Bugaboo to Horn Cr	15	9/28	5
	Horn Cr	76	9/28	17
	Marion Cr	29	10/8	14
	Horn Cr to Minto Cr	7	9/23	11
	Minto Cr to Pamelia Cr	29	9/28	10
	Pamelia Cr to Whitewater Cr	NOT	SURVEYED	
	Whitewater Cr to Misery Cr	NOT	SURVEYED	
	Misery Cr to Cooper's Ridge	13	10/5	4
	Coopers Ridge Rd to Idanha Br	3	10/5	4
Breitenbush	S Fk Breitenbush to Hill Cr	18	9/24	9
	Hill Cr to Scorpion Cr	41	9/24	10
	Scorpion Cr to Fox Cr	28	10/8	6
	Fox Cr to Humbug Cr	14	10/8	6
	Humbug Cr to Byars Cr	5	9/23	7
	Byars Cr to Picnic Area	18	9/29	5
Little N. Fork Santiam	Elkhorn Br to Salmon Falls	3	9/29	5
	Salmon Falls to Camp Cascade	3	9/29	3
	Camp Cascade to Narrows	11	9/29	5
	Narrows to Golf Br	6	9/29	2
	Golf Br to Bear Cr Br	1	9/29	5
	Bear Cr Br to Lunkers Br	0	N/A	1

Table 4. Peak redd counts, date peak count was recorded, and number of surveys conducted by survey section in the South Santiam subbasin, 2015.

Subbasin	Survey Section	Peak Redd Count	Date of Peak Count	Number of Surveys
South Santiam	Foster to Pleasant Valley	408	10/7 LB, 9/22 RB	15
	Pleasant Valley to McDowell Cr Rd	29	9/29	14
	McDowell Cr Rd to Waterloo	7	9/22	13
	Waterloo to Lebanon Dam	NOT	SURVEYED	
	Lebanon Dam to Gill's Landing	NOT	SURVEYED	
	Gill's Landing to Sanderson's	0	N/A	2
	Sanderson's to mouth	0	N/A	2
South Santiam Above Foster	Falls to Soda Fork	25	9/22	13
	Soda Fork to Little Boulder Cr	20	9/22	14
	Little Boulder Cr to Trout Cr C.G.	20	9/22, 9/23	13
	Trout Cr C.G. to 2nd Trib	24	9/22	14
	2nd Trib to Gordon Cr Rd	45	9/30	14
	Gordon Cr Rd to Moose Cr Br	7	9/22	14
	Moose Cr Br to Cascadia	16	10/7	11
	Cascadia to High Deck	4	10/7	13
	High Deck to Shot Pouch	7	9/21	13
	Shot Pouch to Riverbend Park	9	10/7	15
	Riverbend Park to Reservoir	0	N/A	13

Table 5. Peak redd counts, date peak count was recorded, and number of surveys conducted by survey section in the McKenzie subbasin, 2015. LB and RB indicate left and right bank count dates. SC indicates side channel count date(s).

Subbasin	Survey Section	Peak Redd Count	Date of Peak Count	Number of Surveys
McKenzie R.	Spawning Channel	38	9/15	4
	Olallie C.G. to Belknap	83	10/6 LB, 9/30 RB	5
	Belknap to Paradise	86	9/30	5
	Paradise to McKenzie Trail	45	10/6 LB, 9/30 RB	5
	McKenzie Trail to McKenzie Br.	15	9/30	4
	McKenzie Br to Hamlin	53	9/30	5
	Hamlin to S.F. McKenzie	1	9/23	5
	S.F. McKenzie to Forest Glen	91	9/30	5
	Forest Glen to Rosboro Br.	209	10/6 LB, 9/30 RB, 9/28 SC	10
	Rosboro Br to Ben & Kay	65	9/30	7
	Helfrich to Leaburg Lake	25	9/30	12
	Leaburg Dam to Leaburg Landing	150	10/12	16
	Leaburg Landing to Dearhorn	0	N/A	5
	Dearhorn to Hendricks	0	N/A	3
	Hendricks to Bellinger	0	N/A	2
S. Fork McKenzie	Cougar Dam to Br	39	9/29	19
	Br to Mouth	27	9/24	16
S. Fork McKenzie Above Cougar	Elk Cr. To Roaring River	11	9/22	11
	Roaring River to Twin Springs C.G.	11	9/30	11
	Twin Springs C.G. to Homestead	40	9/30	13
	Homestead to Dutch Oven	25	9/23	10
	Dutch Oven to Rebel Cr.	18	10/7	13
	Rebel Cr. to NFD 1980	15	9/23	12
	NFD 1980 to Reservoir	16	9/23	13
Horse Cr.	Pothole Cr. to Trail Br.	18	10/1	4
	Trail Br. to Separation Cr.	8	10/1	3
	Separation Cr. to Road Access	13	10/1	4
	Road Access to Braids	21	9/24	4
	Braids to Avenue Cr.	12	10/1	4
	Avenue Cr to Br.	64	10/1	4
	Br. to Mouth	21	10/8	4
Lost Cr.	Cascade to Campground	11	9/22	2
	Campground to Split Pt	13	9/23	2
	Split Pt to Hwy Br.	26	9/23	2
	Highway Br. to Mouth	1	9/23	2

Table 6. Peak redd counts, date peak count was recorded, and number of surveys conducted by survey section in the Middle Fork Willamette subbasin, 2015. LB and RB indicate left and right bank counts.

Subbasin	Survey Section	Peak Redd Count	Date of Peak Count	Number of Surveys
Middle Fork Willamette	Dexter to Pengra	0	N/A	14
	Pengra to Jasper	0	N/A	14
	Jasper to Clearwater	0	N/A	2
Fall Cr.	Johnny Cr. Br. to Big Pool Campground	0	N/A	3
	Bedrock Campground to Johnny Cr. Br.	0	N/A	3
	Portland Cr to Bedrock Campground	0	N/A	7
	NFD 1828 Br. to Portland Cr.	6	9/24	10
	Hehe Cr. to NFD 1828 Br.	4	10/1	11
	NFD 1833 Br. to Hehe Cr.	6	10/1	12
	Gold Cr. to NFD 1833 Br.	18	9/24	12
	Falls to Gold Cr.	6	9/24	12
Little Fall Cr.	Trib below NFD 400 to NFD 1806 Br.	0	N/A	7
	NFD 1806 Br. to NFD 1818 Br.	0	N/A	5
	NFD 1818 Br. to Fish Ladder	0	N/A	7
	Fish Ladder to MP 17	NOT	SURVEYED	
	MP 17 to Norton Cr.	NOT	SURVEYED	
NFMF	Kiahanie Br. to Release Site	85	9/21	15
	NFD 1944 Br. to Kiahanie Br.	147	9/23	12
	Minute Cr. to NFD 1944 Br.	39	9/23	12
	N Fk #3666 trailhead to Minute Cr.	7	9/21	9
MF Above Hills Cr.	Big Swamp to Paddy's Valley Br.	23	9/22	12
	Paddy's Valley to Beaver Cr.	19	9/29	12
	Beaver Cr. to Chuckle Springs	NOT	SURVEYED	
	Chuckle Springs to Found Cr.	3	9/24	2
	Found Cr. to Echo Br.	16	9/24	5
	Echo Br. to Young's Cr.	100	9/15	12
	Young's Cr. to Reservoir	4	9/17	6

Table 7. Peak redd counts, date peak count was recorded, and number of surveys conducted by survey section in the North Santiam subbasin, 2016. LB and RB indicate left and right bank counts.

Subbasin	Survey Section	Peak Redd Count	Date of Peak Count	Number of Surveys
North Santiam	Minto Dam to Packsaddle	35	9/19	12
	Packsaddle to Gate's Br	142	9/26 LB,9/19 RB	13
	Gate's Br to Mill City	45	9/26	12
	Mill City to Fisherman's Bend	44	9/19	11
	Fisherman's Bend to Mehama	22	9/19	11
	Mehama to Powerlines	1	9/19	10
	Powerlines to Upper Bennett	1	9/12	11
	Upper Bennett to Stayton	4	9/19	11
	Lower Bennett to Stayton	NOT	SURVEYED	
	Stayton to Mouth	0	N/A	7
North Santiam Above Detroit	Parish Lake Road to Straight Cr	0	N/A	4
	Straight Cr to Bugaboo	0	N/A	4
	Bugaboo to Horn Cr	11	10/6	5
	Horn Cr	61	9/26	14
	Marion Cr	50	9/18	7
	Horn Cr to Minto Cr	38	9/29	9
	Minto Cr to Pamelia Cr	65	9/18	8
	Pamelia Cr to Whitewater Cr	4	9/20	3
	Whitewater Cr to Misery Cr	4	9/20	3
	Misery Cr to Cooper's Ridge	6	9/20	3
	Coopers Ridge Rd to Idanha Br	1	9/20	3
Breitenbush	S Fk Breitenbush to Hill Cr	86	10/3	6
	Hill Cr to Scorpion Cr	38	9/21	6
	Scorpion Cr to Fox Cr	15	9/21	6
	Fox Cr to Humbug Cr	44	9/21	4
	Humbug Cr to Byars Cr	20	9/21	6
	Byars Cr to Picnic Area	9	9/22	6
L. N. Santiam	Elkhorn Br to Salmon Falls	5	9/22	6
	Salmon Falls to Camp Cascade	0	N/A	5
	Camp Cascade to Narrows	9	9/26	6
	Narrows to Golf Br	10	9/26	7
	Golf Br to Bear Cr Br	2	8/30	5
	Bear Cr Br to Lunkers Br	0	N/A	6

Table 8. Peak redd counts, date peak count was recorded, and number of surveys conducted by survey section in the South Santiam subbasin, 2016.

Subbasin	Survey Section	Peak Redd Count	Date of Peak Count	Number of Surveys
South Santiam	Foster to Pleasant Valley	1107	10/4 LB, 9/23RB	14
	Pleasant Valley to McDowell Cr Rd	63	9/27	10
	McDowell Cr Rd to Waterloo	22	9/13	12
	Waterloo to Lebanon Dam	NOT	SURVEYED	
	Lebanon Dam to Gill's Landing	NOT	SURVEYED	
	Gill's Landing to Sanderson's	0		6
	Sanderson's to mouth	0		7
South Santiam Above Foster	Falls to Soda Fork	42*	10/3	16
	Soda Fork to Little Boulder Cr	21	9/29	19
	Little Boulder Cr to Trout Cr C.G.	35	10/3	18
	Trout Cr C.G. to 2nd Trib	3	9/27	10
	2nd Trib to Gordon Cr Rd	22	9/27	21
	Gordon Cr Rd to Moose Cr Br	32	9/22	15
	Moose Cr Br to Cascadia	5	9/28	10
	Cascadia to High Deck	2	9/28	14
	High Deck to Shot Pouch	0	N/A	15
	Shot Pouch to Riverbend Park	0	N/A	12
	Riverbend Park to Reservoir	0	N/A	12

*Table 9. Peak redd counts, date peak count was recorded, and number of surveys conducted by survey section in the McKenzie subbasin, 2016. LB and RB indicate left and right bank count dates.*SC indicates side channel count dates.*

Subbasin	Survey Section	Peak Redd Count	Date of Peak Count	Number of Surveys
McKenzie R.	Spawning Channel	22	9/27	5
	Olallie C.G. to Belknap	84	10/5 LB, 9/28 RB	4
	Belknap to Paradise	71	10/5 LB, 9/28 RB	4
	Paradise to McKenzie Trail	42	10/5 LB, 9/28 RB	4
	McKenzie Trail to McKenzie Br.	17	9/28	8
	McKenzie Br to Hamlin	50	10/5	8
	Hamlin to S.F. McKenzie	2	10/5	7
	S.F. McKenzie to Forest Glen	38	9/28	7
	Forest Glen to Rosboro Br.	207*	9/21 LB, 9/28RB, 10/10SC	8
	Rosboro Br to Ben & Kay	76	9/28 LB, 10/5 RB	8
	Helfrich to Leaburg Lake	22	9/28	9
	Leaburg Dam to Leaburg Landing	170	9/28	13
	Leaburg Landing to Dearhorn	0	N/A	8
	Dearhorn to Bellinger	0	N/A	4
S. Fork McKenzie	Cougar Dam to Br	56	10/12	7
	Br to Mouth	39	10/6	7
S. Fork McKenzie Above Cougar	Elk Cr to Frissel	80	10/10	5
	Frissel to Roaring River	10	9/28	4
	Roaring River to Twin Springs C.G.	26	10/4	6
	Twin Springs C.G. to Homestead	57	10/5	6
	Homestead to Dutch Oven	29	10/5	6
	Dutch Oven to Rebel Cr.	16	10/11	7
	Rebel Cr. to NFD 1980	44	10/5	7
	NFD 1980 to Reservoir	32	10/5	9
Horse Cr.	Pothole Cr. to Trail Br.	10	9/29	5
	Trail Br. to Separation Cr.	13	9/29	5
	Separation Cr. to Road Access	15	9/22	5
	Road Access to Braids	53	9/28	5
	Braids to Avenue Cr.	32	9/22	5
	Avenue Cr to Br.	176	9/28	5
	Br. to Mouth	42	9/22 LB, 10/11 RB	5
Lost Cr.	Cascade to Campground	14	10/6	5
	Campground to Split Pt	10	9/27	5
	Split Pt to Hwy Br.	11	10/6	4
	Highway Br. to Mouth	2	9/27	5

Table 10. Peak redd counts, date peak count was recorded, and number of surveys conducted by survey section in the Middle Fork Willamette subbasin, 2016. LB and RB indicate left and right bank counts.

Subbasin	Survey Section	Peak Redd Count	Date of Peak Count	Number of Surveys
Middle Fork Willamette	Dexter to Pengra	6	9/20 LB, 10/11RB	12
	Pengra to Jasper	1	9/20	12
	Jasper to Clearwater	0	N/A	7
	Clearwater to Mouth	0	N/A	2
Fall Cr.	Johnny Cr. Br. to Big Pool Campground	0	N/A	7
	Big Pool Campground to Release	0	N/A	10
	Release to Res	0	N/A	8
	Bedrock Campground to Johnny Cr. Br.	0	N/A	13
	Portland Cr to Bedrock Campground	0	N/A	13
	NFD 1828 Br. to Portland Cr.	3	9/15	13
	Hehe Cr. to NFD 1828 Br.	8	9/15	13
	NFD 1833 Br. to Hehe Cr.	48	9/22	13
	Gold Cr. to NFD 1833 Br.	29	9/15	12
	Falls to Gold Cr.	10	10/6	12
Little Fall Cr.	Trib below NFD 400 to NFD 1806 Br.	0	N/A	2
	NFD 1806 Br. to NFD 1818 Br.	0	N/A	3
	NFD 1818 Br. to Fish Ladder	0	N/A	3
	Fish Ladder to MP 17	0	N/A	2
	MP 17 to Norton Cr.	0	N/A	2
NFMF	Kiahanie Br. to Release Site	NOT	SURVEYED	
	NFD 1944 Br. to Kiahanie Br.	NOT	SURVEYED	
	Minute Cr. to NFD 1944 Br.	NOT	SURVEYED	
	N Fk #3666 trailhead to Minute Cr.	NOT	SURVEYED	
MF Above Hills Cr.	Big Swamp to Paddy's Valley Br.	NOT	SURVEYED	
	Paddy's Valley to Beaver Cr.	NOT	SURVEYED	
	Beaver Cr. to Chuckle Springs	NOT	SURVEYED	
	Chuckle Springs to Found Cr.	NOT	SURVEYED	
	Found Cr. to Echo Br.	NOT	SURVEYED	
	Echo Br. to Young's Cr.	NOT	SURVEYED	
	Young's Cr. to Reservoir	NOT	SURVEYED	

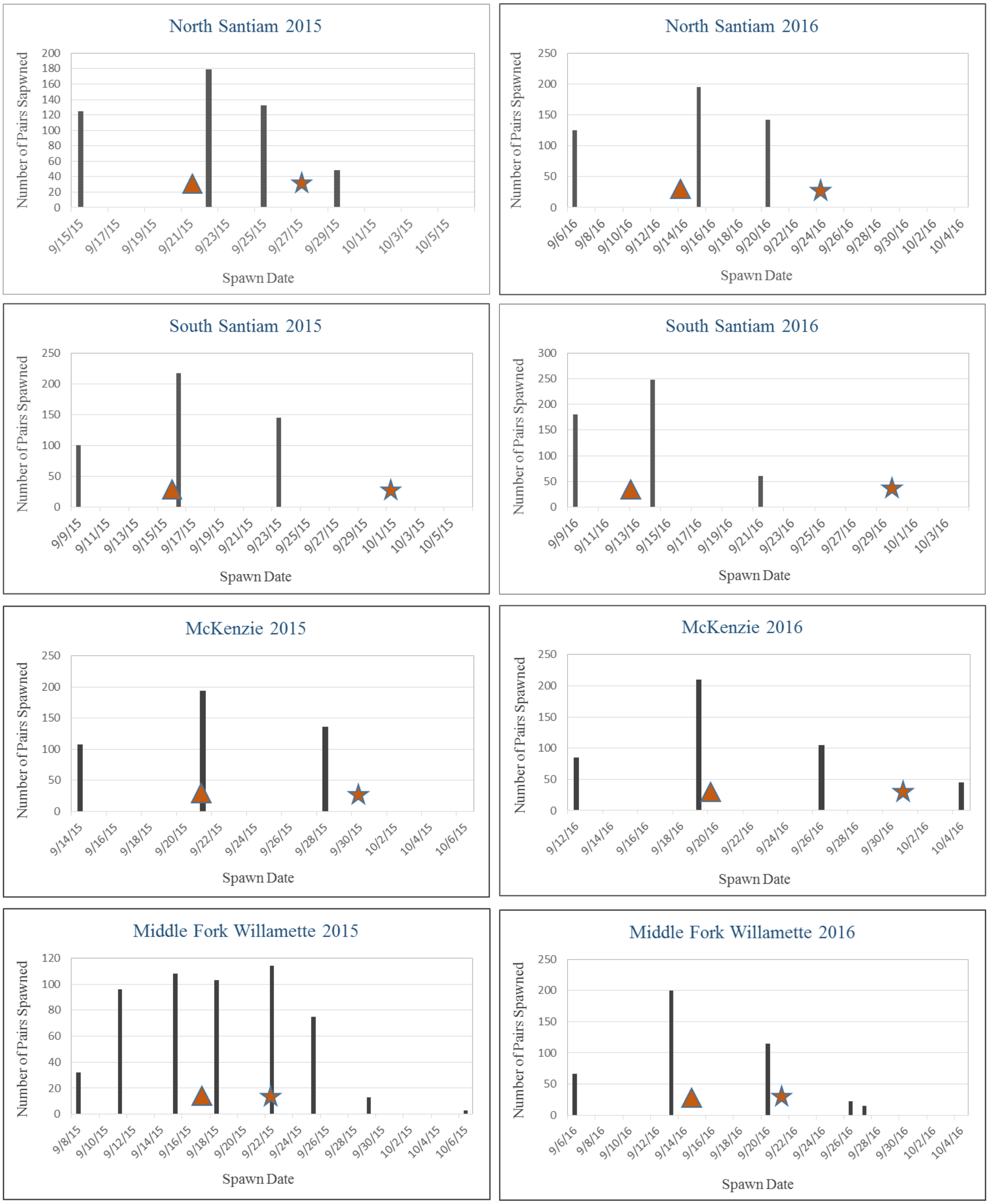

Figure 5. Comparison of spawn timing in the rivers and spawn timing at the hatcheries in 2015 (left) and 2016 (right). Bars indicate the number of pairs spawned in the hatchery on a particular date. Triangles indicate mean spawn timing at the hatcheries. Stars indicate estimated long-term (2008-2014) mean spawn timing in rivers in each basin. Note variable axes.

McKenzie River: In 2015, the McKenzie River was surveyed beginning 9 June and ending 14 October. Redd construction was first observed on 27 August and peak redd counts (Table 5) were observed between 15 September and 12 October, depending on the particular river reach surveyed. As in previous years, the redd density in 2015 was highest in the section below Leaburg Dam. Within that reach the highest redd densities were observed immediately below Leaburg Dam and further downstream near the McKenzie Fish Hatchery. Moderate redd densities were observed above Leaburg Dam with low PSM and a decreasing trend in pHOS upstream. We estimated that the average spawn timing in the McKenzie River was 30 September (Figure 5).

In 2016, the McKenzie River (Figure 8) was surveyed beginning 2 June and ending 13 October. Redd construction was first observed on 6 September and peak redd counts (Table 4) were observed between 21 September and 12 October, depending on the particular river reach surveyed. As in previous years, the redd density in 2016 was highest in the section below Leaburg Dam (Figure 9). Within that reach the highest redd densities were observed immediately below Leaburg Dam and further downstream near the McKenzie Fish Hatchery. Moderate redd densities were observed above Leaburg Dam with low PSM and a decreasing trend in pHOS upstream. We estimated that the average spawn timing in the McKenzie River was October 1 (Figure 5).

We compared spawner abundance estimates for the reaches above Leaburg Dam based on dam counts and on redd count expansion. Estimates were essentially identical for 2005-2016 but differed greatly for 2002-2004 (Figure 6).

Middle Fork Willamette River: In 2015 the Middle Fork Willamette River was surveyed beginning 11 June and ending 1 October 8. Few redds were observed (Figure 11). Redd construction was first observed on 31 August. The peak redd count (Table 6) was obtained between 14 September and 1 October, depending on the particular river reach surveyed. We estimated that the average spawn timing in the Middle Fork Willamette River was 26 September 26 (Figure 5).

In 2016 the Middle Fork Willamette River was surveyed beginning 16 June and ending 11 October. Redd construction was first observed on 20 September. The peak redd count (Table 5) was obtained between 20 September and 11 October, depending on the particular river reach surveyed. We estimated that the average spawn timing in the Middle Fork Willamette River was 21 September (Figure 5).

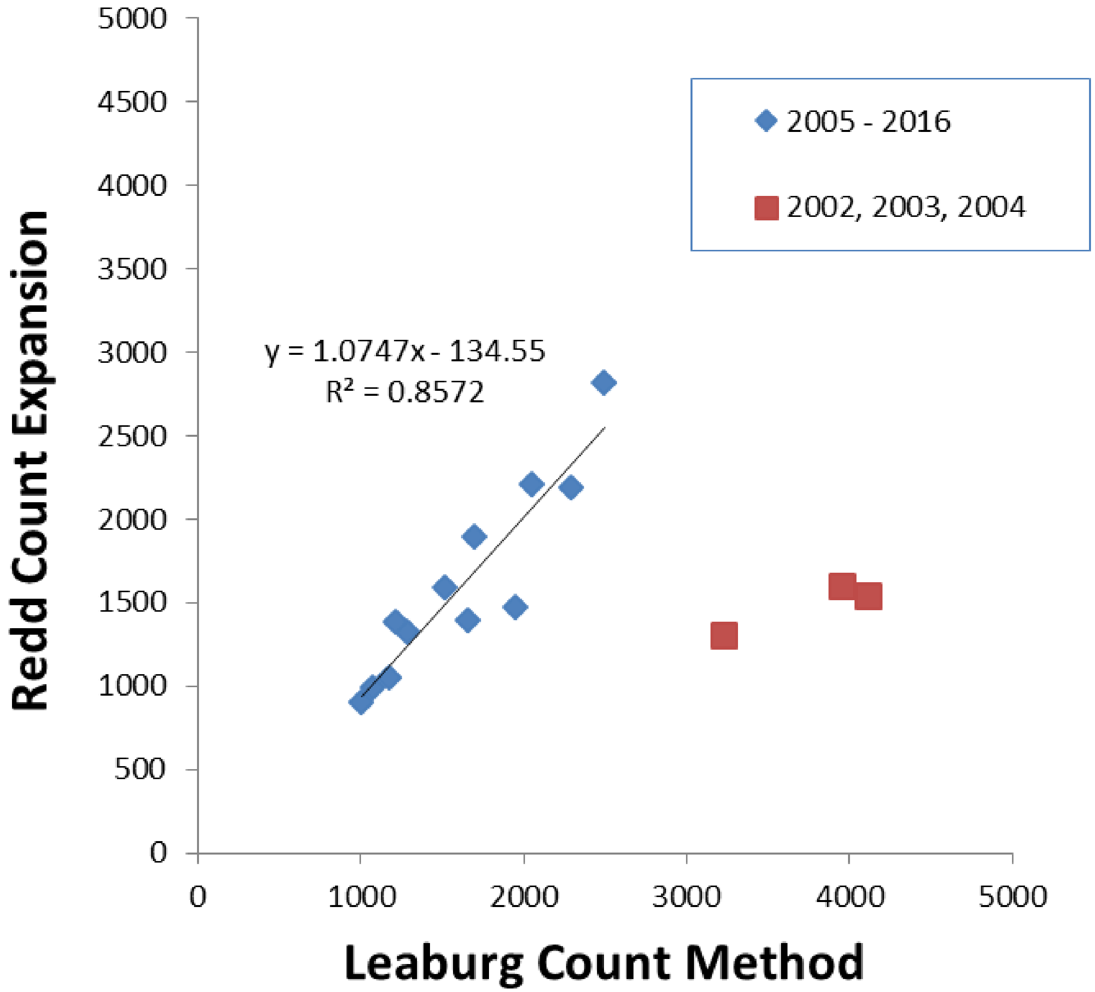

Figure 6. Relationship between natural-origin spawner abundance above Leaburg Dam comparing estimates from redd count expansion to estimates from dam counts

Section 3.1.3 Age Structure and Size Distribution on Spawning Grounds:

The age structure of natural- and hatchery-origin fish collected in 2015 and 2016 during spawner and carcass surveys, as determined from analysis of fish scales and coded wire tags, is presented in Table 11. Size distribution of natural- and hatchery-origin fish collected in 2015 and 2016 during spawner and carcass surveys is shown in Table 11.

In both 2015 and 2016, wild McKenzie fish tended to be significantly older and larger than fish collected elsewhere as has typically been the case in recent years (Figure 7). Among hatchery fish, Chinook in the North Santiam River tended to be older and larger than hatchery fish collected elsewhere.

Section 3.1.4 Spawner Abundance:

Spawner abundance estimates were obtained by multiplying the peak redd counts in reaches of interest by the expansion factor 2.5 spawners/redd and then parsed into natural- and hatchery-origin spawners using the estimates of pHOS for those specific reaches (see Figures 3 and 4)

3.1.4.1: North Santiam River: In 2015 we estimated that total spawner abundance in the North Santiam subbasin, based strictly on redd count expansion, was 1,330 fish;361 were natural-origin and 969 were hatchery-origin (Table 13). Spawner abundance above Detroit Dam was 733 fish; 201 were natural-origin.

In 2016, we estimated that total spawner abundance in the North Santiam subbasin, based strictly on redd count expansion, was 2,228 fish;417 were natural-origin and 1,810 were hatchery-origin (Table 14). Spawner abundance above Detroit Dam was 1,203 fish all of which were hatchery-origin.

3.1.4.2: South Santiam: In 2015 we estimated that spawner abundance of natural-origin and hatchery-origin fish in the South Santiam subbasin was 627 and 916 fish, respectively (Table 13). Above Foster Dam we estimated 332 natural-origin and 103 hatchery-origin spawners. We observed no redds and infer no spawning occurred below Lebanon Dam in 2015.

In 2016, we estimated that spawner abundance of natural-origin and hatchery-origin fish in the South Santiam subbasin was 498 and 2,907 fish, respectively (Table 14). Above Foster Dam we estimated 263 natural-origin and 142 hatchery-origin spawners. We observed no redds and infer no spawning occurred below Lebanon Dam in 2016, again supporting the idea that another video monitoring site might be useful at that location because the video system is likely to detect essentially all spring Chinook spawners returning to the basin.

3.1.4.3: McKenzie: In 2015, total spawner abundance in the McKenzie subbasin was estimated at 3,203 spawners (1,778 natural-origin and 1,424 hatchery-origin; Table 13). By convention, the McKenzie subbasin is divided into three reaches of interest:

- Below Leaburg Dam, where we estimated spawner abundance of 120 and 280 wild- and hatchery-origin spawners respectively.
- Above Leaburg Dam, where we estimated 1,589 natural-origin and 871 hatchery-origin fish.
- The South Fork McKenzie River above Cougar Reservoir. Surveys in this reach support a broad-reaching experiment attempting to evaluate potential for using hatchery-origin fish to achieve recovery in otherwise depauperate habitat, the details of which have been reported elsewhere (Zymonas et al. 2014; Banks et al. 2014). Our expansion of redd counts generated estimates of 69 natural-origin and 274 hatchery-origin spawners.

In 2016, total spawner abundance in the McKenzie subbasin was estimated at 3,943 spawners (1,993 natural-origin and 1,950 hatchery-origin; Table 14). By convention, the McKenzie subbasin is divided into three reaches of interest:

- Below Leaburg Dam, where we estimated spawner abundance of 47 and 403 wild- and hatchery-origin spawners, respectively.
- Above Leaburg Dam where we estimated 1,882 natural-origin and 878 hatchery-origin fish.
- The South Fork McKenzie River above Cougar Reservoir. Our expansion of redd counts generated estimates of 64 natural-origin and 669 hatchery-origin spawners.

3.1.4.4 Middle Fork Willamette: In 2015 results from our surveys indicated that 1,160 fish (139 natural-origin and 1,021 hatchery-origin; Table 14) spawned in the Middle Fork Willamette subbasin. The reaches of interest in the Middle Fork Willamette subbasin include:

- Below Dexter Dam. We estimated that no successful spawning occurred below Dexter Dam in 2015 including in Little Fall Creek.
- Fall Creek. We estimated that 96 wild-origin and four hatchery-origin fish (identified by otolith marks) spawned above Fall Creek Reservoir.
- North Fork Middle Fork. We estimated that 43 natural-origin and 672 hatchery-origin fish spawned in the North Fork Middle Fork Willamette River above Lookout Point Reservoir.
- Middle Fork above Hills Creek Reservoir. We estimated that 345 hatchery-origin fish spawned in the Middle Fork Willamette River above Hills Creek Reservoir.

In 2016 results from our surveys were incomplete in that no surveys occurred above Lookout Point or Hills Creek reservoirs. The reaches of interest in the Middle Fork Willamette subbasin include:

- Below Dexter Dam. We estimated that 18 Chinook salmon spawned below Dexter Dam in 2016, four of which were natural-origin. No spawning was observed in Little Fall Creek.
- Fall Creek. We estimated that 221 wild-origin and 24 hatchery-origin fish (identified by otolith marks) spawned above Fall Creek Reservoir.
- North Fork Middle Fork. No surveys in 2016.
- Middle Fork above Hills Creek Reservoir. No surveys in 2016.

Table 11. Age structure (sample size and proportion of fish at each age) of natural- and hatchery-origin Chinook salmon, 2015 and 2016. Scales were collected during spawning ground surveys (SGS). H = hatchery origin; W = natural origin. NSNT, SSNT, McK and MFW refer to the North Santiam, South Santiam, McKenzie, and Middle Fork Willamette rivers.

2015 Age	NSNT SGS W	NSNT SGS H	SSNT SGS W	SSNT SGS H	McK SGS W	McK SGS H	MFW SGS W	MFW SGS H
3	7	0	28	0	3	0	7	1
4	46	12	155	71	145	47	35	35
5	13	40	18	10	72	20	5	17
6	0	0	0	0	5	0	0	0
Age								
3	0.11	0.00	0.14	0.00	0.01	0.00	0.15	0.02
4	0.70	0.23	0.77	0.88	0.64	0.70	0.74	0.66
5	0.20	0.77	0.09	0.12	0.32	0.30	0.11	0.32
6	0.00	0.00	0.00	0.00	0.02	0.00	0.00	0.00
N	66	52	201	81	225	67	47	53
Mean	4.09	4.77	3.95	4.12	4.35	4.30	3.96	4.30
SEM	0.07	0.06	0.03	0.04	0.04	0.06	0.07	0.07

2016 Age	NSNT SGS W	NSNT SGS H	SSNT SGS W	SSNT SGS H	McK SGS W	McK SGS H	MFW SGS W	MFW SGS H
3	3	0	19	2	7	0	3	1
4	27	2	79	31	54	9	36	4
5	15	10	32	33	138	5	10	7
6	0	0	0	0	4	0	2	0
Age								
3	0.07	0.00	0.15	0.03	0.03	0.00	0.06	0.08
4	0.60	0.17	0.61	0.47	0.27	0.64	0.71	0.33
5	0.33	0.83	0.25	0.50	0.68	0.36	0.20	0.58
6	0.00	0.00	0.00	0.00	0.02	0.00	0.04	0.00
N	45	12	130	66	203	14	51	12
Mean	4.27	4.83	4.09	4.47	4.68	4.36	4.22	4.50
SEM	0.09	0.11	0.06	0.07	0.04	0.13	0.09	0.19

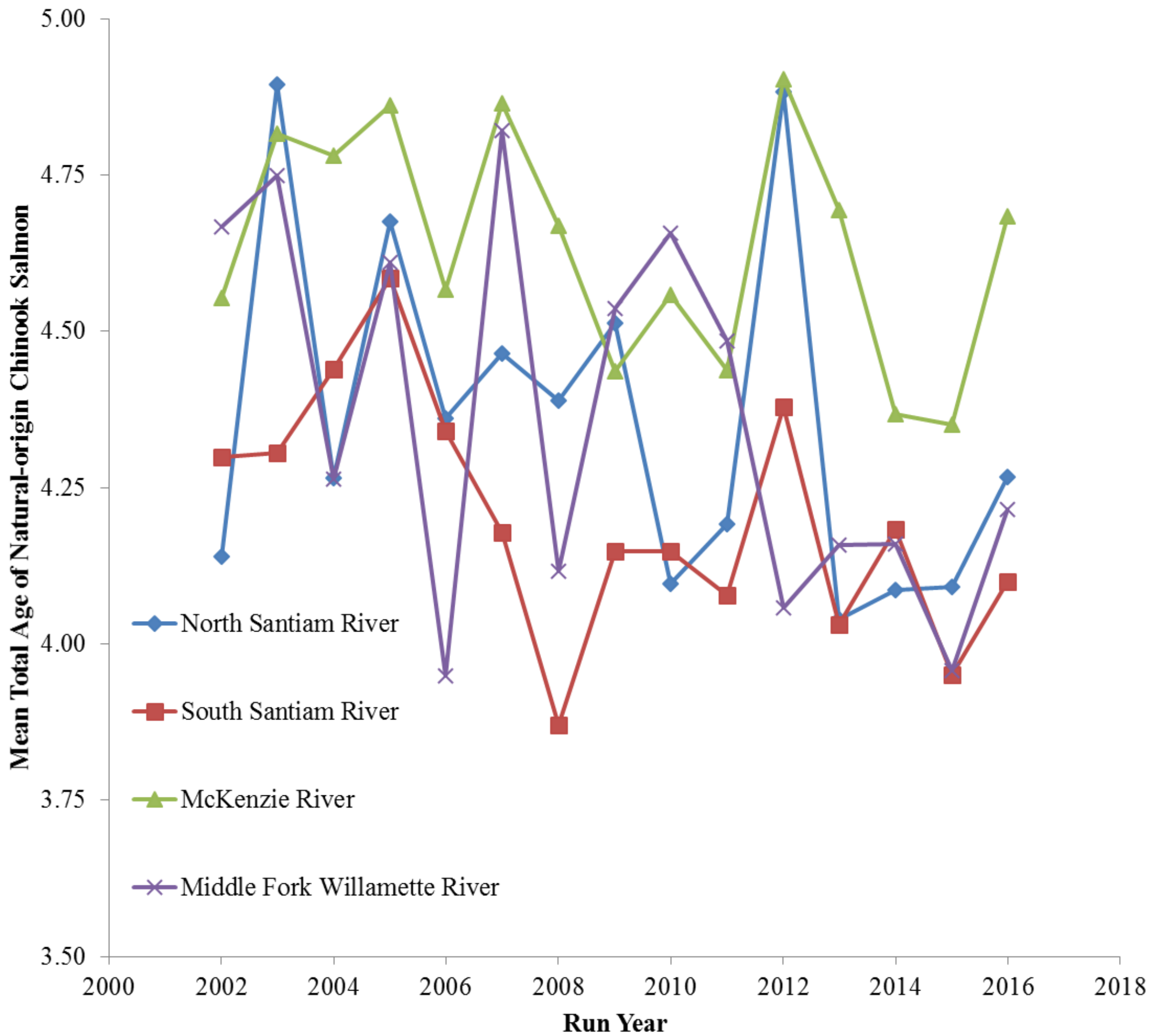

Figure 7. Recent historical mean age of natural-origin Chinook salmon in Upper Willamette subbasins.

Table 12. Size distribution (sample size and proportion of fish in each 10 mm size bin) of natural- and hatchery-origin Chinook salmon, 2015 and 2016. Scales were collected during spawning ground surveys (SGS) in the North Santiam (NSNT), South Santieam (SSNT, McKenzie (McK) and Middle Fork Willamette (MFW) rivers.

2015 FL	NSNT SGS W	NSNT SGS H	SSNT SGS W	SSNT SGS H	McK SGS W	McK SGS H	MFW SGS W	MFW SGS H
60	0	0	4	1	0	0	3	2
70	12	2	22	11	19	8	3	13
80	28	18	98	50	114	47	25	33
90	26	21	80	22	101	9	4	8
FL								
60	0.00	0.00	0.02	0.01	0.00	0.00	0.09	0.04
70	0.18	0.05	0.11	0.13	0.08	0.13	0.09	0.24
80	0.42	0.44	0.49	0.60	0.49	0.73	0.78	0.61
90	0.39	0.51	0.40	0.27	0.43	0.14	0.13	0.15
N	72	53	214	84	250	69	36	56
Mean	79.29	83.30	78.56	76.89	79.82	76.58	74.31	73.77
SEM	0.94	1.10	0.50	0.66	0.43	0.76	1.28	0.95

2016 FL	NSNT SGS W	NSNT SGS H	SSNT SGS W	SSNT SGS H	McK SGS W	McK SGS H	MFW SGS W	MFW SGS H
60	0	0	4	0	3	0	1	1
70	3	0	1	3	8	4	13	5
80	18	2	13	20	87	7	32	5
90	22	12	10	17	99	2	8	2
FL								
60	0.00	0.00	0.17	0.00	0.02	0.00	0.02	0.08
70	0.07	0.00	0.04	0.08	0.04	0.31	0.25	0.42
80	0.42	0.14	0.54	0.50	0.45	0.54	0.60	0.42
90	0.51	0.86	0.42	0.43	0.51	0.15	0.15	0.17
N	46	14	32	42	223	15	55	13
Mean	81.11	83.14	78.25	79.64	81.30	76.20	75.09	72.46
SEM	1.04	1.11	2.03	1.11	0.53	2.22	0.85	2.39

Table 13. Chinook salmon spawner abundance estimates, 2015. Estimates derived by redd count expansion were parsed into hatchery- and natural-origin using carcass counts after adjustment using otolith data.

Subbasin, section	Peak Redd Count	Spawner Abundance Estimate (redds*2.5)	Reach-specific pHOS	Hatchery-origin Abundance Estimate	Natural-origin Abundance Estimate
North Santiam					
Below Detroit Reservoir	239	598	73.2%	437	160
Above Detroit Reservoir	293	733	72.6%	532	201
South Santiam					
Below Foster Dam	444	1,110	73.3%	814	296
Above Foster Dam	174	435	23.6%	103	332
McKenzie					
Below Leaburg Dam	160	400	69.9%	280	120
Above Leaburg Dam	984	2,460	35.4%	871	1,589
S Fork McKenzie Above Cougar	137	343	80.0%	274	69
Middle Fork Willamette					
Below Dexter	0	0	81.0%	0	0
Little Fall Creek	0	0	0.0%	0	0
Fall Creek	40	100	3.8%	4	96
North Fork Middle Fork	286	715	94.0%	672	43
Above Hills Creek Reservoir	138	345	100.0%	345	0

Table 14. Chinook salmon spawner abundance estimates, 2016. Estimates derived by redd count expansion were parsed into hatchery- and natural-origin using carcass counts after adjustment using otolith data.

Subbasin, section	Peak Redd Count	Spawner Abundance Estimate (redds*2.5)	Reach-specific pHOS	Hatchery-origin Abundance Estimate	Natural-origin Abundance Estimate
North Santiam					
Below Detroit Reservoir	410	1,025	59.3%	608	417
Above Detroit Reservoir	481	1,203	100.0%	1,203	0
South Santiam					
Below Foster Dam	1,200	3,000	92.2%	2,765	235
Above Foster Dam	162	405	35.2%	142	263
McKenzie					
Below Leaburg Dam	180	450	89.5%	403	47
Above Leaburg Dam	1,104	2,760	31.8%	878	1,882
S Fork McKenzie Above Cougar	293	733	91.3%	669	64
Middle Fork Willamette					
Below Dexter	7	18	77.9%	14	4
Little Fall Creek	0	0	0.0%	0	0
Fall Creek	98	245	9.6%	24	221
North Fork Middle Fork	--	--	--	--	--
Above Hills Creek Reservoir	--	--	--	--	--

Section 3.1.5 Estimates of prespawning mortality:

Prespawning mortality varied widely among subbasins and among river reaches within subbasins. Prespawning Mortality rates are affected by numerous factors including as stressors migration timing, trapping procedures, and protocols associated with transport and release (Bowerman et al. 2017, Jepson et al. 2015, Mann et al. 2011, Naughton et al. 2016). Several factors can potentially affect estimates of pre-spawning mortality derived from recovery of female carcasses. Survey efforts can vary spatially and temporally from year to year. These differences can affect recovery of salmon carcasses: scavengers and high river flow can affect the length of time that carcasses remain in river sections where they can be located and recovered by surveyors. Late-season carcasses can be difficult to recover after flows begin to increase, and since these fish are more likely to be successful spawners, there is the potential for systematic bias. Therefore, estimates of pre-spawning mortality should be evaluated in relative terms of low, medium or high corresponding to estimates of <20%, 20-50%, and >50%, respectively, rather than as absolute values. Overall, in 2015 26% of the female carcasses recovered during surveys were prespawn mortalities, ranging from a low of 5% in the upper McKenzie River to a high of 99% below Dexter Dam in the Middle Fork Willamette River. In 2016, overall PSM was estimated as 8%. The range in 2016 was from 0% PSM (upper McKenzie) to 96% below Dexter Dam.

3.1.5.1 North Santiam: In 2015 the greatest rate of prespawning mortality in the North Santiam River was observed below Minto Dam (63%; Table 15). In 2016, PSM in that reach was only estimated as 3%. Above Detroit Dam we estimated PSM as 12% in 2015 and 5% in 2016 (Table 16).

3.1.5.2 South Santiam: Estimates of PSM in the South Santiam River in 2015 (Table 15) were 40% above Foster Dam and 12% below Foster. In 2016, the estimate above Foster was 11% and 4% below (Table 16).

3.1.5.3 McKenzie: Prespawning mortality in 2015 was 35% below Leaburg Dam, 5% above Leaburg Dam, and 9% above Cougar Dam (Table 15). In 2016, PSM was 17% below Leaburg Dam and not detected above Leaburg or Cougar dams (Table 16).

3.1.5.1 Middle Fork Willamette: Prespawning mortality in 2015 was estimated as 99% below Dexter Dam, 60% above Fall Creek Dam, 30% in the North Fork Middle Fork, and 89% above Hills Creek Reservoir (Table 15). In 2016, PSM was estimated as 96% below Dexter Dam, 15% in Fall Creek (Table 16). No surveys were conducted in 2016 above Hills Creek or Lookout Point reservoirs.

Table 15. Estimates of prespawning mortality of Chinook salmon in 2015. Estimate is based on visual inspection of female carcasses. Any female carcass containing more than an estimated 50% of its eggs was counted as a prespawn mortality.

Subbasin, section	Total Females	Unspawned Females	PSM	PSM Lower 95% CI	PSM Upper 95% CI
North Santiam					
Below Detroit Reservoir	100	63	63%	56%	70%
Above Detroit Reservoir	77	9	12%	5%	18%
TOTAL	177	72	41%	35%	47%
South Santiam					
Below Foster Dam	290	36	12%	9%	16%
Above Foster Dam	42	17	40%	28%	53%
TOTAL	332	53	16%	12%	20%
McKenzie					
Below Leaburg Dam	40	14	35%	22%	48%
Above Leaburg	143	7	5%	1%	8%
South Fork McKenzie Above Cougar	11	1	9%	-7%	25%
TOTAL	194	22	11%	7%	16%
Middle Fork Willamette					
Below Dexter	94	93	99%	97%	100%
Little Fall Creek	0	0	--	--	--
Fall Creek	5	3	60%	26%	94%
North Fork Middle Fork	47	14	30%	18%	41%
Above Hills Creek Reservoir	83	74	89%	84%	94%
TOTAL	229	184	80%	77%	84%

Table 16. Estimates of prespawning mortality of Chinook salmon in 2016. Estimate is based on visual inspection of female carcasses. Any female carcass containing more than an estimated 50% of its eggs was counted as a prespawn mortality.

Subbasin, section	Total Females	Unspawned Females	PSM	PSM Lower 95% CI	PSM Upper 95% CI
North Santiam					
Below Detroit Reservoir	72	2	3%	-1%	7%
Above Detroit Reservoir	58	3	5%	0%	11%
TOTAL	130	5	4%	1%	7%
South Santiam					
Below Foster Dam	530	20	4%	2%	5%
Above Foster Dam	47	5	11%	2%	19%
TOTAL	577	25	4%	3%	6%
McKenzie					
Below Leaburg Dam	60	10	17%	8%	25%
Above Leaburg	181	0	0%	0%	0%
South Fork McKenzie Above Cougar	34	0	0%	0%	0%
TOTAL	275	10	4%	1%	6%
Middle Fork Willamette					
Below Dexter	52	50	96%	92%	100%
Little Fall Creek	0	0	--	--	--
Fall Creek	20	3	15%	0%	30%
North Fork Middle Fork	--	--	--	--	--
Above Hills Creek Reservoir	--	--	--	--	--
TOTAL	72	53	74%	66%	81%

Section 3.1.6 Origin on Spawning Grounds (pHOS):

During 2015 surveys, we sampled unclipped Chinook salmon carcasses and collected 104 readable otoliths (Table 17) in the North Santiam River, 221 in the South Santiam River, 249 in the McKenzie River, and 54 in the Middle Fork Willamette River. In 2016 we collected 46 readable otoliths in the North Santiam River, 190 in the South Santiam River, 153 in the McKenzie River, and 58 in the Middle Fork Willamette River (Table 18). Fish were initially categorized as naturally produced based on absence of an adipose fin clip. Final estimates of the proportion of hatchery-origin spawners were derived after otolith analyses allowed adjustments based on the proportions of unclipped hatchery-origin fish (see Figures 3 and 4).

3.1.6.1 North Santiam: As in previous years the pHOS estimates (Tables 19 and 20) in the North Santiam River exceeded the long-term recovery goal of 10% basinwide. To achieve a basinwide pHOS < 10% requires substantial natural production above Detroit Dam and pHOS below Big Cliff Dam not to exceed 21%. At this time, and until successful downstream passage at Detroit Dam has been completed, only hatchery origin fish are being outplanted in waters upstream of Detroit Dam, so basin-wide pHOS is expected to remain very high in the near term. An unresolved issue is how to estimate pHOS and spawner abundance, both necessary to calculate an aggregate pHOS for the subbasin, between Minto and Big Cliff dams where unclipped fish are currently passed. Only one or two redd surveys can be conducted before water releases from Big Cliff Dam make survey conditions too dangerous and carcass recoveries are too limited in number and over time to estimate PSM.

3.1.6.2 South Santiam: As in previous years the pHOS estimates (Tables 19 and 20) in the South Santiam River exceeded the recovery goal of < 10% above Foster and < 30% basin-wide. Unlike outplanting operations in the North Santiam River, only unclipped Chinook salmon are outplanted above Foster Dam but, because a substantial number of unclipped fish were actually hatchery-origin (24% in 2015 and 33% in 2016, based on thermal marks), pHOS targets were exceeded in this reach.

3.1.6.3 McKenzie: As in previous years the pHOS estimates (Tables 19 and 20) in the McKenzie River exceeded the recovery goal of 10%, ranging in 2015 from 35% above Leaburg Dam to

80% above Cougar Reservoir. In 2016, pHOS estimates ranged from 32% above Leaburg Dam to 91% above Cougar Reservoir.

3.1.6.4 Middle Fork Willamette: The pHOS estimates (Tables 19 and 20) in the Middle Fork Willamette River greatly exceeded the recovery goal of 10% in both 2015 and 2016. However, as in the South Santiam above Foster Dam, only unclipped fish are outplanted in Fall Creek. Estimates of pHOS in that portion of the subbasin (4% and 9%) met the recovery goal. The remainder of the subbasin was dominated by hatchery spawners.

Section 3.1.7 Straying:

We report straying as the incidence of hatchery-origin fish released as juveniles in one Willamette subbasin and recovered as adults in a different Willamette subbasin. As in past years the vast majority of tags were recovered in the subbasins into which the tagged juveniles were released, in both samples collected at hatcheries and on spawning ground surveys (Table 15). In 2015 there was a single CWT recovery in the North Santiam River from a fish released from the Elk River Hatchery on the Southern Oregon Coast. In 2016 there were 12 CWTs recovered at various locations from Young's Bay net pen releases in 2011 and 2012; seven were recovered at the McKenzie Hatchery, three in the North Santiam, and two in the South Santiam.

Table 17. Analysis results for otoliths collected from spawning ground surveys in 2015 and examined for thermal marks to verify wild status of unclipped adults. Percent marked indicates the proportion of unclipped hatchery-origin fish sampled.

Subbasin	Section	Total Readable Otoliths	Thermally Marked Otoliths	% Marked
North Santiam River	Below Bennett Dam	--	--	--
	Bennett to Minto Dam	44	4	8.3%
	Minto to Big Cliff	7	0	0.0%
	Little North Santiam	--	--	--
	North Santiam Above Detroit	53	11	17.2%
	Marion Forks Hatchery			--
	North Santiam Total	**104**	**15**	**12.6%**
South Santiam River	South Santiam Below Foster	124	17	12.1%
	South Santiam Above Foster	165	51	23.6%
	South Santiam Total	**221**	**68**	**23.5%**
McKenzie River	McKenzie Below Leaburg	24	3	11.1%
	Leaburg to S. Fk McKenzie	90	4	4.3%
	South Fork McKenzie Below Cougar	58	0	0.0%
	Above S. Fk McKenzie	75	3	3.8%
	South Fork McKenzie Above Cougar	2	0	0.0%
	McKenzie Hatchery			--
	McKenzie Total	**249**	**10**	**3.9%**
Middle Fork Willamette River	Middle Fork Below Dexter	25	4	13.8%
	Fall Creek	21	1	4.5%
	Little Fall Creek	4	1	20.0%
	North Fork Middle Fork	--	--	--
	Middle Fork Above Hills Creek	--	--	--
	Willamette Hatchery			--
	Middle Fork Total	**54**	**6**	**10.0%**

Table 18. Analysis results for otoliths collected from spawning ground surveys in 2016 and examined for thermal marks to verify wild status of unclipped adults. Percent marked indicates the proportion of unclipped hatchery-origin fish sampled.

Subbasin	Section	Total Readable Otoliths	Thermally Marked Otoliths	% Marked
North Santiam River	Below Bennett Dam			
	Bennett to Minto Dam	31	3	9.7%
	Minto to Big Cliff	15	0	0.0%
	Little North Santiam	0	--	--
	North Santiam Above Detroit	0	--	--
	Marion Forks Hatchery	0	--	--
	North Santiam Total	**46**	**3**	**6.1%**
South Santiam River	South Santiam Below Foster	106	32	30.2%
	South Santiam Above Foster	84	28	33.3%
	South Santiam Total	**190**	**60**	**24.0%**
McKenzie River	McKenzie Below Leaburg	15	4	26.7%
	Leaburg to S. Fk McKenzie	36	1	2.8%
	South Fork McKenzie Below Cougar	40	1	2.5%
	Above S. Fk McKenzie	58	0	0.0%
	South Fork McKenzie Above Cougar	4	0	0.0%
	McKenzie Hatchery	0	--	--
	McKenzie Total	**153**	**6**	**3.8%**
Middle Fork Willamette River	Middle Fork Below Dexter	33	7	21.2%
	Fall Creek	25	1	4.0%
	Little Fall Creek	0	--	
	North Fork Middle Fork	--	--	--
	Middle Fork Above Hills Creek	--	--	--
	Willamette Hatchery	--	--	--
	Middle Fork Total	**58**	**8**	**12.1%**

Table 19. Estimates of pHOS in 2015 based on counts of clipped and unclipped carcasses after adjustments following otolith analyses.

Subbasin, section	Peak Redd Count	Unclipped	Clipped	% Thermally Marked Otoliths from Unclipped Carcasses	Wild Estimate	Hatchery Estimate	PHOS	PHOS Lower 95% CI	PHOS Upper 95% CI
North Santiam									
Below Detroit Reservoir	239	50	122	7.8%	46	126	73.2%	67%	94%
Above Detroit Reservoir	293	56	113	17.2%	46	123	72.6%	66%	80%
				Weighted Basin-wide pHOS			72.8%		
South Santiam									
Below Foster Dam	444	133	305	12.1%	117	321	73.3%	69%	78%
Above Foster Dam	174	68	0	23.6%	52	16	23.6%	14%	34%
				Weighted Basin-wide pHOS			59.3%		
McKenzie									
Below Leaburg Dam	160	22	43	11.1%	20	45	69.9%	59%	83%
Above Leaburg Dam	984	184	92	3.1%	178	98	35.4%	30%	41%
South Fork McKenzie Above Cougar	137	2	8	0.0%	2	8	80.0%	55%	117%
				Weighted Basin-wide pHOS			44.5%		
				Weighted Basin-wide pHOS w/o abv Cougar			40.2%		
Middle Fork Willamette									
Below Dexter	0	39	138	13.8%	34	143	81.0%	75%	88%
Little Fall Creek	0	0	0	20.0%	0	0	0.0%	0.0%	0.0%
Fall Creek	40	12	0	4.5%	11	1	4.5%	-7%	17%
North Fork Middle Fork	286	6	94	0.0%	6	94	94.0%	89%	100%
Above Hills Creek Reservoir	138	0	167	0.0%	0	167	100.0%	100%	100%
				Weighted Basin-wide pHOS			88.0%		

Table 20. Estimates of pHOS in 2016 based on counts of clipped and unclipped carcasses after adjustments following otolith analyses.

Subbasin, section	Peak Redd Count	Unclipped	Clipped	% Thermally Marked Otoliths from Unclipped Carcasses	Wild Estimate	Hatchery Estimate	PHOS	PHOS Lower 95% CI	PHOS Upper 95% CI
North Santiam									
Below Detroit Reservoir	410	49	62	7.8%	45	66	59.3%	50%	94%
Above Detroit Reservoir	481	0	146	0.0%	0	146	100.0%	100%	100%
				Weighted Basin-wide pHOS			81.3%		
South Santiam									
Below Foster Dam	1200	112	889	30.0%	78	923	92.2%	91%	94%
Above Foster Dam	162	90	3	33.0%	60	33	35.2%	25%	46%
				Weighted Basin-wide pHOS			85.4%		
McKenzie									
Below Leaburg Dam	180	15	90	26.6%	11	94	89.5%	84%	97%
Above Leaburg Dam	1104	209	90	2.5%	204	95	31.8%	27%	37%
South Fork McKenzie Above Cougar	293	4	42	0.0%	4	42	91.3%	83%	103%
				Weighted Basin-wide pHOS			49.5%		
				Weighted Basin-wide pHOS w/o abv Cougar			39.9%		
Middle Fork Willamette									
Below Dexter	7	33	96	13.8%	28	101	77.9%	71%	86%
Little Fall Creek	0	0	0	0.0%	0	0	0.0%	0.0%	0.0%
Fall Creek	40	32	1	4.0%	31	2	6.9%	-2%	17%
North Fork Middle Fork	--	--	--	0.0%	--	--	--	--	--
Above Hills Creek Reservoir	--	--	--	0.0%	--	--	--	--	--
				Weighted Basin-wide pHOS			--		

Table 21. Analysis of CWT recoveries during spawning ground surveys, at hatchery traps, and at hatcheries for run years 2015 and 2016.

Run Year	Stock	Release Location	Recovery Location	Tags Recovered	Recovered In Release Basin?
2015	MCKENZIE R	MCKENZIE R-1	012R - MCKENZIE R	28	Y
		MCKENZIE R-1	013R - S FK MCKENZIE R	12	Y
		MCKENZIE R-1	17 - MCKENZIE	2,396	Y
		MCKENZIE R-1	19 - WILLAMETTE	2	N
		MCKENZIE R-1	28 - SOUTH SANTIAM	1	N
		MCKENZIE R-1	34 - DEXTER PONDS	1	N
		WILLAMETTE R CST FK	0112 - MIDDLE FORK WILLAMETTE SGS	1	N
		WILLAMETTE R CST FK	0116 - ROW R CST FK WILLAMETTE	6	Y
		WILLAMETTE R CST FK	0117 - MOSBY CR (ROW WILLAMETTE)	1	Y
		WILLAMETTE R CST FK	012R - MCKENZIE R	2	N
		WILLAMETTE R CST FK	17 - MCKENZIE	61	N
		WILLAMETTE R CST FK	19 - WILLAMETTE	7	N
	MID WILLAMETTE R	LOOKOUT POINT RES	19 - WILLAMETTE	3	Y
		LOOKOUT POINT RES	34 - DEXTER PONDS	2	Y
		MID FK WILLAMETTE R	0112 - MIDDLE FORK WILLAMETTE SGS	17	Y
		MID FK WILLAMETTE R	012R - MCKENZIE R	1	N
		MID FK WILLAMETTE R	17 - MCKENZIE	3	N
		MID FK WILLAMETTE R	19 - WILLAMETTE	1,034	Y
		MID FK WILLAMETTE R	34 - DEXTER PONDS	269	Y
	N SANTIAM R	DETROIT RES	011 - N FK SANTIAM R	1	Y
		DETROIT RES	7 - MINTO PONDS	136	Y
		SANTIAM R & N FK-1	011 - N FK SANTIAM R	45	Y
		SANTIAM R & N FK-1	0111 - SOUTH FORK SANTIAM R	1	N
		SANTIAM R & N FK-1	0112 - MIDDLE FORK WILLAMETTE SGS	1	N
		SANTIAM R & N FK-1	19 - WILLAMETTE	1	N
		SANTIAM R & N FK-1	28 - SOUTH SANTIAM	10	N
		SANTIAM R & N FK-1	7 - MINTO PONDS	1,246	Y
	S SANTIAM R	MOLALLA R	0112 - MIDDLE FORK WILLAMETTE SGS	1	N
		MOLALLA R	0118 - MOLALLA R	18	Y
		MOLALLA R	28 - SOUTH SANTIAM	8	N
		MOLALLA R	7 - MINTO PONDS	30	N
		SANTIAM R, S FK	0111 - SOUTH FORK SANTIAM R	10	Y
		SANTIAM R, S FK	17 - MCKENZIE	1	N
		SANTIAM R, S FK	28 - SOUTH SANTIAM	684	Y
		SANTIAM R, S FK	7 - MINTO PONDS	2	N
2016	MCKENZIE R	MCKENZIE R-1	012R - MCKENZIE R	17	Y
		MCKENZIE R-1	013R - S FK MCKENZIE R	6	Y
		MCKENZIE R-1	17 - MCKENZIE	798	Y
		ROW R (WILL R CST FK)	17 - MCKENZIE	2	N
		WILLAMETTE R CST FK	012R - MCKENZIE R	2	N
		WILLAMETTE R CST FK	013R - S FK MCKENZIE R	2	N
		WILLAMETTE R CST FK	17 - MCKENZIE	90	N
		WILLAMETTE R CST FK	19 - WILLAMETTE	2	N
	MID WILLAMETTE R	MID FK WILLAMETTE R	0112 - MIDDLE FORK WILLAMETTE SGS	6	Y
		MID FK WILLAMETTE R	19 - WILLAMETTE	354	Y
		WILLAMETTE R CST FK	17 - MCKENZIE	1	N
		DETROIT RES	7 - MINTO PONDS	10	Y
		SANTIAM R & N FK-1	01 - SANTIAM R MAINSTEM	1	Y
		SANTIAM R & N FK-1	011 - N FK SANTIAM R	8	Y
		SANTIAM R & N FK-1	17 - MCKENZIE	1	N
		SANTIAM R & N FK-1	28 - SOUTH SANTIAM	2	N
		SANTIAM R & N FK-1	7 - MINTO PONDS	245	Y
		MOLALLA R	011 - N FK SANTIAM R	2	N
		MOLALLA R	7 - MINTO PONDS	17	N
		SANTIAM R, S FK	0111 - SOUTH FORK SANTIAM R	17	Y
		SANTIAM R, S FK	17 - MCKENZIE	8	N
		SANTIAM R, S FK	28 - SOUTH SANTIAM	143	Y
		SANTIAM R, S FK	7 - MINTO PONDS	1	N

Section 3.1.8 Video Monitoring:

3.1.8.1 North Santiam (Upper and Lower Bennett Dams): Counts of spring Chinook salmon and other species passing upstream of Upper Bennett Dam and Lower Bennett Dam in 2015 and 2016 are provided in Table 22. Adipose clips on jack salmon could not readily be discerned because of the size of the fish and fin so those counts were pooled. The Lower Bennett video system was operated continuously from 1 May to 15 December in 2015 and from 1 May to 17 December in 2016. The Upper Bennett video system was operated continuously throughout both years. More detailed summary counts of passage at Upper and Lower Bennett dams are available online at http://www.dfw.state.or.us/fish/fish_counts/north_santiam/bennett_dams.asp.

3.1.8.2 McKenzie River (Leaburg Dam): Counts of spring Chinook salmon and other species passing upstream of Leaburg Dam in 2015 and 2016 are provided in Table 22. Both left-bank and right-bank video systems were operated continuously. More detailed summary counts of passage at Upper and Lower Bennett dams are available online at http://www.dfw.state.or.us/fish/fish_counts/leaburg_dam/index.asp.

Section 3.1.9 Harvest*:*

The estimated numbers of harvested Chinook salmon and other salmonids in upper Willamette River subbasins from 2000 through 2015 is provided in Table 23. Catch record reports for fisheries that occurred in 2016 have not yet been released. More detailed summary data on harvest statistics over many years are available online at http://www.dfw.state.or.us/resources/fishing/sportcatch.asp.

Table 22. Net number of marked and unmarked spring Chinook salmon (ChS) and other species counted at Upper (UB), Lower (LB) Bennett Dam and at Leaburg Dam in 2015 and 2016. Counts of jacks are provided but were not differentiated between marked (ad) and unmarked (Nm). StS = summer steelhead; StW = winter steelhead.

	StS	StW	St Total	ChS Ad	ChS Nm	ChS Jack	ChS Total	Lamprey	Coho	Coho Jacks
UB 2015	545	781	1,327	5,767	861	53	6,683	172	133	13
LB 2015	281	48	330	920	198	50	1,168	1	64	6
2015 TOTALS	826	829	1,657	6,687	1,059	103	7,851	173	197	19
UB 2016	3,934	680	4,614	3,118	761	61	3,940	379	347	55
LB 2016	1,470	132	1,602	827	157	15	999	18	148	39
2016 TOTALS	5,404	812	6,216	3,945	918	76	4,939	397	495	94
Leaburg 2015	251	11	262	914	1,544	6	2,464	35	0	0
Leaburg 2016	1,320	24	1,344	1,096	1,616	11	2,723	37	0	0

Table 23. Estimated salmonid harvest in upper Willamette River subbasins from catch record card reports, 2000 - 2015. Harvest data for 2016 are not yet available.

Subasin	Fish Species	00	01	02	03	04	05	06	07	08	09	10	11	12	13	14	15
N. Santiam																	
	Coho	0	0	0	0	0	0	0	0	0	0	7	0	24	82	70	24
	Fall Chinook	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0
	Spring Chinook	1,210	1,040	2,714	3,520	1,573	441	642	356	12	497	800	644	596	295	1,398	2,239
	Summer Steelhead	1,550	2,334	4,387	1,524	2,444	1,586	1,685	1,207	698	592	876	1,151	2,921	562	1,418	508
	Winter Steelhead	127	476	327	144	144	105	77	39	28	24	49	27	47	29	22	36
S. Santiam																	
	Coho	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	8
	Fall Chinook	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0
	Spring Chinook	1,372	2,320	4,074	2,864	4,169	1,118	1,113	333	67	731	2,204	1,372	1,717	634	556	1,027
	Summer Steelhead	4,231	5,478	5,086	2,546	5,120	2,087	4,404	2,245	1,755	3,581	4,305	2,859	5,134	2,109	2,845	214
	Winter Steelhead	66	108	32	20	38	14	19	11	11	13	26	9	12	15	3	3
Santiam Confluence																	
	Coho	0	0	0	0	0	0	0	0	0	0	0	0	0	0	10	0
	Fall Chinook	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0
	Spring Chinook	134	178	359	284	227	73	39	28	4	62	135	137	79	74	80	112
	Summer Steelhead	383	505	554	336	382	272	280	118	227	159	234	148	428	108	138	77
	Winter Steelhead	86	205	107	65	64	46	19	8	17	7	26	5	70	27	22	27
McKenzie																	
	Coho	0	0	0	0	0	0	0	0	0	0	0	0	0	0	10	16
	Fall Chinook	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0
	Spring Chinook	63	474	1,812	1,260	2,698	667	1,094	571	24	808	1,794	1,289	1,195	635	701	554
	Summer Steelhead	2,309	2,850	4,667	1,185	3,660	1,430	3,304	1,985	1,885	1,645	2,290	3,063	3,015	1,685	2,671	838
	Winter Steelhead	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0
Mid Fork Wil																	
	Coho	0	0	0	0	0	0	4	0	0	0	0	0	0	0	10	0
	Fall Chinook	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0
	Spring Chinook	1,224	1,316	2,301	1,888	3,845	1,488	2,300	737	12	784	3,828	833	789	543	431	2,014
	Summer Steelhead	855	2,907	5,529	2,599	5,710	2,625	3,208	2,276	1,799	2,038	4,291	4,555	4,165	2,073	4,286	926
	Winter Steelhead	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0
Coast Fork Wil																	
	Coho	0	0	0	0	0	0	0	0	0	0	0	0	0	0	45	48
	Fall Chinook	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0
	Spring Chinook	84	83	151	57	46	38	55	20	4	55	64	37	58	49	100	465
	Summer Steelhead	45	40	21	27	19	28	56	88	8	32	41	42	33	20	37	69
	Winter Steelhead	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0

Section 3.2: Reintroduction Efforts

Section 3.2.1 Number of Chinook Salmon Released Upstream of Dams*:*

In this section we outline outplanting records for 2015 and 2016. Additional detail is provided in Appendix 5.

3.2.1.1 North Santiam: Outplanting of adult Chinook salmon above Detroit Dam in the North Santiam in 2015 (Table 24) and 2016 (Table 25) was accomplished using the new Minto Fish Collection Facility. In 2015 both clipped and unclipped Chinook salmon were outplanted above Detroit Reservoir because the drought conditions in 2015 were likely to cause high prespawning mortality for any fish left in the lower river. Direct estimates of PSM from female carcasses collected above (12%) and below (63%) the projects support the decision to outplant some unclipped fish. However, it is likely that the direct estimates of PSM, at least above Detroit Reservoir, are biased low. If our assumption that each surviving female constructs approximately one redd then the number of females outplanted adjusted using the PSM rates should approximately equal the peak count of redds. In 2015 we outplanted 689 females, PSM was estimated as 12%; therefore we estimate 606 females survived to spawn (Table 26). The peak redd count in 2015 above Detroit Reservoir was 293, indicating that either our surveys missed a large proportion of redds or less than half of the females outplanted survived to spawn. A similar outcome was seen in 2016 when 804 females were outplanted; direct estimates of PSM were low (5%), and yet we observed only 481 redds.

3.2.1.2 South Santiam: In 2015 and 2016 all unclipped fish captured in the trap at the base of Foster Dam were DNA sampled and trucked to release sites above Foster Dam. Although only unclipped Chinook salmon were outplanted in 2015 and 2016, 24% and 33% of otoliths collected from carcasses during spawner surveys above Foster Dam indicated the fish were unclipped hatchery adults. A review of the fin clipping procedures for the 2011 and 2012 broods indicated that most of the fish were hand-clipped, a procedure known to be less efficient than automated clipping. Subsequent broods were fin-marked using the ODFW auto-trailers so returning adults in 2017 and thereafter will have a lower mismark rate. A summary of outplanting activities is provided in Tables 24 and 25.

3.2.1.3 McKenzie: The principal activities included outplanting to sites above Cougar Dam as part of a DNA pedigree study where hatchery-origin spring Chinook salmon were outplanted from the McKenzie Hatchery to supplement the small number of natural-origin spring Chinook salmon outplanted from a trapping operation below Cougar Dam (Tables 24 and 25). Results of a comparison between females outplanted and redds counted were similar to those obtained in the North Santiam (Table 26); outplanted females were "missing" in both years and the discrepancy was not fully explained by PSM estimated by recovery of carcasses.

3.2.1.4 Middle Fork Willamette: In 2015 and 2016 adult spring Chinook salmon were captured at the Dexter Dam trap and trucked to various release locations in the Middle Fork and North Fork Middle Fork in support of an ongoing project examining prespawning mortality rates. A relatively small number of fish (100) were outplanted in Little Fall Creek in 2015 and we continued spawning surveys in that tributary to assess the potential for recovery of the species there. No outplanting to Little Fall Creek occurred in in 2016. No surveys above Lookout Point and Hills Creek Reservoirs occurred in 2016.

Outplanting in Fall Creek was conducted by USACE staff, and involved transportation of only unclipped Chinook salmon fish above Fall Creek Reservoir. A summary of outplanting activities in the Middle Fork Willamette River is provided in Tables 24 and 25. Results of a comparison between females outplanted and redds counted were similar to those obtained in the North Santiam (Table 26); in both 2015 and 2016 outplanted females were "missing" and the discrepancy was not fully explained by PSM.

Table 24. Spring Chinook salmon outplanted, 2015.

Subbasin	Release Site Name	# Chinook Salmon Outplanted						
		Unclipped			Clipped			
		Males	Females	Jacks	Males	Females	Jacks	Total
North Santiam	Above Minto	99	69	3	0	0	0	171
	Breitenbush	0	0	0	313	313	0	626
	Horn Dr	53	42	0	0	0	0	95
	Dry Creek	257	122	3	206	212	0	800
	Totals	409	233	6	519	525	0	1,692
South Santiam	Calkins Park	19	19	0	0	0	0	38
	Gordon Road	197	141	3	0	0	0	341
	Riverbend	131	110	1	0	0	0	242
	Totals	347	270	4	0	0	0	621
South Fork McKenzie	430 Bridge (from McK Hatchery)	0	0	0	119	230	0	349
	Hard Rock (from Mck Hatchery)	0	0	0	81	170	0	251
	Hard Rock (from Cougar Dam trap)	86	52	1	14	4	0	157
	Totals	86	52	1	214	404	0	757
Middle Fork Willamette	Fall Creek	111	125	23	0	0	0	259
	Little Fall Creek	68	32	0	0	0	0	100
	Above Hills Cr Reservoir	0	0	0	1,115	724	58	1,897
	North Fork Middle Fork Willamette	0	0	0	553	533	0	1,086
	Totals	179	157	23	1,668	1,257	58	3,342

Table 25. Spring Chinook outplanted, 2016

Subbasin	Release Site Name	# Chinook Salmon Outplanted						
		Unclipped			Clipped			
		Males	Females	Jacks	Males	Females	Jacks	Total
North Santiam	Above Minto	307	214	8	0	0	0	529
	Breitenbush	0	0	0	146	321	0	467
	Horn Dr	0	0	0	30	30	0	60
	Dry Creek	0	0	0	258	453	0	711
	Totals	307	214	8	434	804	0	1,767
South Santiam	Calkins Park	0	0	0	0	0	0	0
	Gordon Road	150	98	0	0	0	0	248
	Riverbend	18	11	0	0	0	0	29
	Totals	168	109	0	0	0	0	277
South Fork McKenzie	Frissel Crossing (from McK Hatchery)	0	0	0	151	324	0	475
	Hard Rock (from Cougar Dam trap)	107	65	2	49	21	0	244
	Totals	107	65	2	200	345	0	719
Middle Fork Willamette	Fall Creek	201	185	38	0	0	0	424
	Above Hills Cr Reservoir	0	0	0	345	269	57	671
	North Fork Middle Fork Willamette	42	10	1	304	299	31	687
	Totals	243	195	39	649	568	88	1,782

Table 26. A comparison of estimates of live females after outplanting to peak redds observed in 2015 (top) and 2016 (bottom). Note that fewer redds were generally observed than estimated numbers of live female spawners.

Subbasin	Female Outplants 2015	Peak Redd Count	PSM	Estimated Surviving Females	% Discrepancy (Peak Redds/Live Females * 100)
North Santiam Above Detroit	689	293	0.12	606	48%
South Santiam Above Foster	270	174	0.4	162	107%
SF McKenzie Above Cougar	456	137	0.09	415	33%
Fall Creek	125	40	0.6	50	80%
NF Middle Fork Above Lookout	533	286	0.3	373	77%
MF Above Hills Cr. Reservoir	724	138	0.89	80	173%

Subbasin	Female Outplants 2016	Peak Redd Count	PSM	Estimated Surviving Females	% Discrepancy (Peak Redds/Live Females * 100)
North Santiam Above Detroit	804	481	0.05	764	63%
South Santiam Above Foster	109	162	0.11	97	167%
SF McKenzie Above Cougar	410	293	0	410	71%
Fall Creek	185	98	0.15	157	62%
NF Middle Fork Above Lookout	309	NA	NA	NA	NA
MF Above Hills Cr. Reservoir	269	NA	NA	NA	NA

Section 3.2.2 Origin of Chinook Salmon Released Upstream of Dams:

3.2.2.1 North Santiam above Detroit Dam: In 2015 both adipose-clipped and unclipped Chinook salmon were outplanted above Detroit Dam. Unclipped fish were outplanted because poor holding conditions below the projects would very likely have precipitated high prespawn mortality. We estimated that pHOS in 2015 above Detroit Dam was 72.6% (Table 20). An additional 171 unclipped fish were passed above Minto in 2015.

Only adipose-clipped adult Chinook salmon were outplanted above Detroit Reservoir in 2016; pHOS was 100% (Table 20). An additional 529 unclipped fish were passed above Minto Dam.

3.2.2.2 South Santiam above Foster Dam: In 2015 and 2016 only adipose-intact fish were outplanted from the Foster Dam trap to the South Santiam River above the dam and only adipose clipped carcasses were recovered. Analyses were conducted on otoliths collected during pre-spawning mortality and spawner surveys. We found thermal marks on 51 of the 165 readable otoliths from carcasses sampled above Foster Dam during prespawn mortality and spawner surveys (Table 19). Therefore, we estimate that pHOS above Foster Dam in 2015 was 23.6% (Table 20).

In 2016 28 of the 84 readable otoliths were thermally marked indicating that pHOS was 33.3% (Table 20).

3.2.2.3 S. Fork McKenzie above Cougar Dam: A mixture of marked and unmarked fish were released above Cougar Dam in the South Fork McKenzie River in 2015 and 2016. Because of low carcass recovery rates only two otoliths samples were recovered in 2015 and only four were recovered in 2016. None were thermally marked (Table 19). We estimate that pHOS in 2015 and 2016 was 80.0% and 91.3% (Table 20).

3.2.2.4 Fall Creek above Fall Creek Dam and Middle Fork Willamette above Dexter Dam: In 2015 and 2016 only clipped fish were recorded as outplanted above Dexter Dam and pHOS was 100% in both years. In Fall Creek only unclipped fish were outplanted but in both 2015 and 2016 single otolith-marked unclipped CHS carcasses were recovered and pHOS was estimated as 4.5% and 4.0%.

Section 3.3 Broodstock Sampling at Hatcheries

Section 3.3.1 Origin of Broodstock:

3.3.1.1 North Santiam: All broodstock for the North Santiam Hatchery program were collected at the new Minto Dam Fish Collection Facility. All broodstock were clipped hatchery fish; pNOB in 2015 and 2016 was zero.

3.3.1.2 South Santiam: All broodstock for the South Santiam Hatchery program were collected at the Foster Dam trap in 2015 and 2016. Only adipose clipped fish are incorporated into the South Santiam broodstock. Therefore, in 2015 and 2016 pNOB was zero.

3.3.1.3 McKenzie: All broodstock for the McKenzie Hatchery program in 2015 and 2016 were collected at the hatchery. Only adipose clipped fish are incorporated into the broodstock. Therefore, in 2015 and 2016 pNOB was zero.

3.3.1.4 Middle Fork Willamette: All broodstock for the Willamette Hatchery program in 2014 were collected at the Dexter trap. Only adipose clipped fish are incorporated into the broodstock. Therefore, in 2015 and 2016 pNOB was zero.

Section 3.3.2 Broodstock Collection, Disposition, Age, and Size Distributions:

3.3.2.1 North Santiam: Collection timing of broodstock for the North Santiam hatchery program is provided in Table 27. A comparison of broodstock collection timing to the timing that unclipped and clipped Chinook entered the trap in 2015 and 2016 is provided in Figure 8. In 2015 the collection of clipped fish for broodstock closely followed the timing that clipped and unclipped fish entered the trap. In 2016 broodstock collection timing closely matched timing of unclipped fish entering the trap. Of the broodstock collected in 2015 and 2016 (Table 27), 968 and 462 fish were spawned.

We also compared the size and age of fish used as broodstock (Tables 28, 29 and 30) in the North Santiam Hatchery program in 2015 and 2016 to size and age of natural origin spawners

(NOS) in the North Santiam River. We found no statistically significant difference in size between HOR broodstock and naturally spawning NORs but NORs were older in 2015 and younger in 2016.

3.3.2.2 South Santiam: There was little indication that the timing of broodstock collection in 2014 differed either from run timing of wild fish and availability of fish for collection into brood (Figure 8). Of the broodstock collected in 2015 and 2016 (Table 27), 924 and 488 fish were spawned.

We also compared the size and age of fish used as broodstock in the South Santiam Hatchery program in 2015 and 2016 to size and age of natural origin spawners (NOS) in the South Santiam River (Tables 28, 29 and 30). We found no statistically significant difference in size between HOR broodstock and naturally spawning NORs but NORs were older in 2016.

3.3.2.3 McKenzie: In 2015 collection timing of broodstock closely followed the timing of entry of clipped fish into the hatchery and unclipped fish passing Leaburg Dam (Figure 8). Of the broodstock collected in 2015 and 2016 (Table 27), 1,032 and 445 fish were spawned.

We also compared the size and age of fish used as broodstock in the McKenzie Hatchery program in 2015 and 2016 to size and age of natural origin spawners (NOS) in the McKenzie River (Tables 28, 29 and 30). We found no statistically significant difference in size between HOR broodstock and naturally spawning NORs in 2015 but NORs were larger in 2016. The HOR broodstock were significantly older in 2015 but we saw no difference in age in 2016.

3.3.2.4 Middle Fork Willamette: Collection timing of broodstock (Table 27) for the Middle Fork Willamette Hatchery program in 2015 was earlier than overall timing of clipped and unclipped fish entry into the trap at Dexter Dam (Figure 8). In 2016, broodstock were collected with timing similar to entry of all clipped fish but earlier than the timing of clipped fish into the trap. Of the broodstock collected in 2015 and 2016 (Table 27), 932 and 419 fish were spawned.

We also compared the size and age of fish used as broodstock in the Middle Fork Willamette Hatchery program in 2015 and 2016 to size and age of natural origin spawners (NOS) in the Middle Fork Willamette River (Tables 28, 29 and 30. The NOR spawners were larger in 2015

Table 27. Collection timing of Chinook salmon brood in 2015 and 2016. All fish were ad-clipped.

2015 Date	NSNT	SSNT	McK	MFW	2016 Date	NSNT	SSNT	McK	MFW
4/22/15		1			4/20/16		1		
4/29/15		109			4/27/16	1			
5/6/15		101	326		5/4/16				
5/13/15	9	797	165	776	5/11/16	1			
5/20/15	3	162	83	0	5/18/16				
5/27/15	58	352	200	1,302	5/25/16		45		
6/3/15	195	286	477	322	6/1/16		102		682
6/10/15	310	280	97		6/8/16	191		162	686
6/17/15		183	18		6/15/16	13	28	193	681
6/24/15	153	475	94	447	6/22/16	90	27	207	
7/1/15	196	24	77	47	6/29/16	121	61	203	
7/8/15	280	83		215	7/6/16	584	198	280	
7/15/15	226	16		117	7/13/16	218	378	69	
7/22/15	19	54		123	7/20/16	299	155	108	
7/29/15	110	30		77	7/27/16	131	10	119	
8/5/15	91	15		0	8/3/16	53	8	87	
8/12/15	51	17			8/10/16	17	19	36	
8/19/15	62	27			8/17/16	58	141	44	281
8/26/15	155	40			8/24/16	24	26	30	
9/2/15	192	37		266	8/31/16	19	74		199
9/9/15	210	3	14		9/7/16	289	372	183	68
9/16/15	225	85	36		9/14/16	262	303	174	
9/23/15	98	63	37		9/21/16	31	127	202	12
9/30/15			5		9/28/16	23	18	155	

Table 28. Age structure of Chinook salmon collected as brood at UWR hatcheries in 2015 and 2016.

Stock & Brood	Count by Total Age			
	3	4	5	6
N Santiam 2015	2	996	401	1
N Santiam 2016	5	24	243	2
S Santiam 2016	9	99	38	0
S Santiam 2015	11	654	36	0
McKenzie 2015	9	1,529	918	4
McKenzie 2016	25	360	477	7
Middle Fork 2015	3	1,157	159	0
Middle Fork 2016	0	150	205	0
	Percent by Total Age			
	3	4	5	6
N Santiam 2015	0%	71%	29%	0%
N Santiam 2016	2%	9%	89%	1%
S Santiam 2016	6%	68%	26%	0%
S Santiam 2015	2%	93%	5%	0%
McKenzie 2015	0%	62%	37%	0%
McKenzie 2016	3%	41%	55%	1%
Middle Fork 2015	0%	88%	12%	0%
Middle Fork 2016	0%	42%	58%	0%

Table 29. Size distribution of Chinook salmon collected as brood in 2015 and 2016.

Stock & Brood	Mean FL (cm)	SD	N
N Santiam 2015	77.0	77.6	1,567
N Santiam 2016	82.0	79.5	374
S Santiam 2015	75.6	59.0	757
S Santiam 2016	75.2	81.9	180
McKenzie 2015	74.8	64.0	2,634
McKenzie 2016	74.8	113.9	985
Middle Fork 2015	71.2	56.3	1,595
Middle Fork 2016	73.2	71.0	380

Table 30. Comparison of size and age between Chinook salmon used for broodstock and NOR Chinook salmon sampled during spawning ground surveys in 2015 and 2016. Statistically significant differences (Mann-Whitney rank sum test) are in bold text.

Subbasin	Year	HOR Brood Median Size (FL: cm)	NOR Median Size (FL: cm)	M-W *P* for Size	Brood Median Age	NOR Median Age (FL: cm)	M-W *P* for Age
N. Santiam	2015	81.0	78.5	0.067	4	5	**<0.001**
	2016	82.0	83.0	0.868	5	4	**<0.001**
S. Santiam	2015	80.0	79.0	0.073	4	4	0.231
	2016	78.0	79.0	0.827	4	4	**0.007**
McKenzie	2015	79.6	80.0	0.883	5	4	**<0.001**
	2016	80.0	81.0	**0.049**	5	5	0.607
MF Will.	2015	72.0	75.0	**<0.001**	4	4	**0.011**
	2016	74.0	76.0	0.165	5	4	**<0.001**

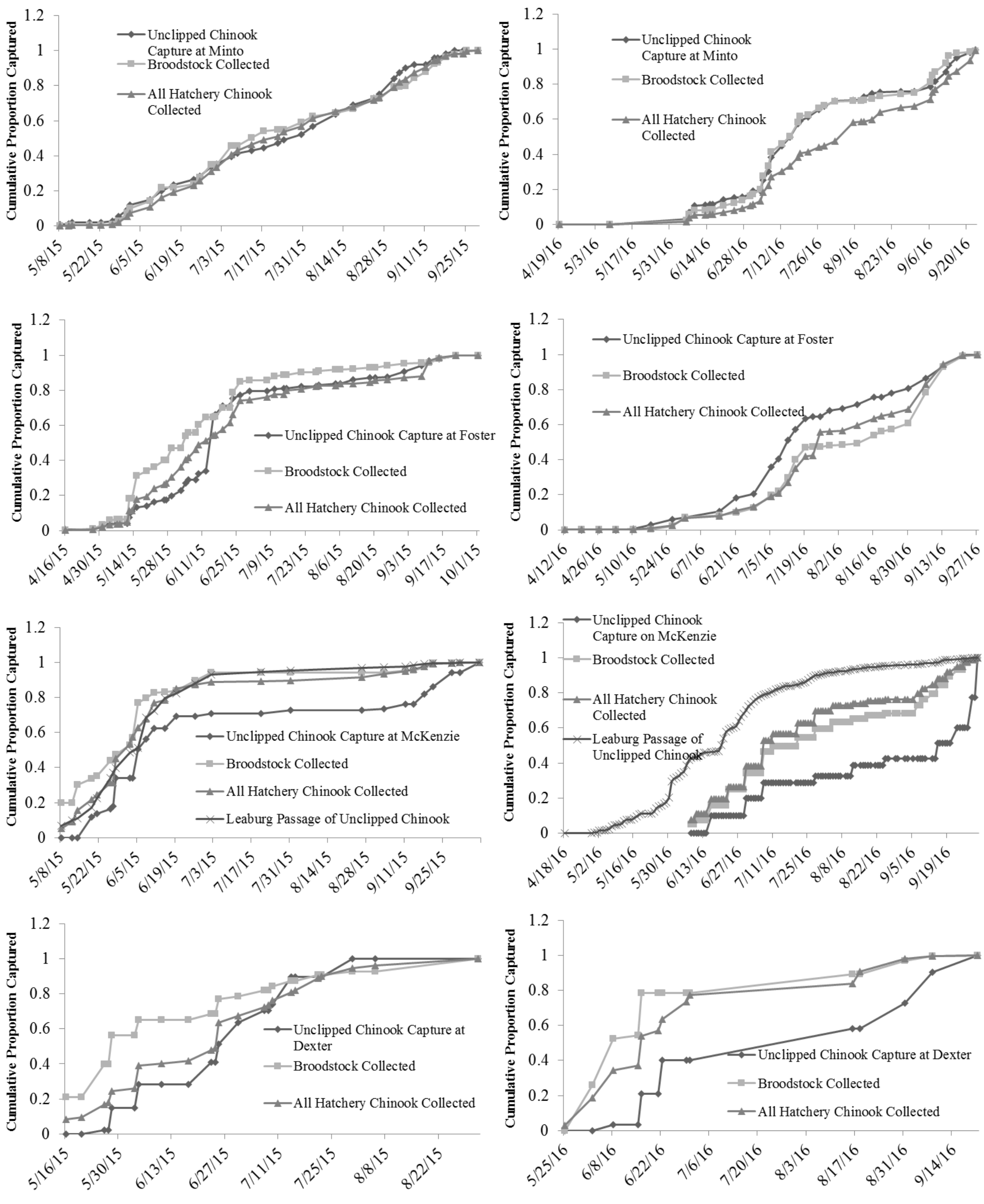

Figure 8. Comparison of broodstock collection timing to run timing of clipped and unclipped Chinook salmon in 2015 and 2016. Note different x-axis scales.

but overall were significantly younger. We saw no difference in size in 2016 but, as in 2015, HOR broodstock were older than NOR spawners.

Section 3.4 Juvenile Monitoring at Hatcheries

Section 3.4.1 Juvenile Production Program Goals: Target smolt numbers for release from upper Willamette River hatcheries are provided in general terms in the relevant HGMPs and, each year, in the Hatchery Operations Plans published online at http://www.dfw.state.or.us/fish/hatchery/ as are the actual production figures for the prior year (available at the same site). Here we provide the projected and actual juvenile production in 2015 and 2016 in flowcharts modified from the annual Hatchery Operations Plans (Figures 9 – 38) and summarized in Table 31. Greater detail is available in the actual plans and reports.

3.4.1.1 North Santiam (Marion Forks Hatchery): Programmed production at the Marion Forks Hatchery in 2015 was as shown in Figure 9 for comparison to actual releases (Figure 10) and in Figures 11 and 12 for 2016.

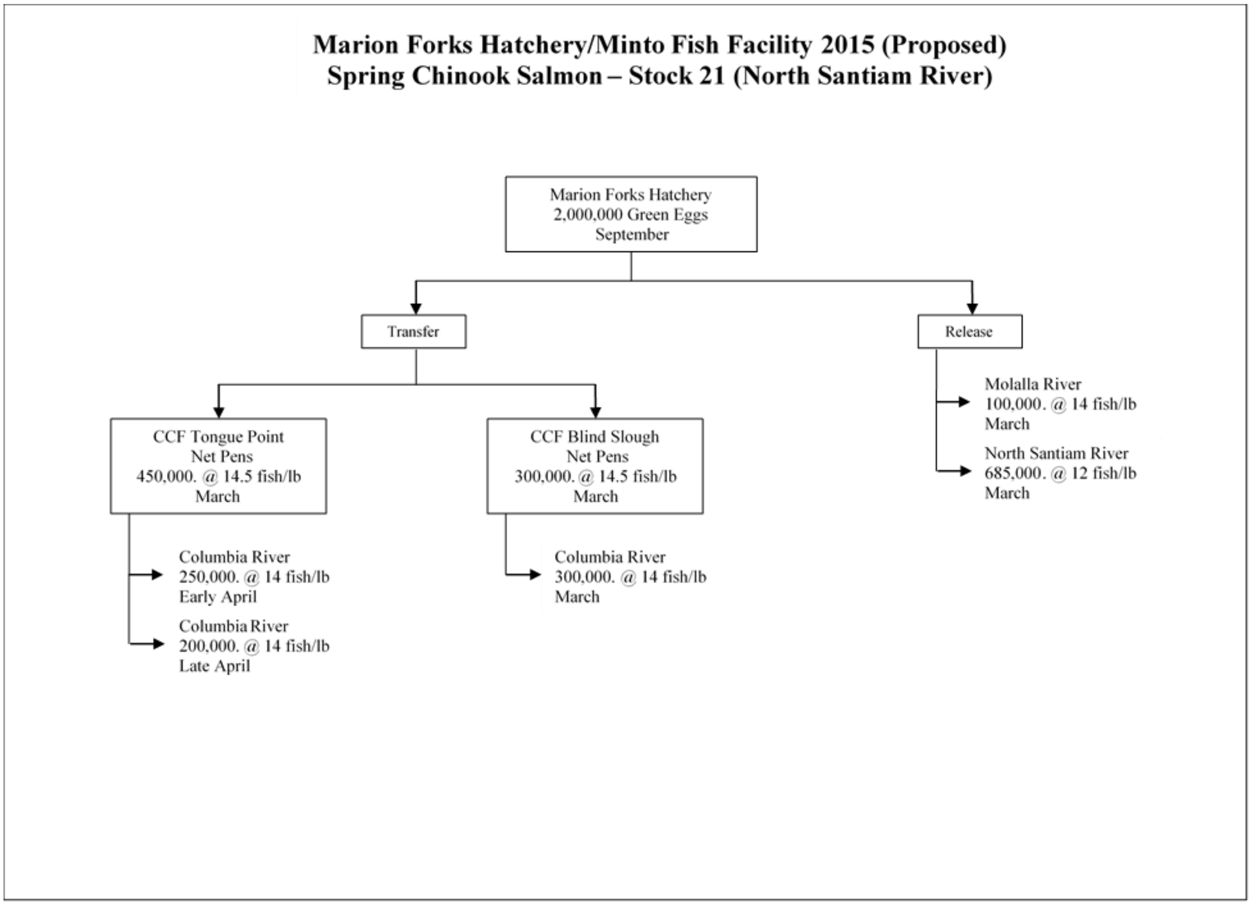

Figure 9. Projected North Santiam spring Chinook salmon production goals, 2015.

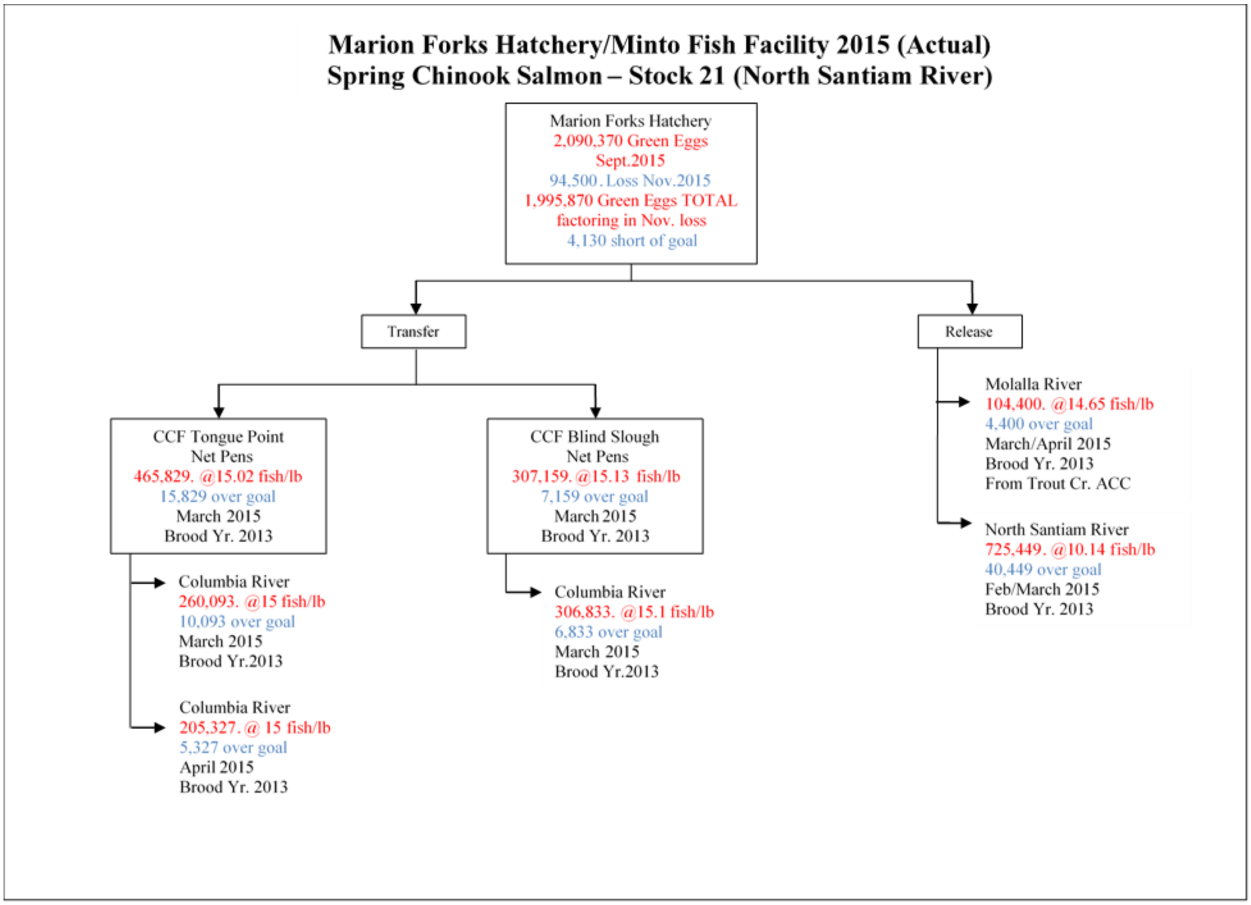

Figure 10. Realized North Santiam spring Chinook salmon production, 2015.

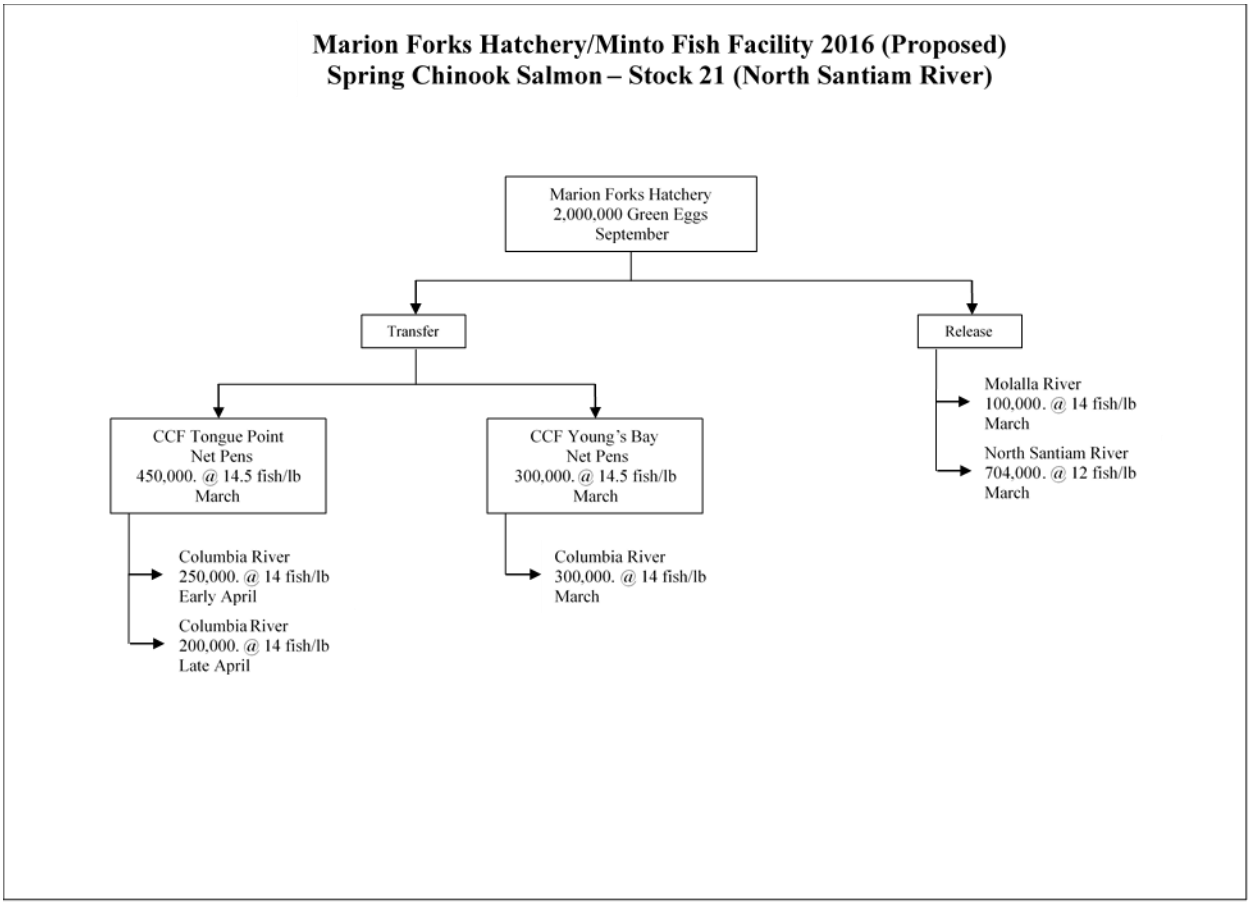

Figure 11. Projected North Santiam spring Chinook salmon production goals, 2016.

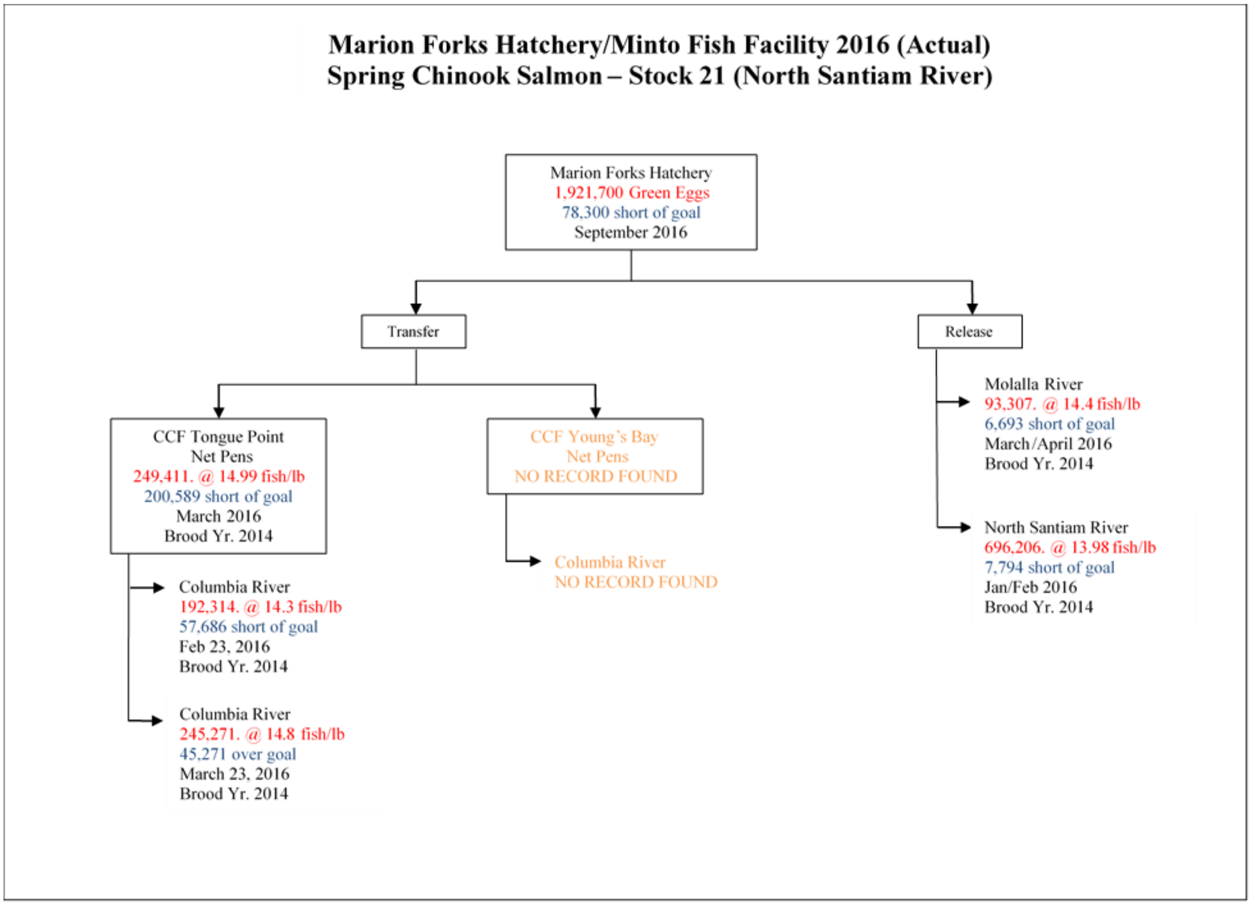

Figure 12. Realized North Santiam spring Chinook salmon production goals, 2016.

3.4.1.1 South Santiam Hatchery: Programmed production for Chinook salmon at the South Santiam Hatchery in 2015 was as shown in Figure 13 for comparison to actual releases (Figure 14) and in Figures 15 and 16 for 2016. Figures 17 through 20 provide comparable information for steelhead trout production.

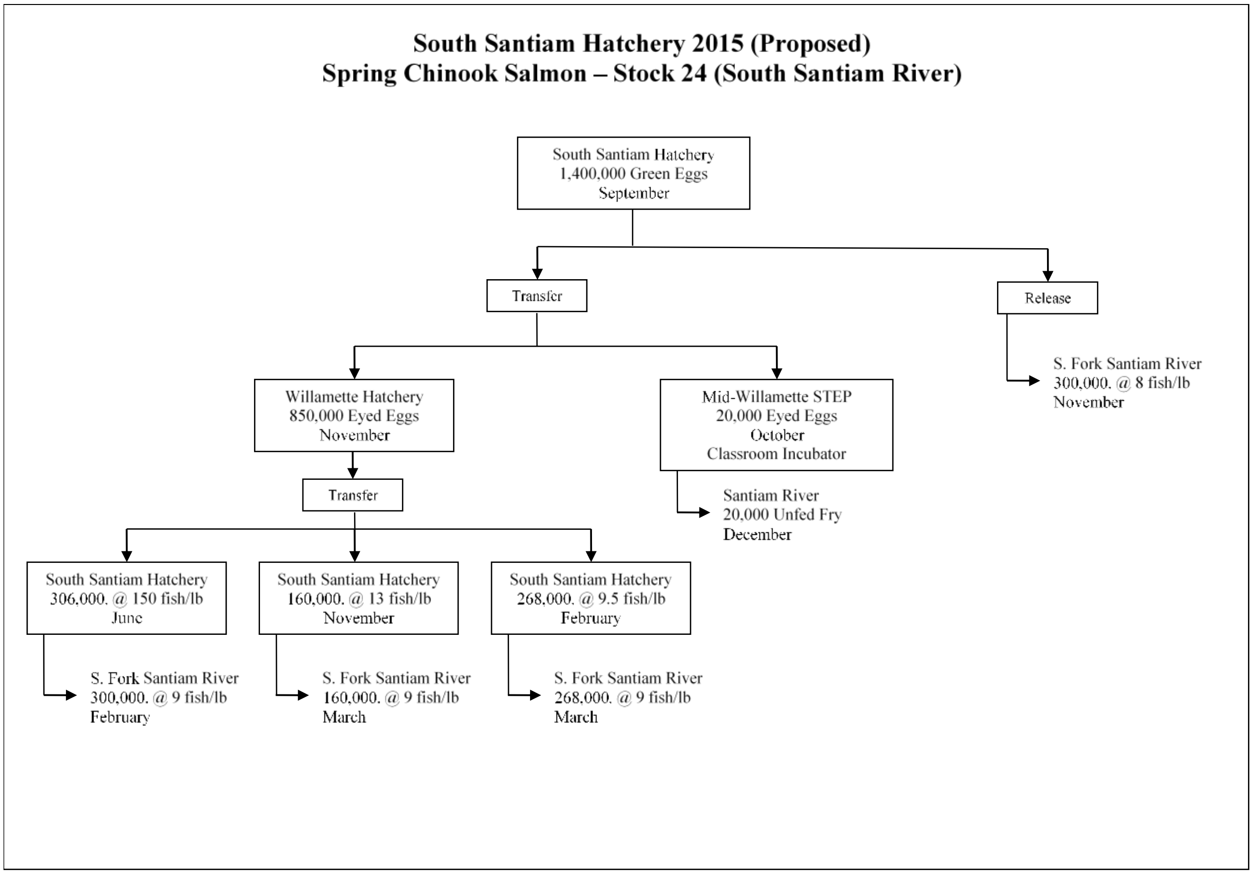

Figure 13. Projected South Santiam spring Chinook salmon production goals, 2015

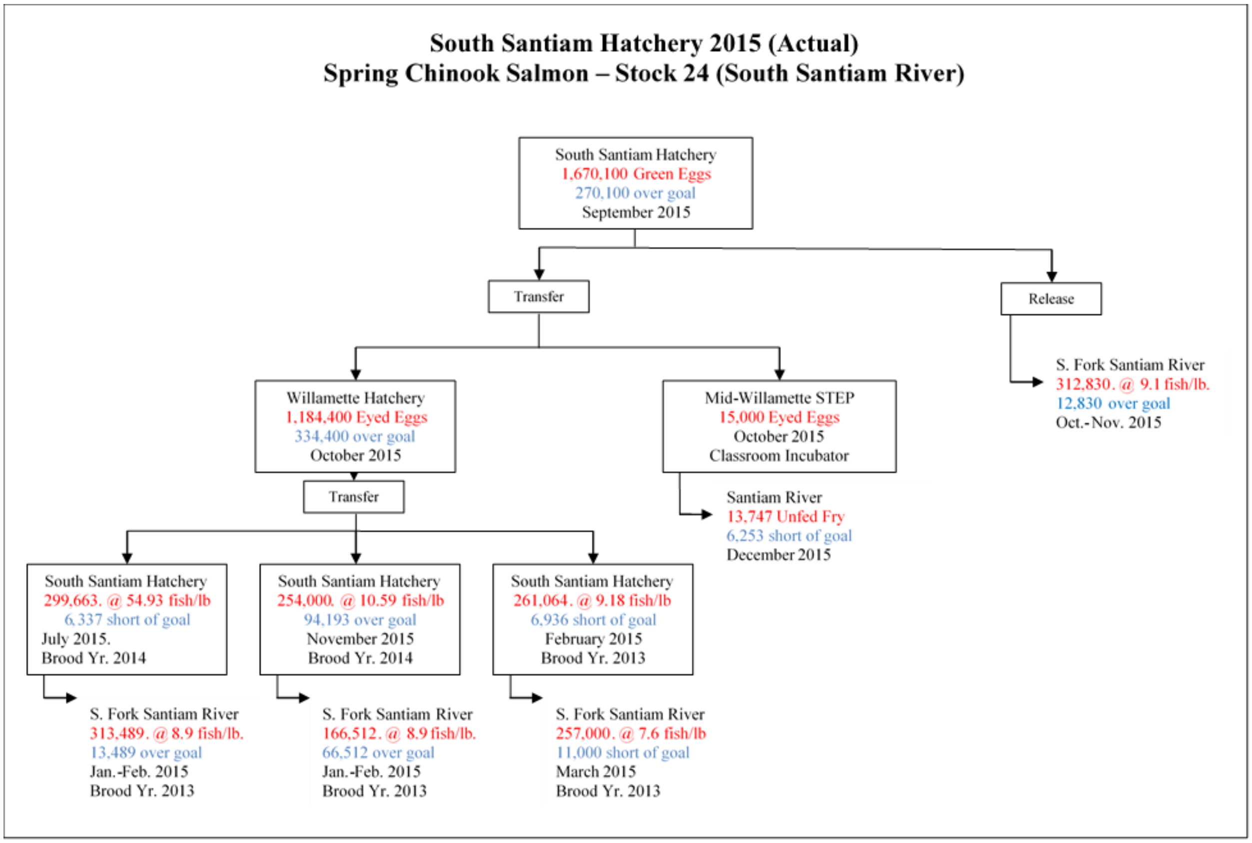

Figure 14. Realized South Santiam spring Chinook salmon production goals, 2015

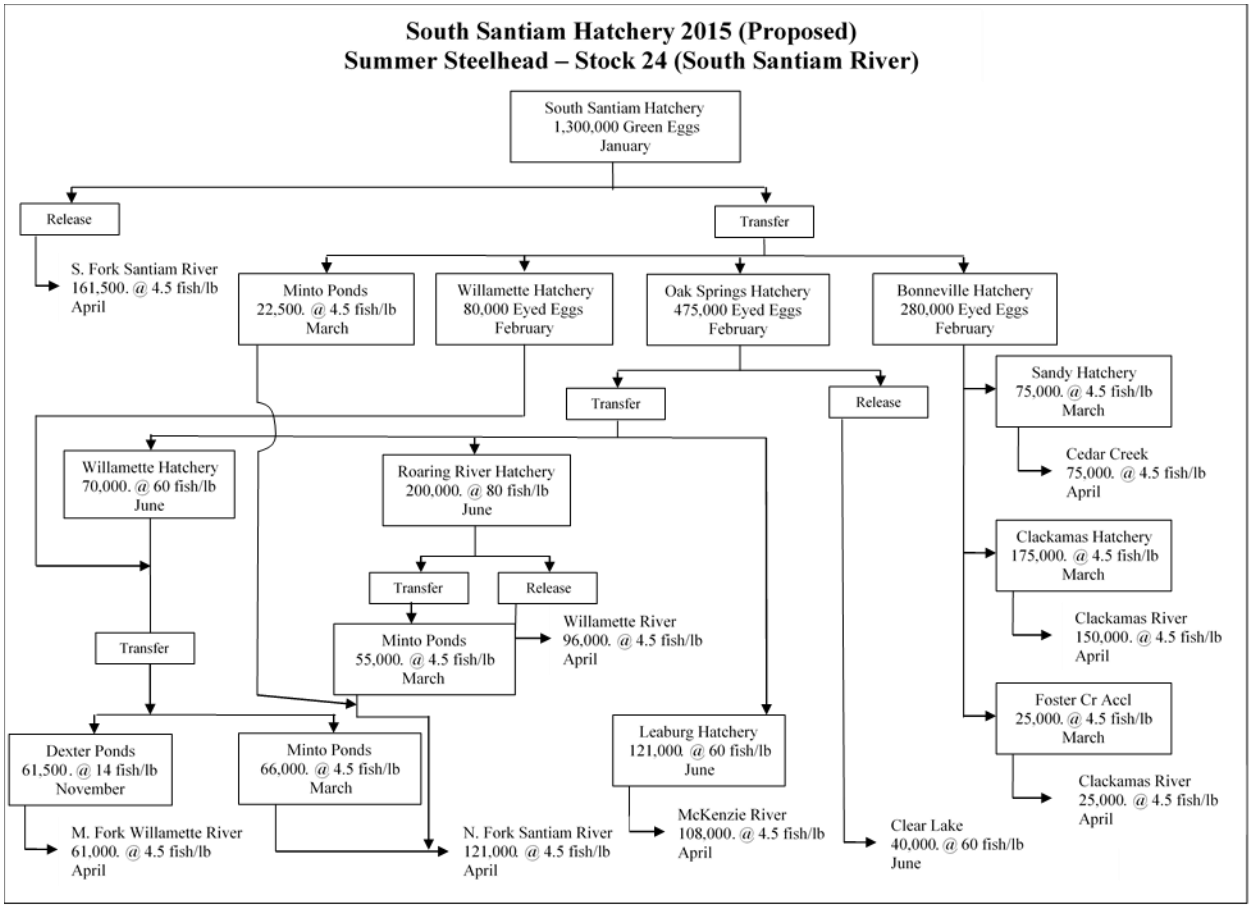

Figure 15. Projected South Santiam summer steelhead production goals, 2015.

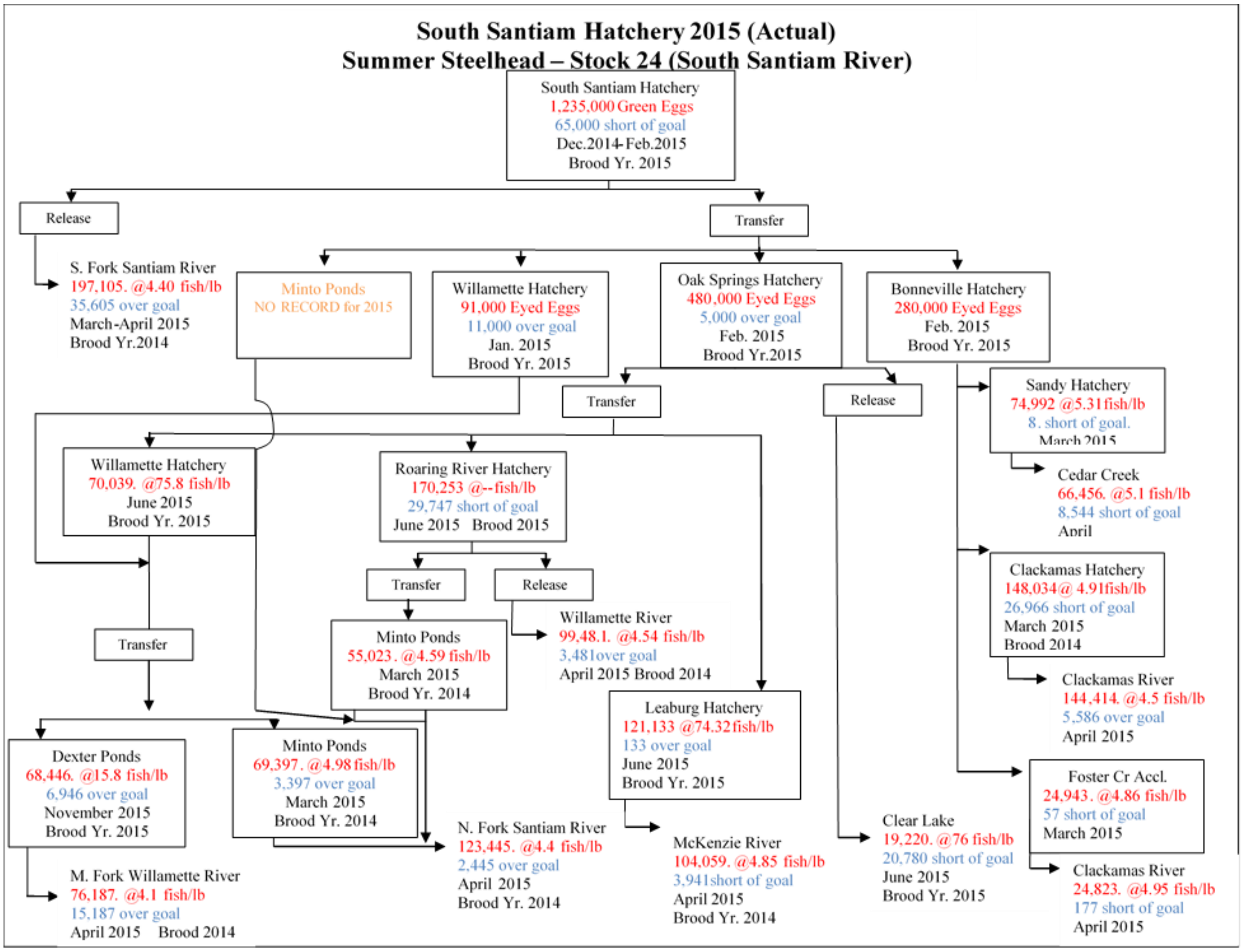

Figure 16. Realized South Santiam summer steelhead production goals, 2015.

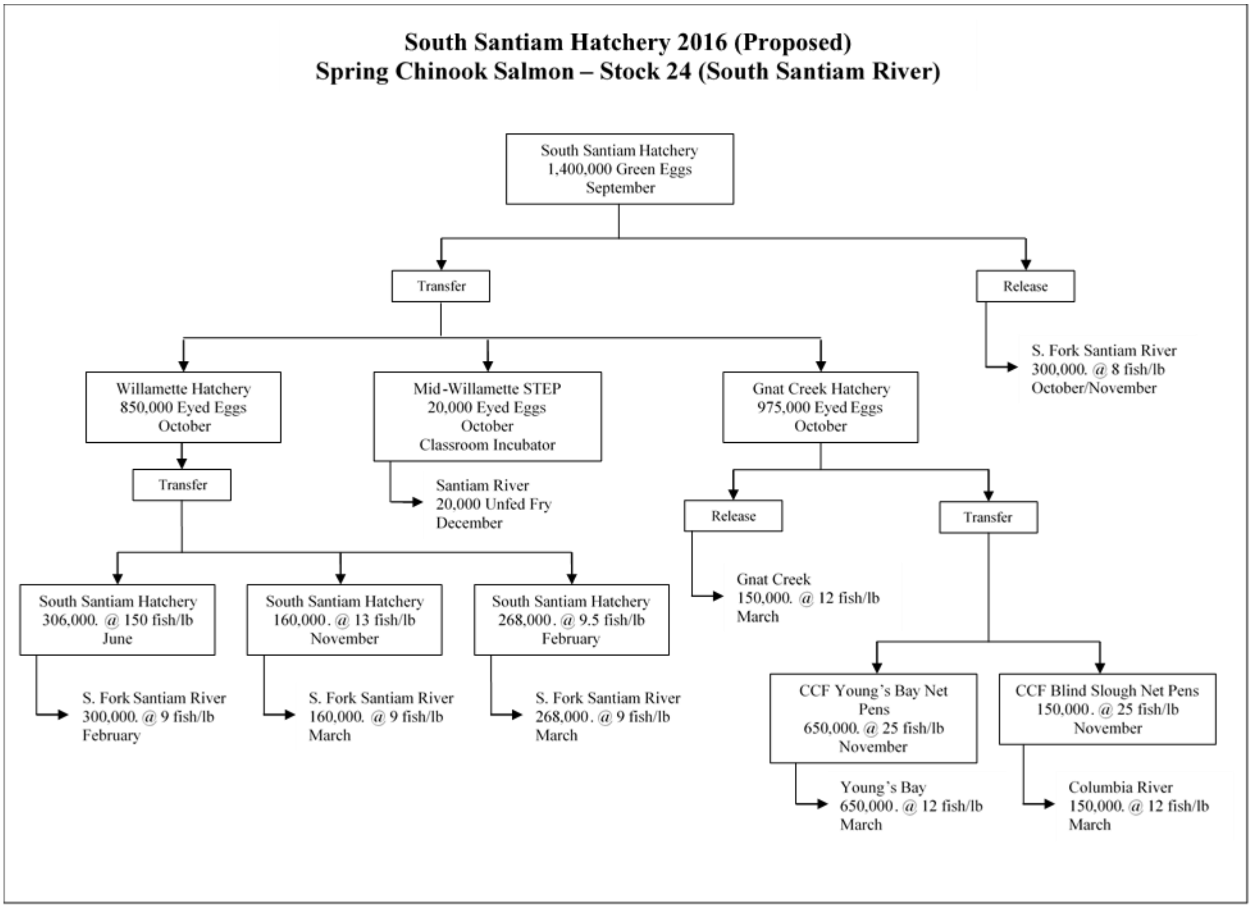

Figure 17. Projected South Santiam spring Chinook salmon production goals, 2016.

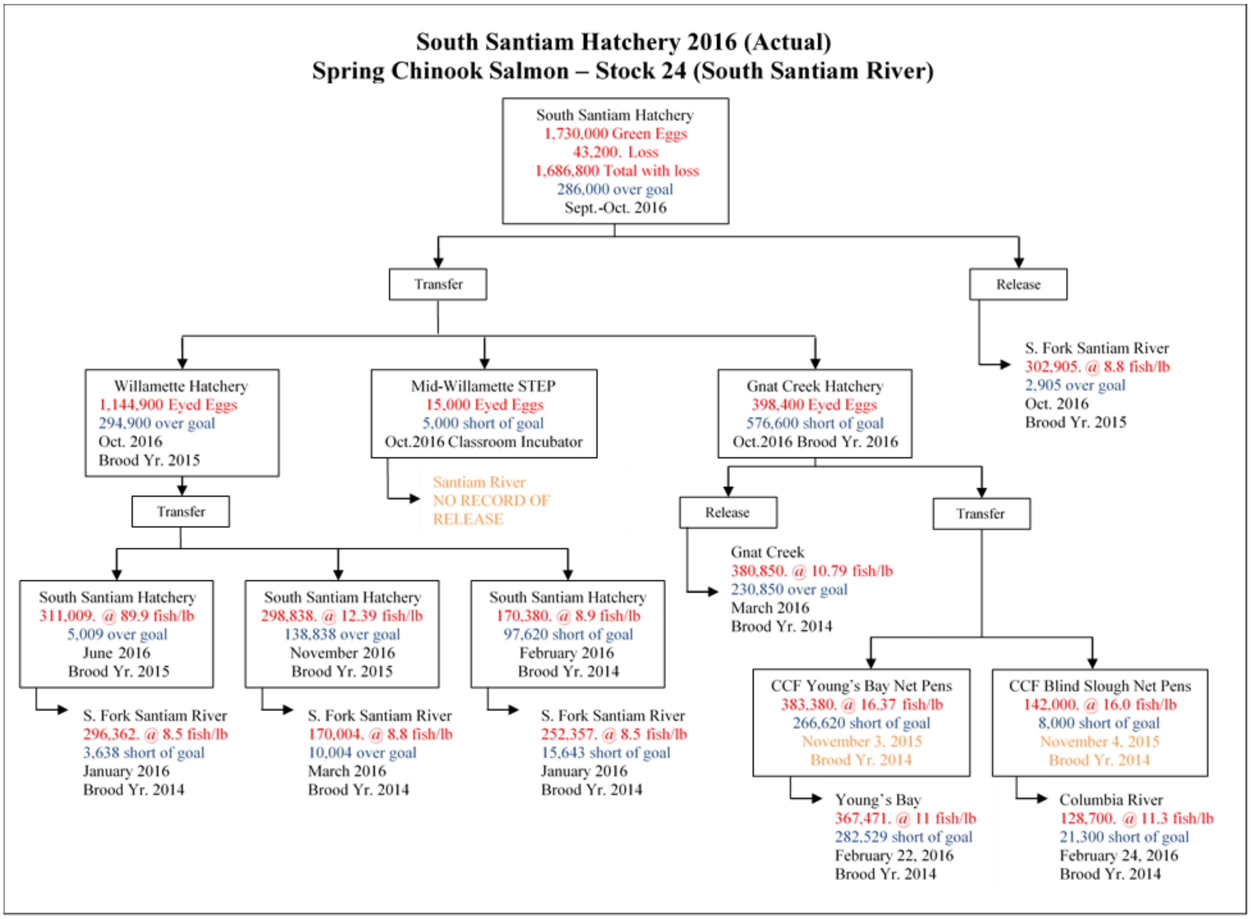

Figure 18. Realized South Santiam spring Chinook salmon production goals, 2016.

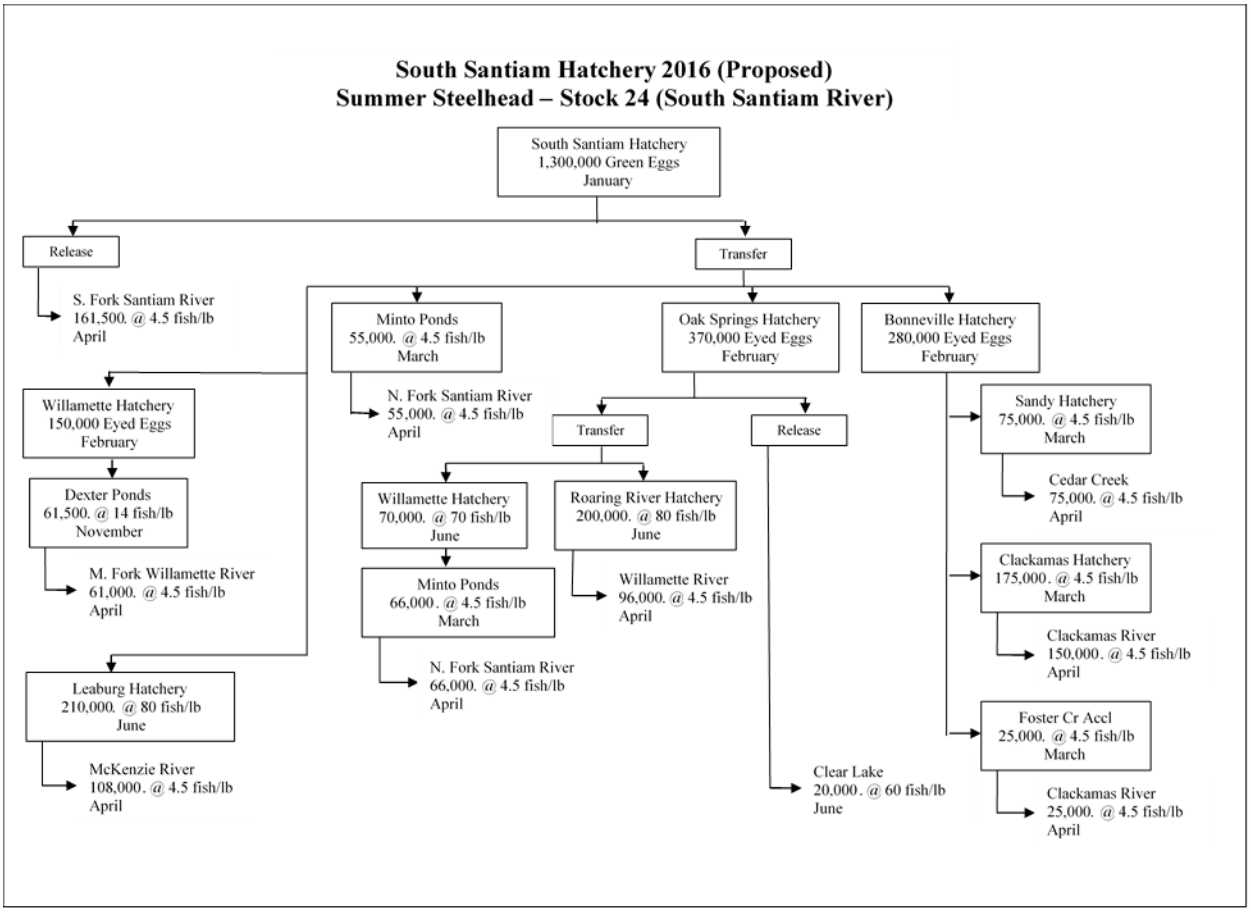

Figure 19. Projected South Santiam summer steelhead production goals, 2016.

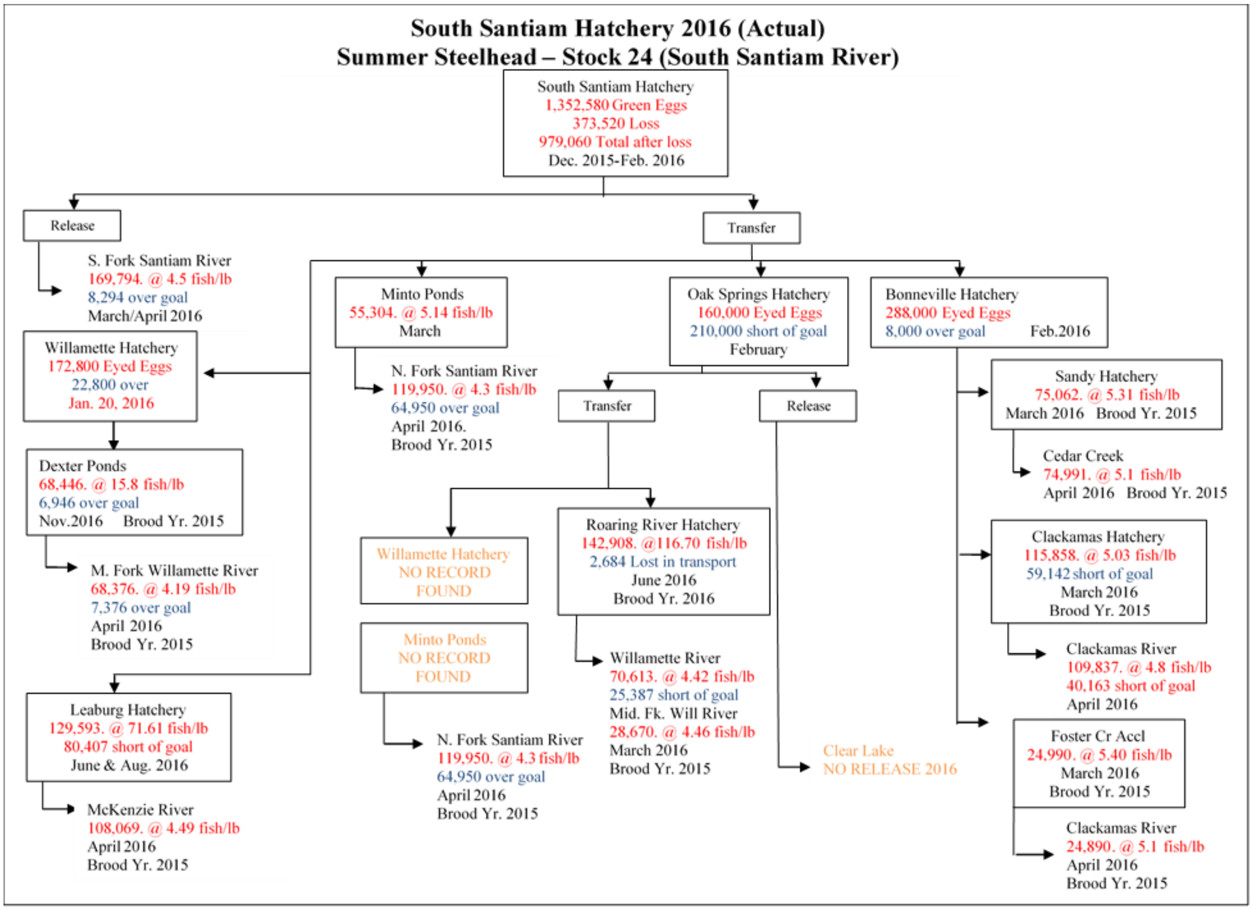

Figure 20. Realized South Santiam summer steelhead production goals, 2016.

3.4.1.1 McKenzie Hatchery: Programmed production at the McKenzie Hatchery in 2015 was as shown in Figure 21 for comparison to actual releases (Table 22). Figures 23 and 24 provide similar information for production in 2016.

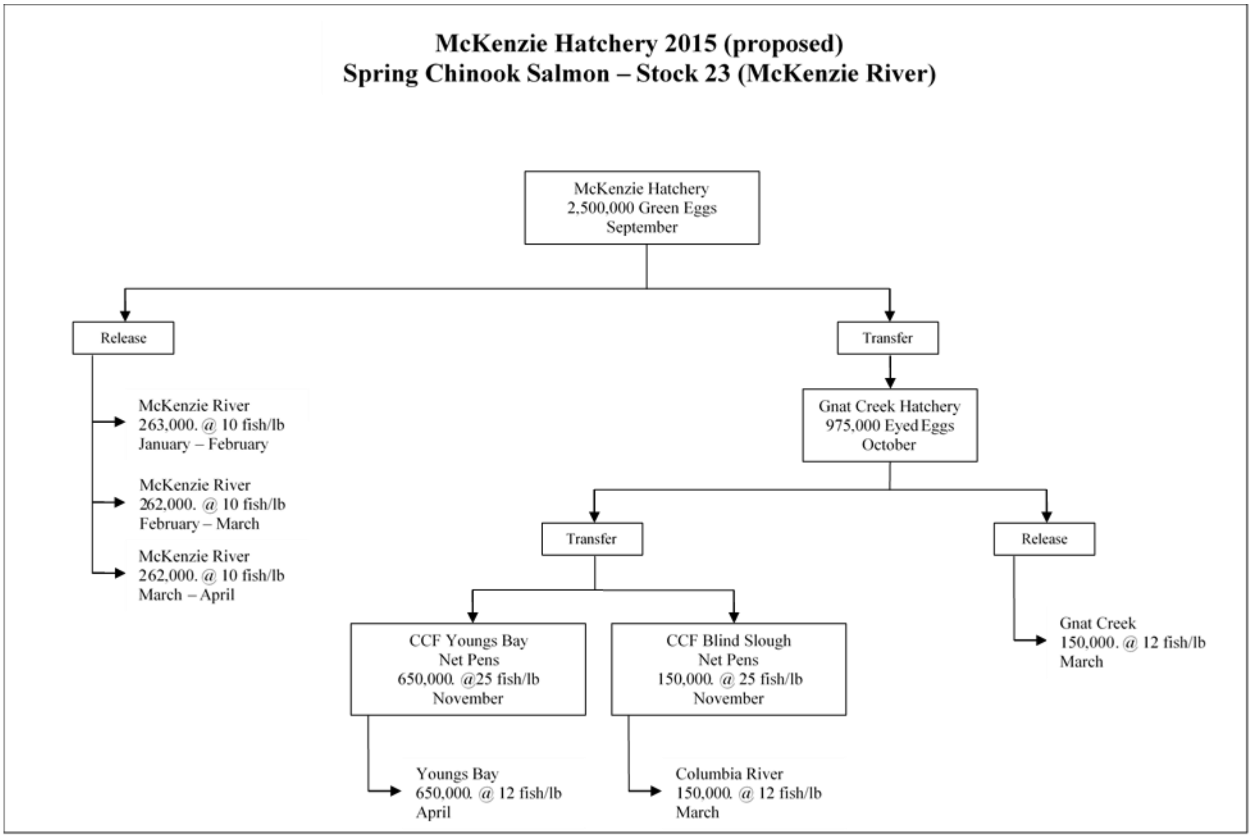

Figure 21. Projected McKenzie Hatchery spring Chinook salmon production goals, 2015.

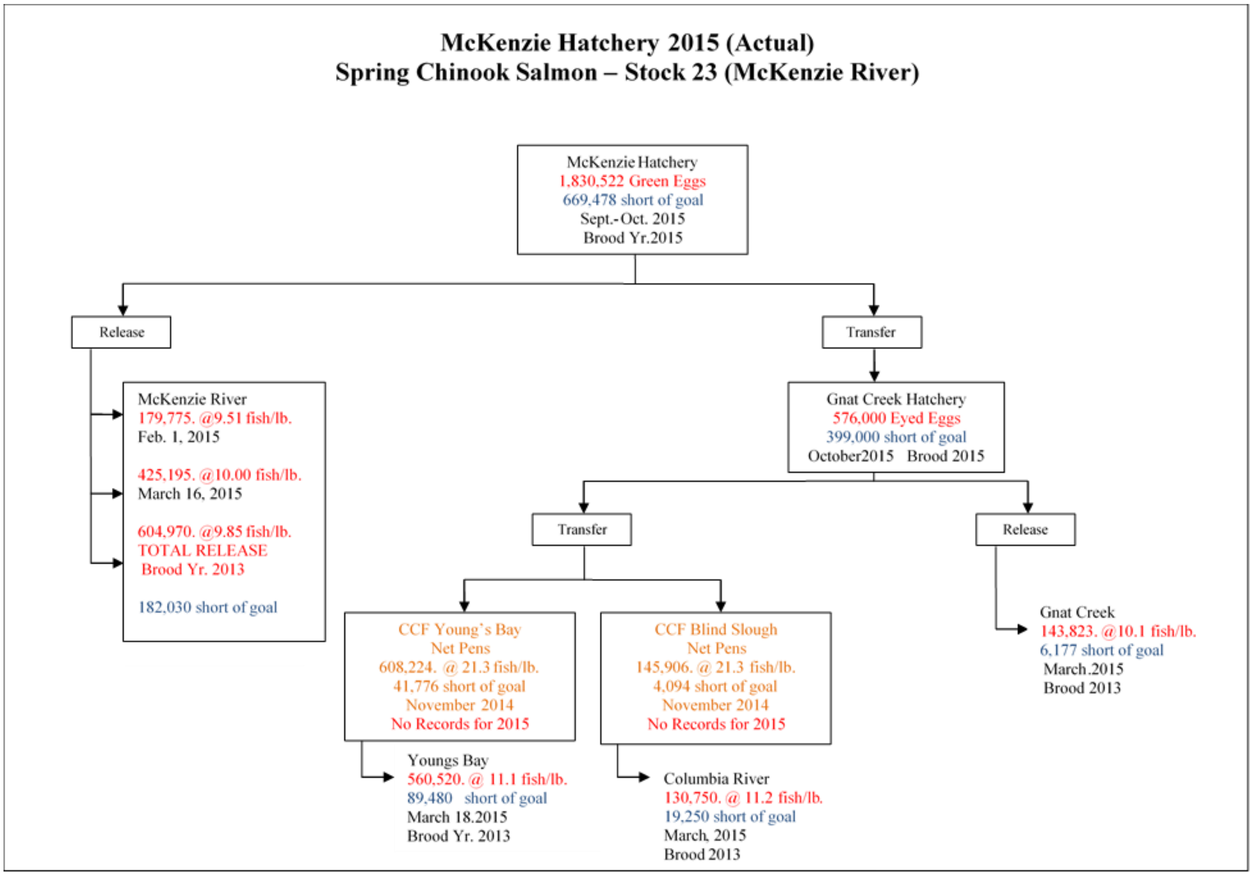

Figure 22. Realized McKenzie Hatchery spring Chinook salmon production, 2015.

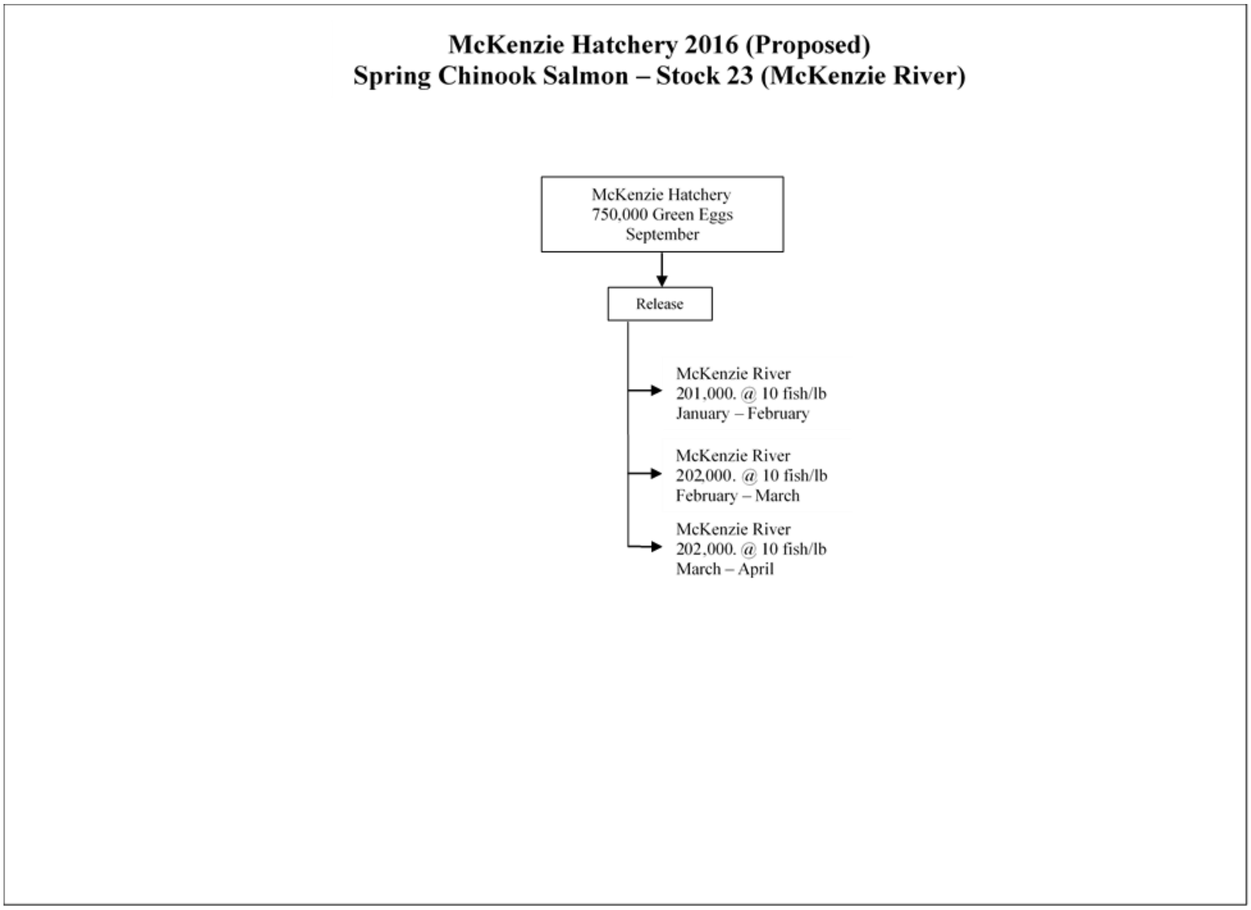

Figure 23. Projected McKenzie Hatchery spring Chinook salmon production goals, 2016.

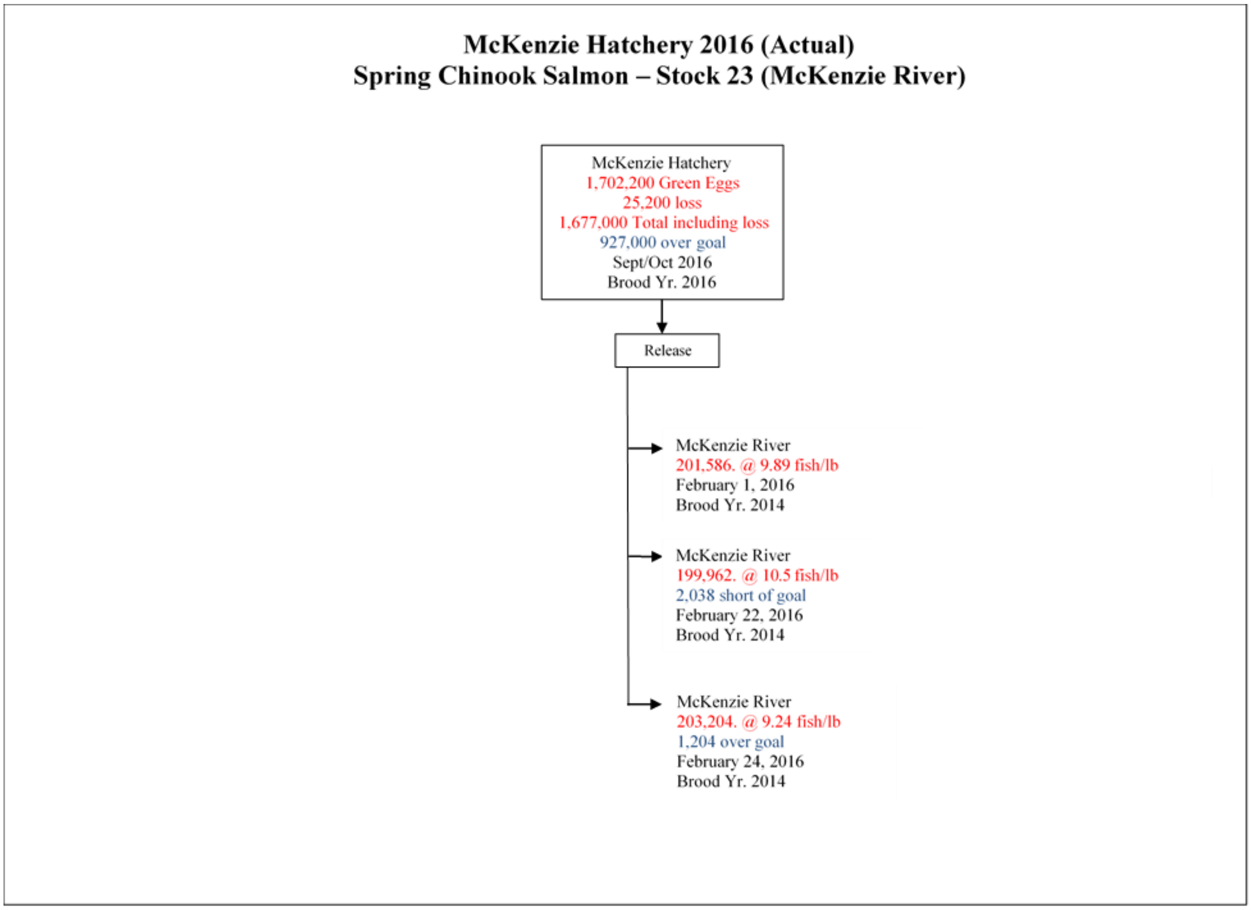

Figure 24. Realized McKenzie Hatchery spring Chinook salmon production goals, 2016.

3.4.1.1 Leaburg Hatchery: Programmed production at the Leaburg Hatchery in 2015 was as shown in Figure 25 for steelhead trout for comparison to actual releases (Figure 26). Figures 27 and 28 provide similar information for production in 2016.

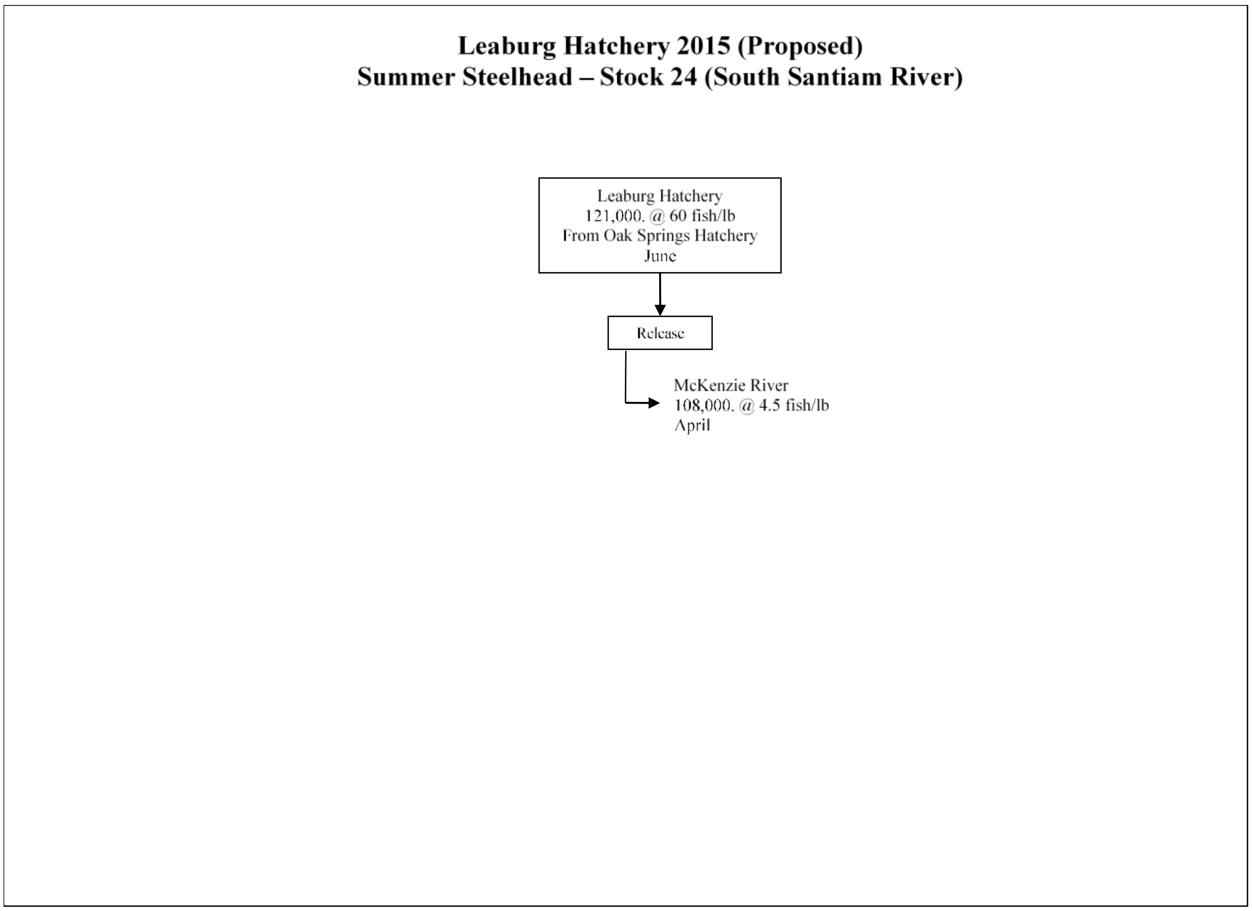

Figure 25. Projected Leaburg Hatchery summer steelhead production goals, 2015.

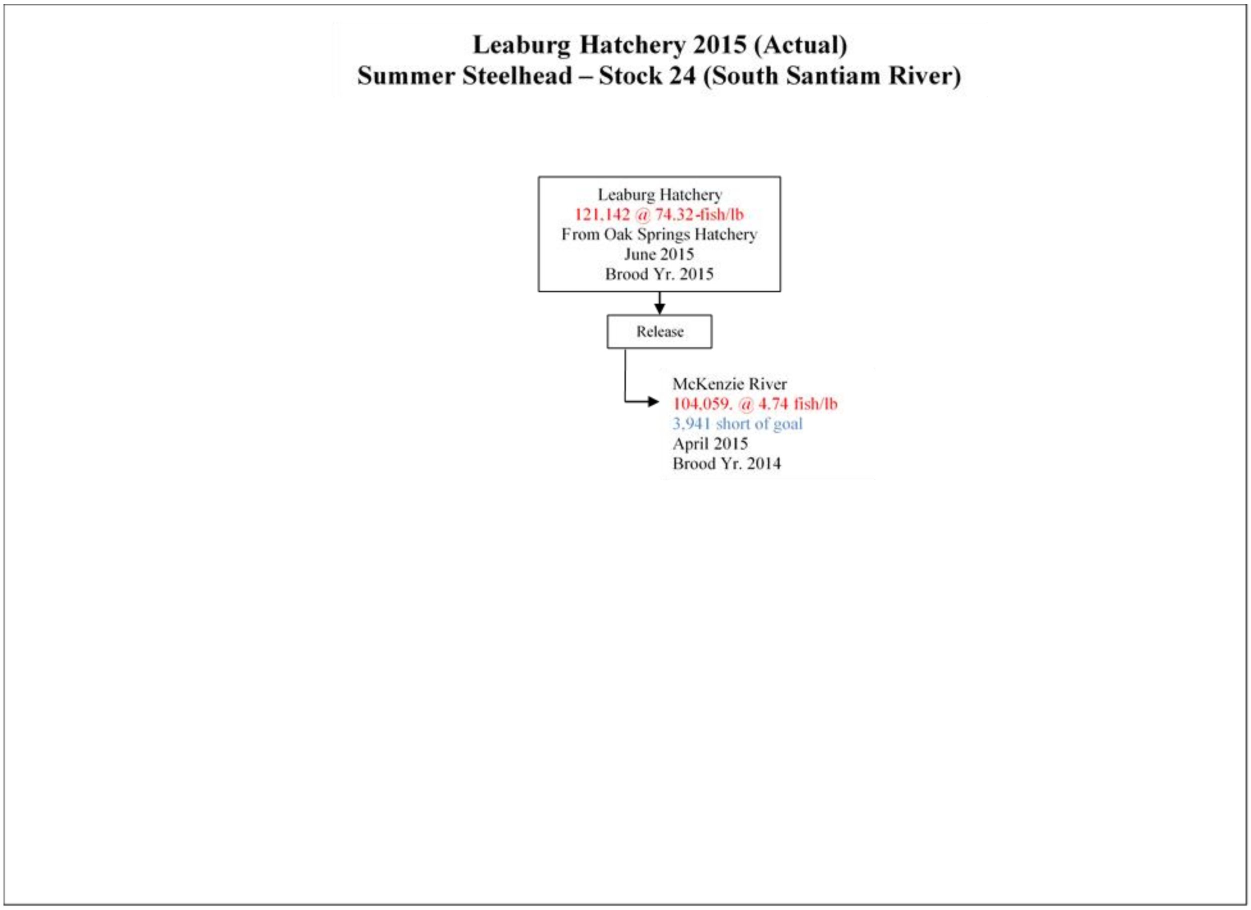

Figure 26. Realized Leaburg Hatchery summer steelhead production, 2015.

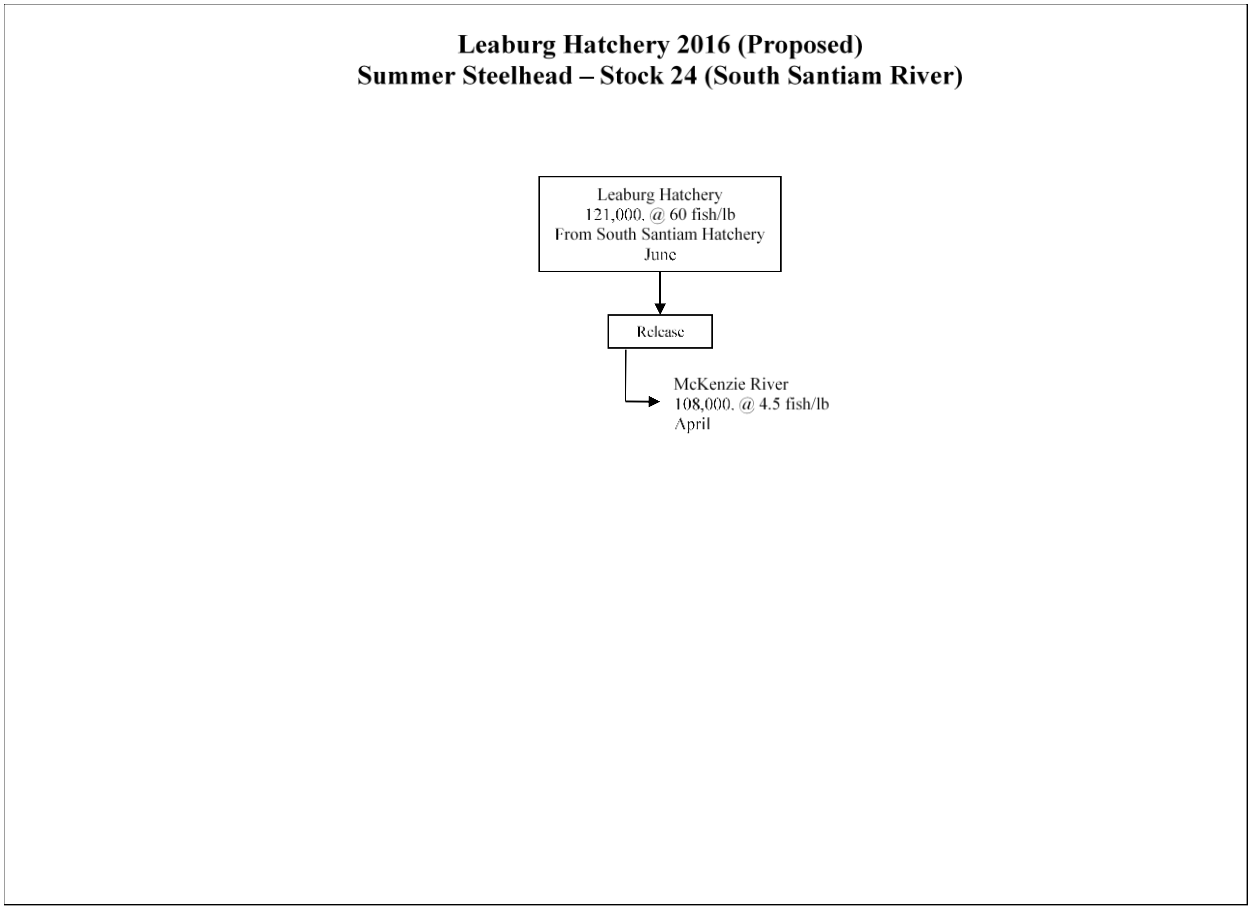

Figure 27. Projected Leaburg summer steelhead production goals, 2016.

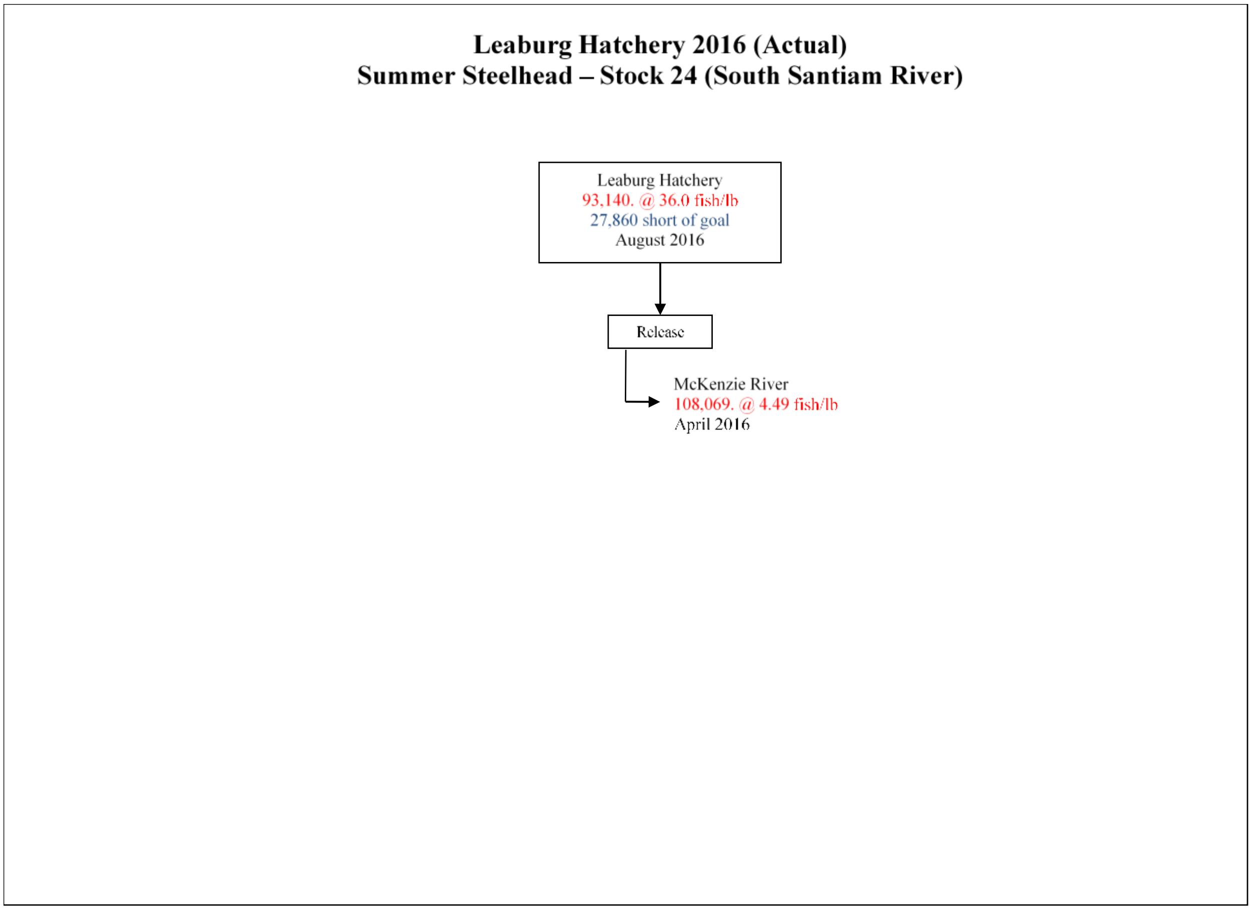

Figure 28. Realized Leaburg summer steelhead production goals, 2016.

3.4.1.1 Willamette Hatchery: Programmed production at the Willamette Hatchery in 2015 was as shown in Figure 29 for Chinook salmon for comparison to actual releases (Figure 30). Figures 31 and 32 provide similar information for summer steelhead production. Figures 35 through 36 provide similar information for 2016.

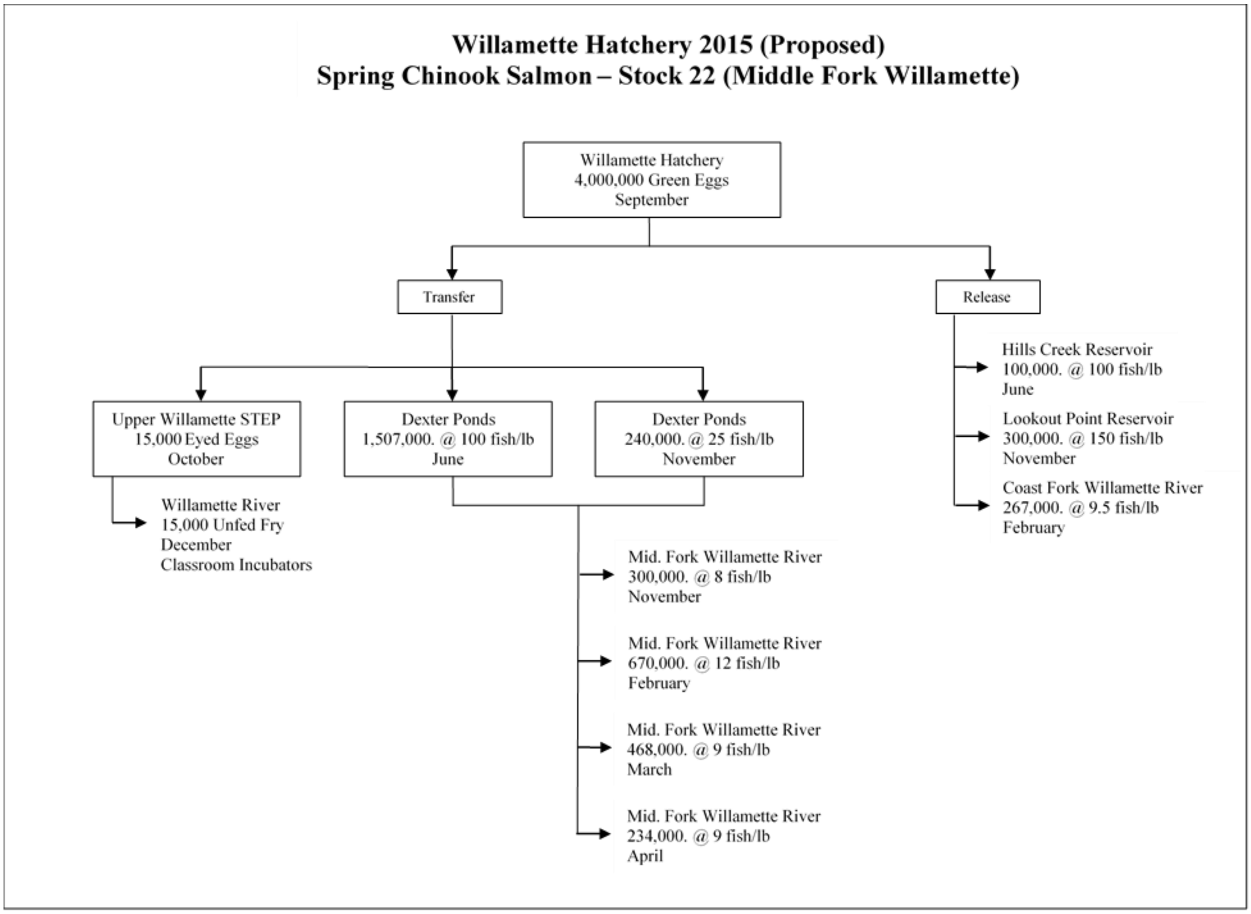

Figure 29. Projected Middle Fork Willamette spring Chinook salmon production goals, 2015.

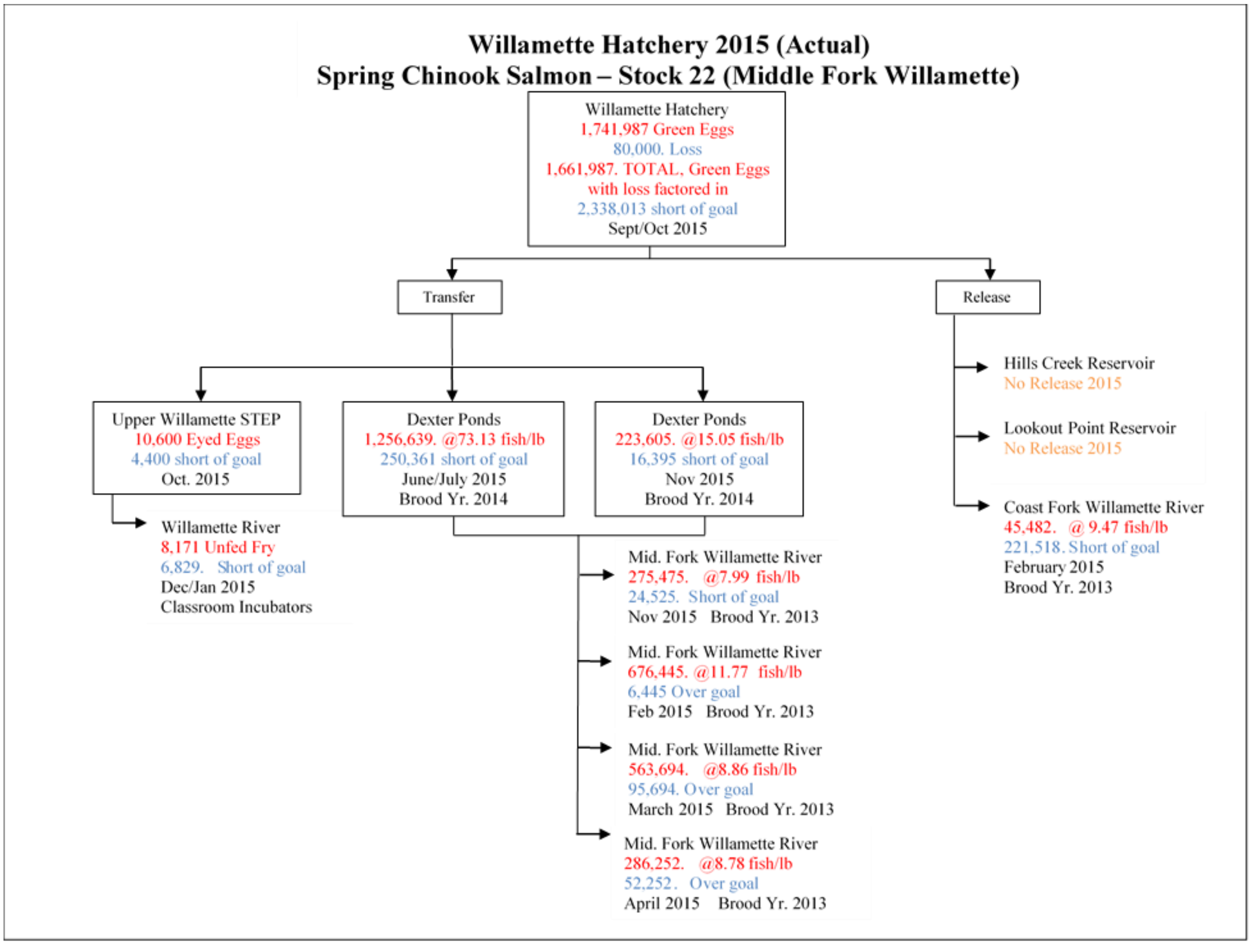

Figure 30. Realized Middle Fork Willamette spring Chinook salmon production, 2015.

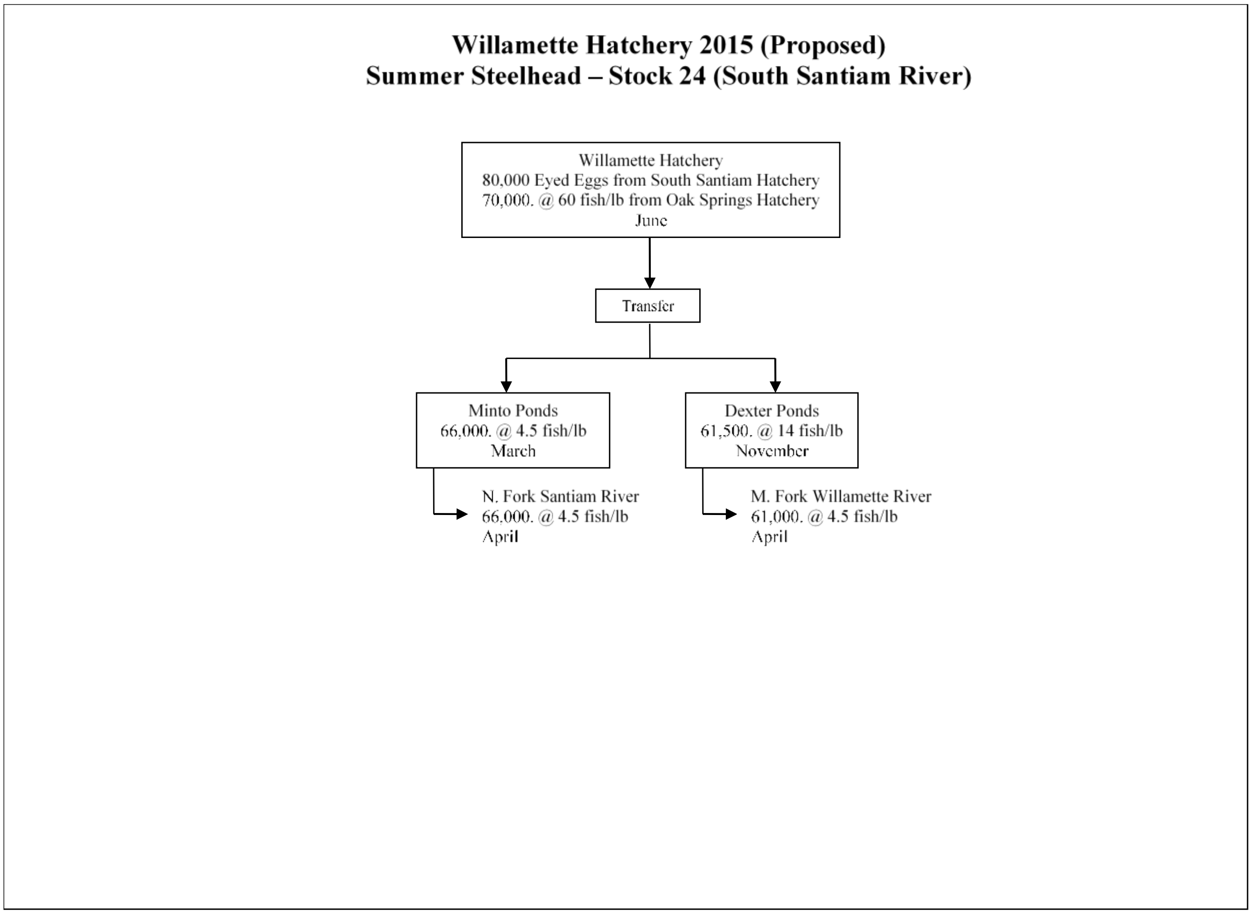

Figure 31. Projected Middle Fork Willamette summer steelhead production goals, 2015.

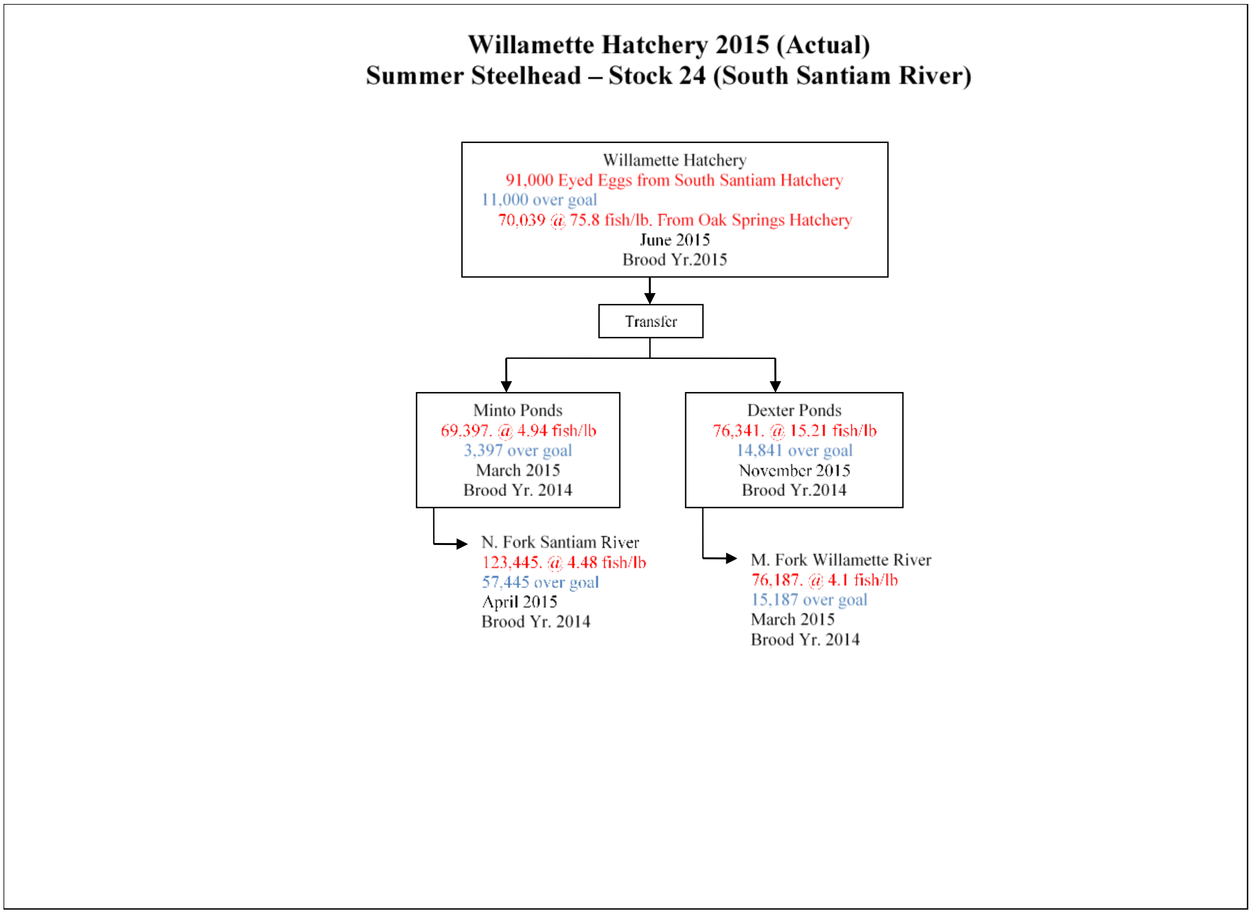

Figure 32. Realized Middle Fork Willamette summer steelhead production, 2015.

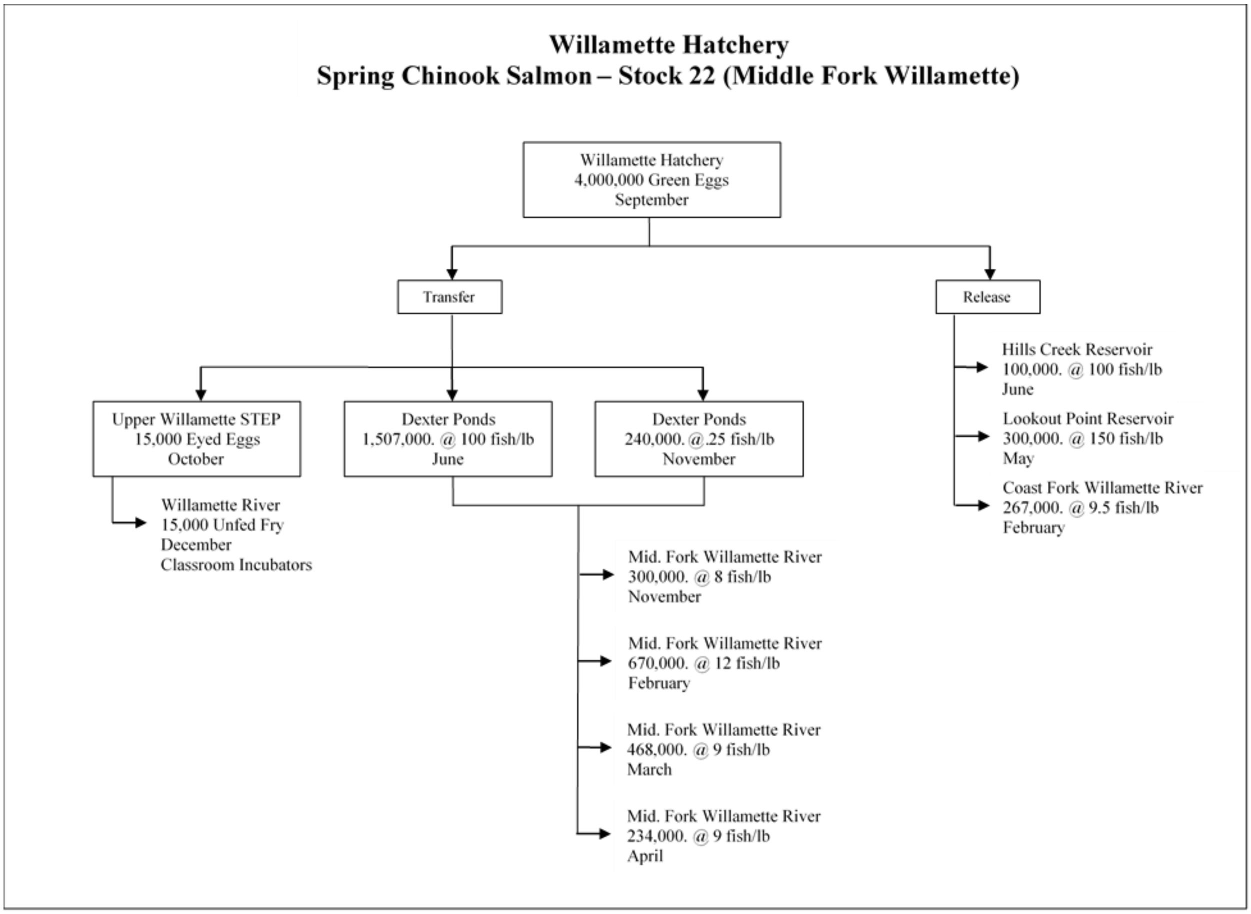

Figure 33. Projected Middle Fork Willamette spring Chinook salmon production goals, 2016.

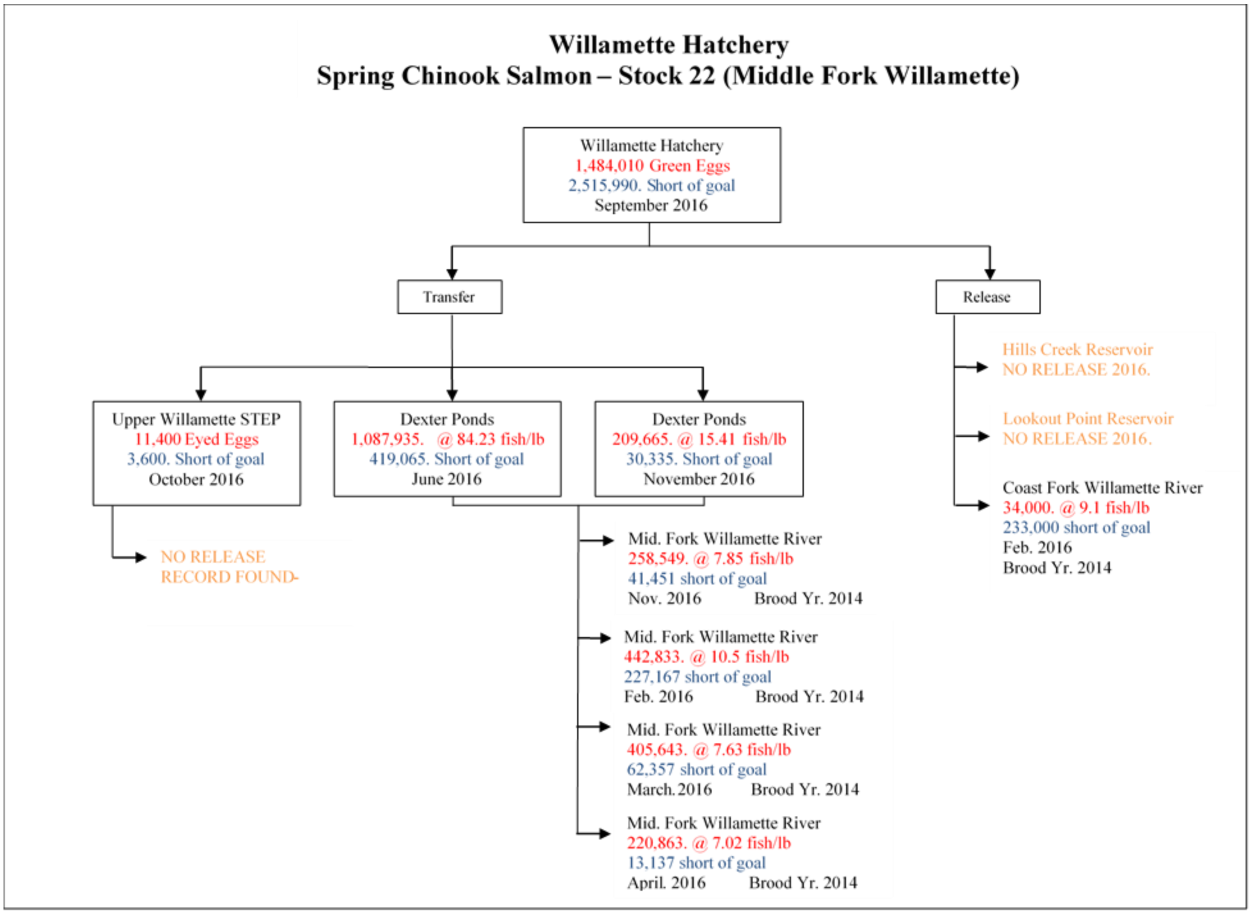

Figure 34. Realized Middle Fork Willamette spring Chinook salmon production goals, 2016.

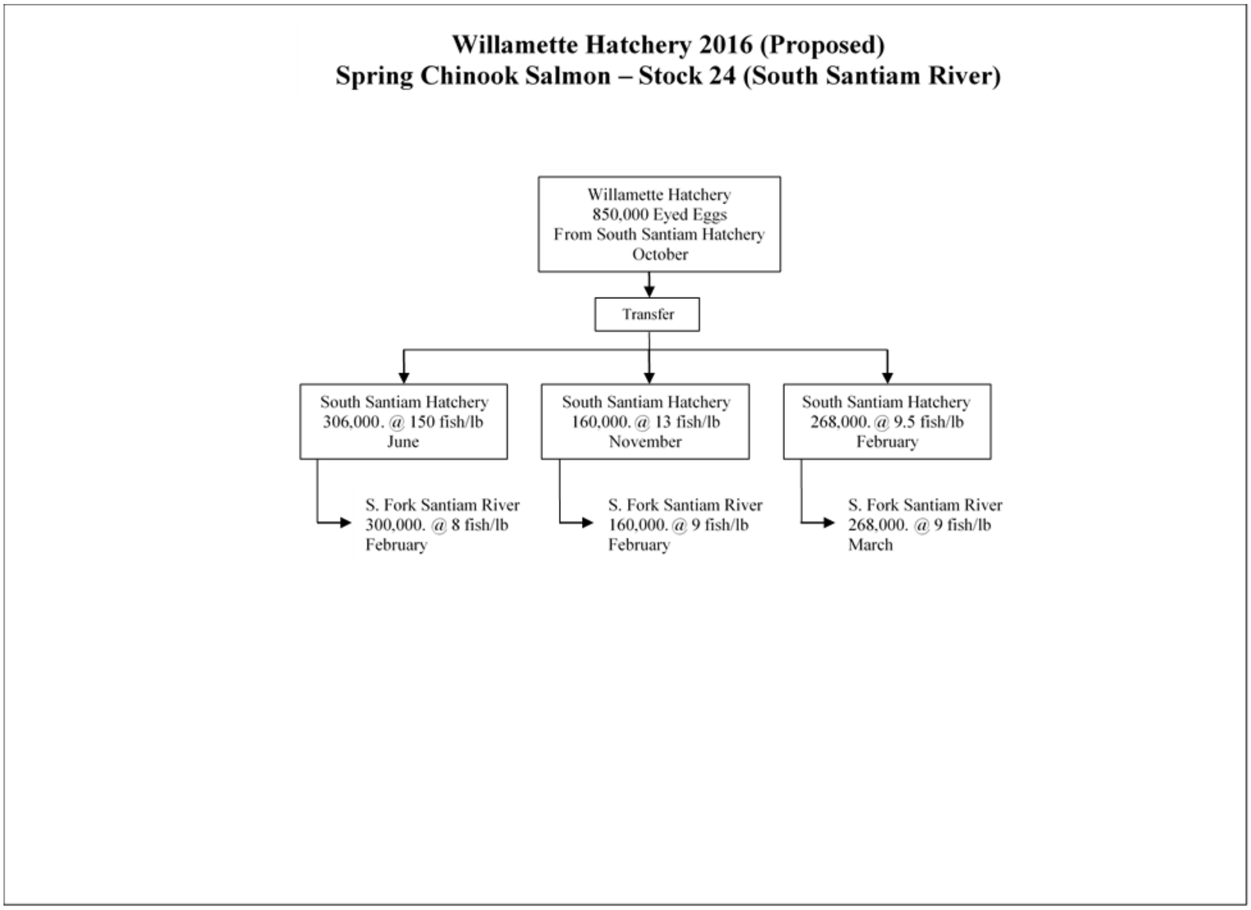

Figure 35. Projected Middle Fork Willamette spring Chinook salmon production goals for the South Santiam River, 2016.

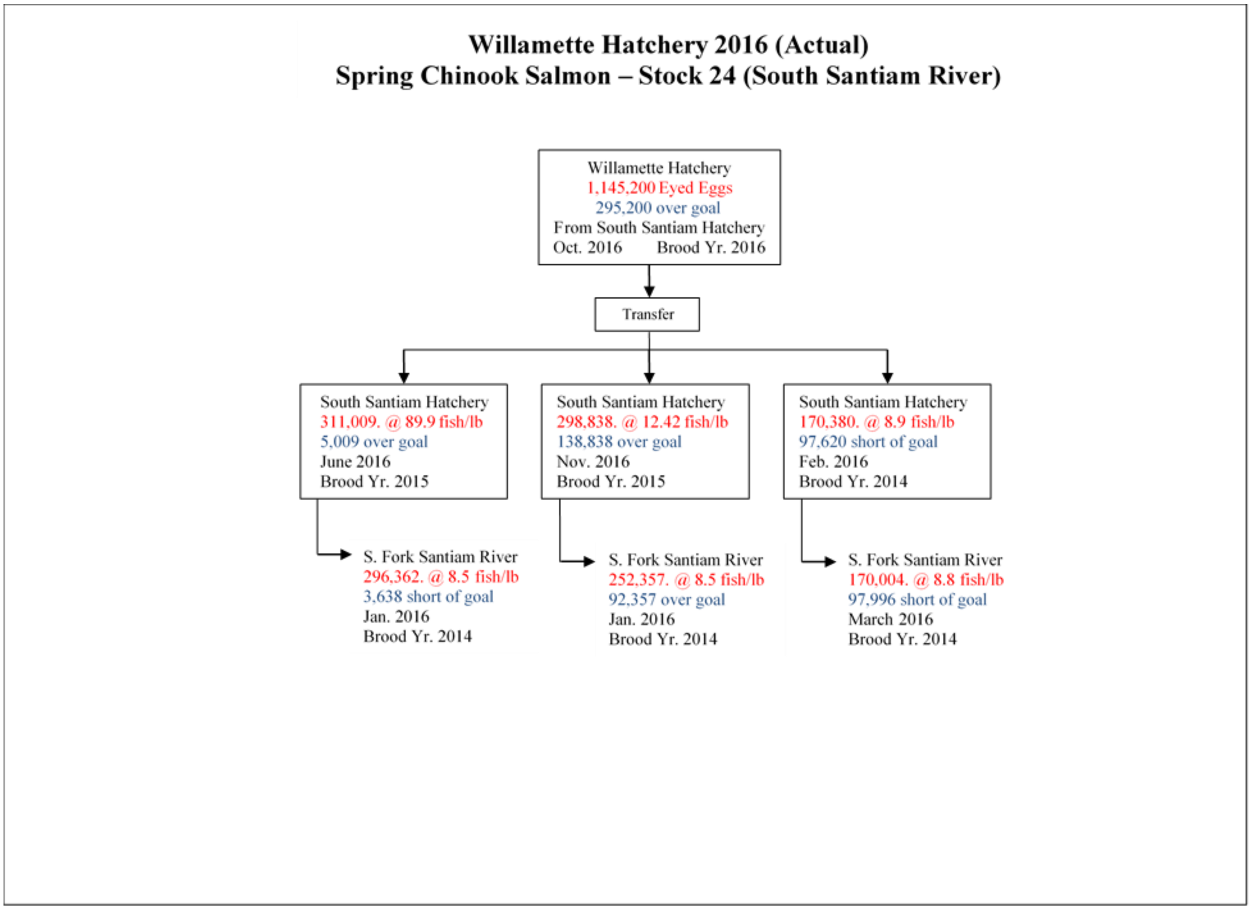

Figure 36. Realized Middle Fork Willamette spring Chinook salmon production goals for the South Santiam River, 2016.

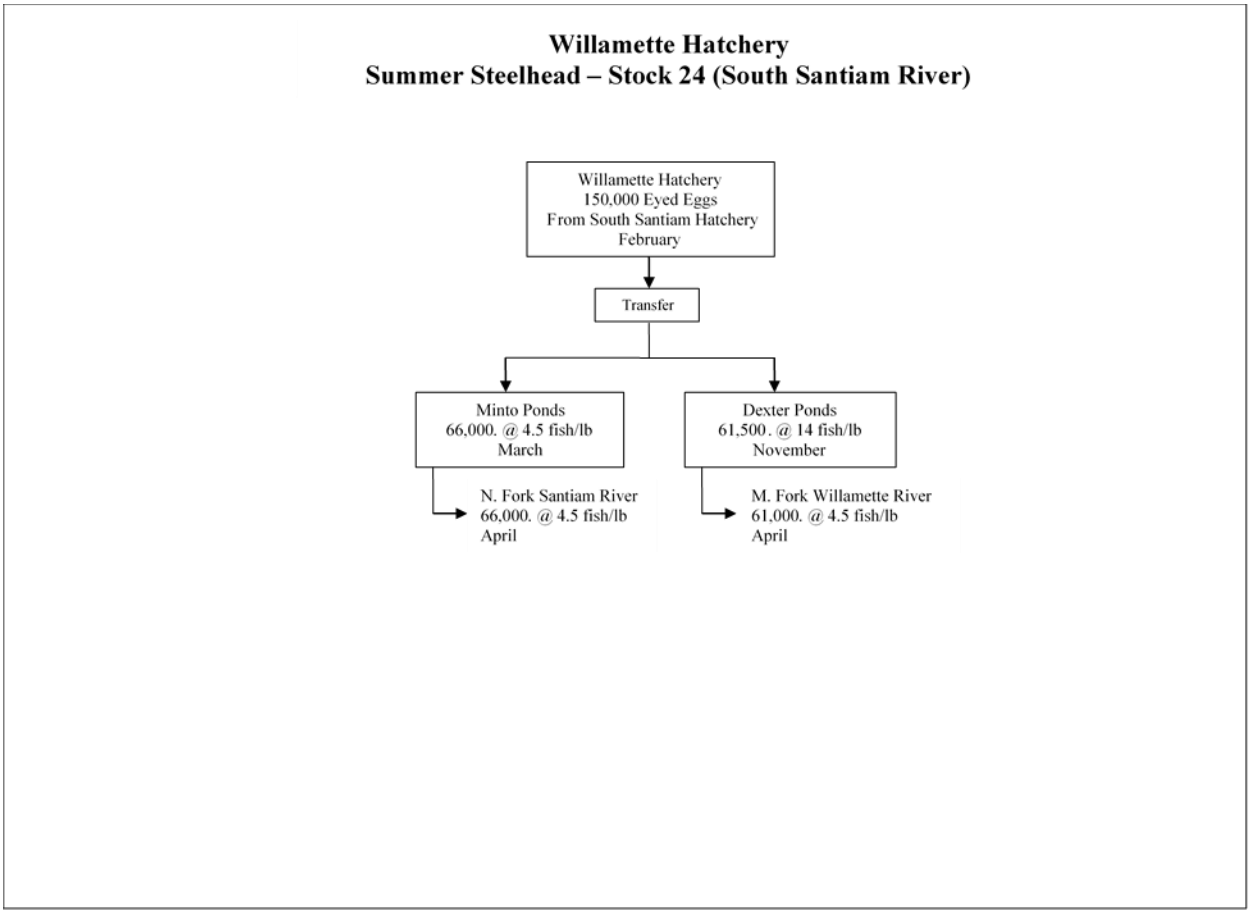

Figure 37. Projected Middle Fork Willamette summer steelhead production goals for the South Santiam River, 2016.

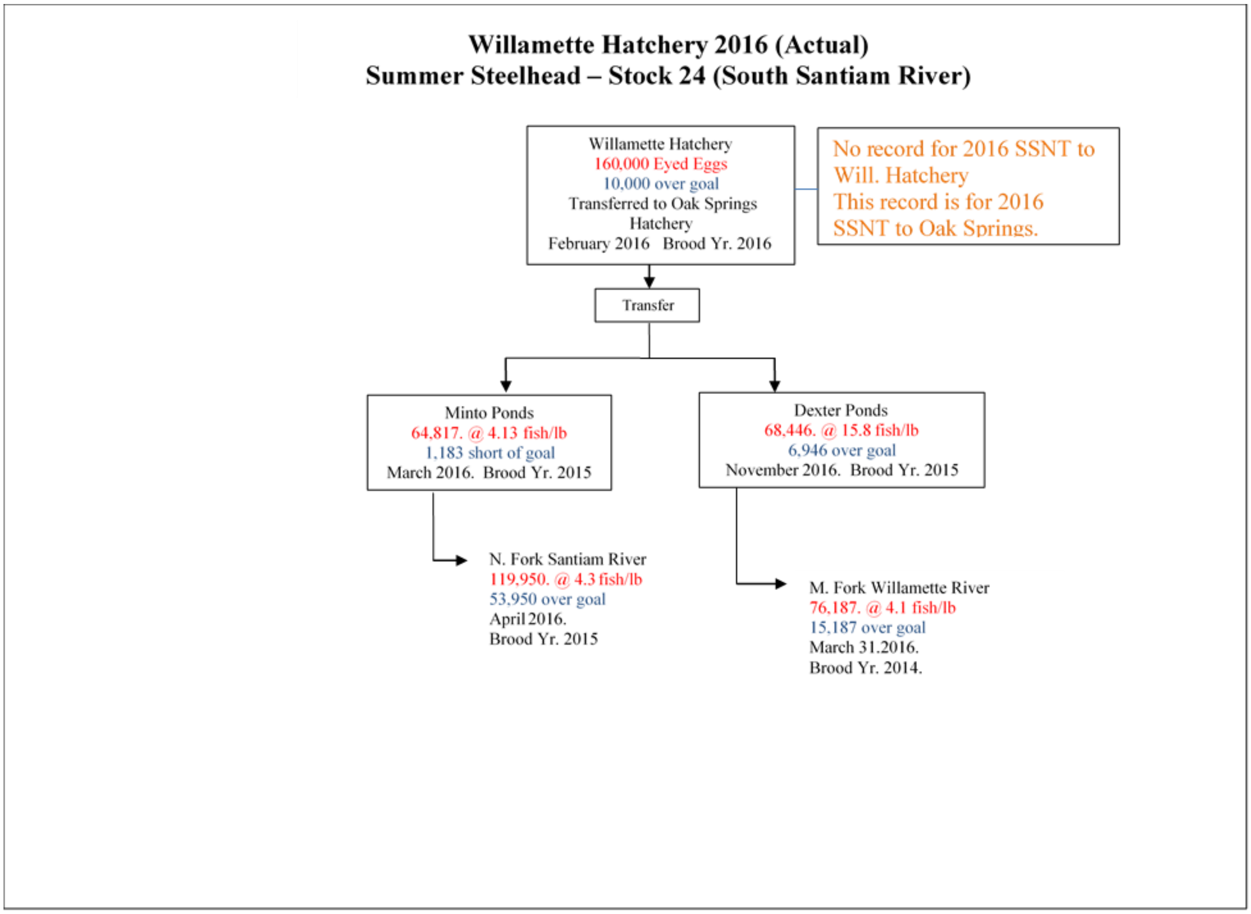

Figure 38. Realized Middle Fork Willamette summer steelhead production goals for the South Santiam River, 2016.

Table 31. Summary of projected (Goal) and realized (Actual) spring Chinook salmon and summer steelhead smolt releases into the UWR in 2015 and 2016.

Species	Release Year	Release Location	Goal	Actual	% of Goal
Spring Chinook Salmon	2015	NSNT	685,000	725,449	105.9%
		Molalla	100,000	104,400	104.4%
		SSNT	1,028,000	1,049,831	102.1%
		McK	787,000	604,970	76.9%
		MFW	1,672,000	1,801,866	107.8%
		Coast FK	267,000	45,482	17.0%
		2015 Totals	4,539,000	4,331,998	95.4%
	2016	NSNT	704,000	696,206	98.9%
		Molalla	100,000	93,307	93.3%
		SSNT	1,028,000	1,021,628	99.4%
		McK	605,000	604,752	100.0%
		MFW	1,672,000	1,327,888	79.4%
		Coast FK	267,000	34,000	12.7%
		2016 Totals	4,376,000	3,777,781	86.3%
Summer Steelhead	2015	NSNT	121,000	123,445	102.0%
		SSNT	161,500	197,105	122.0%
		McK	108,000	104,059	96.4%
		MFW	61,000	76,187	124.9%
		Will	96,000	99,481	103.6%
		2015 Totals	547,500	600,277	109.6%
	2016	NSNT	66,000	119,950	181.7%
		SSNT	161,500	169,794	105.1%
		McK	108,000	108,069	100.1%
		MFW	61,500	68,376	111.2%
		Will	96,000	70,613	73.6%
		2016 Totals	493,000	536,802	108.9%

Section 4: Discussion

We were successful in monitoring hatchery operations and conducting Chinook salmon spawner and prespawn mortality surveys in 2015 and 2016. Records of juvenile Chinook salmon releases were compiled and analyzed and adult Chinook salmon were sampled as broodstock or upon outplanting into otherwise depauperate habitat in the North and South Santiam, McKenzie and Middle Fork Willamette rivers. Spawner surveys were conducted in all reaches that have traditionally been surveyed, both below project dams for naturally-escaped adult Chinook salmon, and in the majority of the reaches above project dams for outplanted fish. Additional supplemental surveys were conducted in the North Santiam above Minto Dam and in the Coast Fork Willamette River.

Adult Abundance, Distribution and Composition: Total counts of natural- and hatchery-origin Chinook salmon adults over Willamette Falls in 2015 and 2016 were lower than the 10-year average but sufficient hatchery-origin fish returned to their natal basins so that adequate numbers of broodstock were collected, most outplanting operations met or exceeded goals, and a fishery occurred. Spawner abundance of NORs in the Santiams and McKenzie subbasins increased or remained stable compared to recent years. No appreciable spawning of NORs occurred in the Middle Fork Willamette except in Fall Creek.

One of the more pressing Conservation and Recovery goals in the upper Willamette River is to achieve low subbasin-wide pHOS. Clearly, that goal is ambitious but in the main instance where only unclipped fish are passed into the spawning reaches above a dam (Foster Dam on the South Santiam River), pHOS estimates were high in both 2015 (23.6%) and 2016 (35.2%). A high mis-clip rate during hand clipping of the contributing broods while they were being reared at Willamette Hatchery contributed to the large number of unmarked hatchery fish. The program has since switched to exclusive use of automatic marking trailers and returns in 2017 and thereafter should have fewer unmarked hatchery fish. The sheer size of juvenile fish releases necessary to support fisheries translates into returns of relatively abundant fish that cannot be visually identified as hatchery origin. Sorting procedures based solely on presence or absence of a fin clip will not always be adequate to permit creation of wild fish sanctuaries that meet existing pHOS goals for the sanctuary itself (pHOS $\lesssim$ 0 – 5%) or adequately mitigate for hatchery fish abundance elsewhere in the subbasins such that subbasin-wide pHOS goals can be met. Finally, the ultimate intent for fish passage at Cougar Dam on the South Fork McKenzie River is to pass only natural-origin fish. Given the similarities between Fall Creek and the South Fork McKenzie where collection facilities are not associated with large aggregations of hatchery fish, it appears that the Cougar Dam program may ultimately succeed when downstream passage issues are resolved.

Out-of-Basin Straying: As in earlier years, we estimated that small numbers of hatchery fish released in one subbasin returned to spawn in another subbasin. Those observations, in combination with the results of genetics analyses by Johnson and Friesen (2014), suggest that inter-basin straying of hatchery fish in the Willamette is a minor issue. We observed an apparent exception in 2016 when of the 1,735 CWTs recovered, 7.5% represented out-of-basin strays. In fact, 90 of the 130 out-of-basin recoveries represented McKenzie stock fish released in the Coast Fork that then returned as adults to the McKenzie. That is technically straying because fish released in one UWR subbasin returned to another. However, the genetic consequences of that particular type of straying is less of concern, since the Coast Fork fish originated from McKenzie Hatchery

Reintroduction above Dams: In 2015 non-marked adult fish captured at the Minto FCF (N = 171) on the North Santiam River were released immediately upstream into the reach between Minto and Big Cliff dams. Due to predicted poor holding conditions below the dams, an additional 474 unclipped fish were outplanted into the upper North Santiam River and 1,044 clipped fish were outplanted. In 2016, unclipped fish (N = 529) were exclusively released above Minto while 1,238 clipped fish were released above Detroit Dam.

In the South Santiam subbasin in both 2015 and 2016 an unexpectedly large proportion of wild Chinook salmon remained in the lower river below Foster Dam and were therefore not available to outplant into the wild fish sanctuary. That outcome is troubling and the mechanisms causing the redistribution are uncertain. A partial explanation is that the new Foster Collection Facility does not attract as large a proportion of both natural- and hatchery-origin fish returning to the subbasin. With fewer natural-origin fish captured and transported above Foster and fewer hatchery-origin fish removed, spawning in the river below Foster might be expected to increase with a commensurate increase in pHOS. Essentially, some of the productivity advantages gained through selection among natural-origin spawners above Foster Dam might be lost in their offspring because relatively more spawning with hatchery-origin fish would occur.

Clearly, the outplanting of only NORs above all projects, not just Foster and Fall Creek dams, is a priority. The draft HGMPs, currently in the late review stages, provide some direction towards when that might occur. In particular, it is necessary to have sufficient confidence that outplanting NORs is a benefit to the populations, not a reproductive sink. The single most important criteria will be confidence that outplanted fish exceed replacement, an outcome that will probably wait until downstream passage issues are resolved.

Broodstock at Hatcheries: Protocols for collection and spawning of hatchery broodstock were in reasonably close compliance with guidelines in the draft HGMPs for each production facility. There did not appear to be a consistent tendency for collection of broodstock with biologically relevant differences in run timing or size distribution from naturally-produced fish in the North Santiam, South Santiam, McKenzie or Middle Fork Willamette hatcheries. We did detect statistically significant differences in size and age between some NOB and HOS but the magnitude of the differences were small and we think the significant differences were driven more by large sample sizes and not in fact associated with biologically relevant differences. Broodstock collection timing in 2016 in the Middle Fork Willamette River occurred early, compared to the timing of entry of unclipped Chinook salmon into the Dexter trap. However, in all cases we think that returning adults were well mixed with respect to run timing before broodstock collection was complete and it is unlikely that the Dexter trapping operation actively selects for early run timing.

Actual peak spawning of hatchery broodstock in 2015 and 2016 did generally occur shortly before our estimated average peak spawning date on the spawning grounds (by approximately one week). We are not certain if one week is a biologically relevant difference but it does appear to be consistent because a similar outcome has been apparent in recent years and, if the incidence is common, then it seems likely that over multiple generations selection in the hatchery for early spawn timing will occur (or has occurred). It should be possible to evaluate the significance of the differences in spawn timing between HORs and NORs when, probably in 2018 when we expect Chinook salmon HGMPs to be authorized, HORs and NORs can be held together on site at the hatcheries and spawned after experiencing identical holding conditions.

It is likely that spawn timing in the hatcheries is less variable than spawn timing in the rivers; redds are always observed before spawning of broodstock begins and new redds or live spawners are always observed after hatchery spawning ends. Altering hatchery protocols to more closely match variance in spawn timing poses many significant logistic challenges. Both early spawners and late spawners would need to be incorporated into the brood to avoid altering timing of peak spawning. Identifying the rare early spawners would require sorting all brood at a time most of the remaining fish are fragile (approaching final maturation). Spawning of late-maturing broodstock would require protracted operation and maintenance of the broodstock holding ponds.

In 2015 broodstock goals (484 pairs) were met for the North Santiam hatchery program and spawn timing in the hatchery (21 September 2015) appeared to precede seasonal timing of naturally spawning fish (27 September 2015). In 2016 broodstock goals (462 pairs) were met for the North Santiam hatchery program and spawn timing in the hatchery (14 September 2016) appeared to precede seasonal timing of naturally spawning fish (24 September 2016).

In the South Santiam River broodstock goals (462 pairs) were met in 2015 and spawn timing in the hatchery (16 September 2015) appeared to precede seasonal timing of naturally spawning fish (1 October 2015). In 2016 broodstock goals (488 pairs) were met for the South Santiam hatchery program and spawn timing in the hatchery (13 September 2016) appeared to precede seasonal timing of naturally spawning fish (30 September 2016).

In the McKenzie River broodstock goals (438 pairs) were met in 2015 and spawn timing in the hatchery (21 September 2015) appeared to precede seasonal timing of naturally spawning fish (30 September 2015). In 2016 broodstock goals (445 pairs) were met for the McKenzie hatchery program and spawn timing in the hatchery (20 September 2016) appeared to precede seasonal timing of naturally spawning fish (1 October 2016).

In the Middle Fork Willamette River broodstock goals (544 pairs) were met in 2015 and spawn timing in the hatchery (17 September 2015) appeared to precede seasonal timing of naturally spawning fish (22 September 2015). In 2016 broodstock goals (418 pairs) were not met for the

Willamette hatchery program because of high mortality in the brood pond. Spawn timing in the hatchery (15 September 2016) appeared to precede seasonal timing of naturally spawning fish (21 September 2016).

Also in the Middle Fork, in Fall Creek, an important error was discovered in earlier abundance data. We (CSS) did not realize that for the 2006 surveys in Fall Creek the protocols for sampling carcasses were different than those in use after 2006 when ODFW began systematic surveys in the tributary. In 2006, only unclipped carcasses were sampled during surveys and clipped carcasses were ignored; our estimate of pHOS in 2006 was biased low. Because we use the estimate of pHOS to parse total spawners into natural- and hatchery-origin, the biased low estimate of pHOS led to a gross overestimate of natural-origin spawners in 2006.

Juvenile Releases: Juvenile releases of Chinook salmon and steelhead trout smolts in 2015 and 2016 generally occurred as planned. In 2015 slightly fewer Chinook salmon and steelhead smolts were released into the UWR than planned (95.4% and 86.3%, respectively) and in 2016 slightly more were released (109.6% and 108.9%, respectively).

Prespawning Mortality: Conditions in 2015 were hot and dry, a drought year, while conditions in 2016 were cool and wet. Our estimates of PSM in those years generally reflected the expectation, given the literature (e.g., Bowerman et al. 2017), that survival would be lower with elevated water temperatures (2015) than otherwise. We are still concerned that the accuracy of our estimates is questionable under circumstances where early-season mortalities are lost to deep pools or, above dams, the reservoirs themselves. We hypothesize that the problem may be most apparent when HOR are outplanted into river reaches or tributaries to which they are naïve. In the North Santiam, for example, some HOR fish raised at the Marion Forks Hatchery on the North Santiam River arm but outplanted as adults into the Breitenbush were recovered as carcasses near the hatchery. They had to fall back out of the Breitenbush, traverse the reservoir, and then ascend the North Santiam. Any en route mortality during that movement would likely occur in the reservoir and the carcasses would not be recovered. In the South Santiam River,, only unclipped fish are outplanted above Foster Dam but in both 2015 and 2016 a substantial portion of the outplanted adults were actually unclipped HORs. It seems likely that they would fall back from the outplant sites and some would die in the reservoir where, as in the North Santiam River, they would not be recovered as carcasses and would not be included in estimates of PSM. In the South Fork McKenzie, because relatively few NOR adults are returning to Cougar Dam, most spawners are outplanted HORs. Again, it seems likely that HORs might fall back in search of their natal "stream" (the McKenzie Hatchery), perish in the reservoir and result in PSM estimates biased low. Zymonas et al. (2014) showed substantial downstream movement of radiotagged HORs outplanted just upstream of the reservoir with most (17/23 = 0.74)) mortalities detected deep in the reservoir via a mortality signal transmitted from the radiotag. Because the radio signal is not detectable in water deeper than approximately 10 meters and the reservoir quickly becomes deeper than 10 meters near the head-of-reservoir it seems probable that more mortalities occurred but were not detected. In the Middle Fork Willamette River, releases of HORs into the North Fork Middle Fork River above Lookout Point Reservoir showed some improvements in PSM compared to earlier years, probably associated with new outplanting protocols. However, in every year, including 2015 and 2016, live spawners were noted by Willamette Hatchery staff in Salmon Creek, the water supply for the hatchery. Salmon Creek is not one of the survey reaches in the subbasin. We think that PSM that occurs outside of surveyed or surveyable reaches would tend to bias PSM estimates low.

Future Monitoring Priorities: In the North Santiam, spawner distribution and success of fish outplanted above the dams suggests that juveniles produced in 2015 and 2016 were numerous and broadly dispersed throughout the Breitenbush and upper North Santiam rivers. In 2019 through 2021, age-4 and age-5 adults will return. Thoughtful application of the pedigree study protocols should be conducted on the returning adults so that we can understand if the various subtleties of outplanting procedures did or did not have the desired outcome.

In the South Santiam River, the apparent lack of attraction into the Foster ladder must be understood and resolved. Increased investment in infrastructure at Lebanon Dam, including improved trapping capabilities and, especially, video monitoring like that in place in the North Santiam and McKenzie rivers, should be seriously considered. The attraction problem is exacerbated by a general lack of understanding of how, and how many, fish approach and use the ladder and adjacent river reach. Improved monitoring of the fish as they make their final approach will inform management to understand and solve the problem. Also in the South Santiam, the large, inadvertent escapement of non-finclipped hatchery-origin Chinook salmon above Foster Dam in 2015 and 2016 has probably been resolved. It seems almost certain that the abundance of those fish was a consequence of poor marking (fin clipping) protocols in place in 2010 and 2011. Because marking procedures thereafter were improved by using the auto trailers, it seems likely that beginning in 2017 fewer non-marked hatchery fish should return. The otoliths acquired from carcasses sampled above and below Foster Dam in 2017, and future years, should be carefully archived with the necessary biological data so that if funding becomes available a substantial decrease in unintentional passage of hatchery-origin fish can be verified or not.

In the McKenzie River, a number of actions are in place with the specific intent of reducing escapement of hatchery-origin Chinook salmon above Leaburg Dam. Two of the actions are increased attraction into McKenzie Hatchery and removal of hatchery-origin fish at Leaburg Dam. Regarding improved entrainment of hatchery-origin fish into the hatchery, it is necessary to have a robust estimate of run size so that the rate of entrainment can be determined and compared to earlier estimates from before the ladder improvements. Run size estimates are derived from spawning ground surveys, video counts at Leaburg, and harvest estimates. If Leaburg counts and spawning ground surveys do not occur then it seems unlikely that the required robust estimates will be obtained. Regarding removal of hatchery-origin fish at Leaburg Dam, serious consideration should be given to adding trapping facilities to the ladder on the right bank to complement the existing trap in the left ladder. Dam operations at Leaburg are fluid in that it is difficult for EWEB to guarantee that spill occurs on river-left. When spill occurs on river right, the majority of all returning adults pass the un-trapped ladder. A trap in that ladder will greatly improve the probability that a useful number of hatchery escapees can be kept out of the wild fish sanctuary above Leaburg Dam.

In the Middle Fork Willamette River the issue of routinely high prespawning mortality, especially below Dexter Dam but also in Fall Creek, the North Fork Middle Fork above Lookout Point Reservoir and the Middle Fork above Hills Cr Reservoir, continues to be of interest. In Fall Creek, construction of a new trap to facilitate capture and transport of natural-origin Chinook salmon over Fall Creek Dam is scheduled for completion in time for the 2018 run return. In 2016 surveys were conducted for the first time below Fall Creek Dam. No redds were observed and only a single carcass was recovered. The lower river surveys are also to occur in 2017. Post construction it will be necessary to determine if the new facility appreciably alters behavior as was apparently the case in the South Santiam subbasin upon construction of the new Foster Dam trap.

System-wide, we have estimated that in recent years in all subbasins our estimates of spawn timing in the hatcheries precede those of spawners in the rivers. The phenomenon, if true, indicates that the hatchery program may be advancing spawn timing. We recommend that a statistically robust test be developed for detecting biologically significant differences in spawn timing. Clearly, if the HGMPS are approved and NOR brood can be used in the hatcheries it should be possible to closely track NOR and HOR brood held in a common garden environment to permit direct comparisons of such metrics as spawn timing, fecundity, fertility rates, egg size, survival to spawning, and susceptibility to pathogens, among others.

Finally, even if ODFW transitions out of the lead role in performing the spawning ground surveys, it seems likely there will be a need to assure continuity of the types and quality of data collected. The Oregon Department of Fish and Wildlife’s Willamette Chinook Salmon (OWCS) Database is complete through 2016, has been distributed to interested parties (UI, USACE, NOAA), and should prove useful. Conceivably, the database could be interrogated in such a way as to model varying survey locations, timing, and intensity to determine at what level fewer, less intense surveys might generate estimates of abundance, distribution and diversity similar enough to current estimates to be useful. The OWCS database also serves as a reference library for the various biological specimens (scales, otoliths, DNA) that have been collected over the years ODFW was funded to conduct the work. Every attempt will be made to append the data collected by ODFW in 2017 to the database but, going forward, any entities conducting monitoring work in the basin should thoroughly examine the material in the database and ensure that their work affords continuity with all the material collected in the past.

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Appendix 1: Conservation and Mitigation Goals

Summary of anadromous fish monitoring and hatchery sampling associated with conservation and mitigation goals addressed in this report.

Reach	NOR Escapement (= peak redds * 2.5 * (1 - pHOS))		pHOS (=HOS/(NOS + HOS)		PNI (= pNOB/(pNOB + pHOS))		Subbasin Harvest (from Catch Record Card returns)		PSM		NOR Freshwater Fishery Exploitation Rate (Table 13. 2014 FMEP)	
	Recent 5-yr Average	Goal	Recent 5-yr Average	Goal (long term rec plan)	Recent 5-yr Average	Goal	Recent 5-yr Average	Goal (From HGMP Tables 1.9.2)	Recent 5-yr Average	Goal ("Low")	Recent 5-yr Average	Goal
Below Minto	375	ND	68%	<21%					33%	<20%		
Big Cliff - Minto	200	ND	10%	<21%					UNK	<20%		
Above Detroit	4	ND	99%	<1%					4%	<20%		
Subbasin-wide	579	5400	71%	<10%	18%	>67%	566	1,400	24%	<20%	10%	<15%
Below Foster	342	ND	72%	<80%					29%	<20%		
Above Foster	296	ND	19%	<1%					15%	<20%		
Subbasin-wide	638	3100	60%	<30%	10%	>50%	1,332	1,600	24%	<20%	NA	<15%
Below Leaburg	89	ND	83%	<95%					30%	<20%		
Above Leaburg (excl. abv Cougar)	1387	ND	15%	<10%					3%	<20%		
Above Cougar	207	ND	70%	<1%					7%	<20%		
Subbasin-wide (excl. abv Cougar)	1476	ND	27%	<10%	13%	>67%			15%	<20%		
Subbasin-wide (incl. abv Cougar)	1683	8376	35%	<10%	10%	>67%	1,144	1,000	15%	<20%	11%	<15%
Below Dexter (incl. LFC)	19	ND	91%	<95%					50%	<20%		
Fall Cr.	105	ND	5%	<1%					13%	<20%		
Above LOP to Below HCD	11	ND	98%	<1%					24%	<20%		
MF Above Hills Cr Res.	6	ND	99%	<1%					10%	<20%		
Subbasin-wide	141	5820	93%	<10%	3%	>50%	1,355	1,250	19%	<20%	NA	<15%

Appendix 2: Spatial Scales Associated With Abundance, Spatial Distribution, and Diversity Metrics

Subbasin	River Section	Survey Reach (downstream to upstream extent)	Carcass Surveys	Redd Surveys	Peak Redd Count	Redd Density	pHOS	PSM	Escape-ment
North Santiam							X		
									X
	Downstream of Minto Dam	Downstream of Upper Bennett Dam			X	X	X	X	
		Green's Bridge to Shelburn	X	X	X				
		Shelburn to Stayton	X	X	X				
		Stayton to South Channel-Upper Bennett Dam	X	X	X				
		Stayton to North Channel-Stayton Island	X	X	X				
		Upper Bennett Dam to Minto Dam			X	X	X	X	
		Stayton to North Channel-Stayton Island	X	X	X				
		Upper Bennett (Stayton Island) to Powerlines	X	X	X				
		Powerlines to Mehama	X	X	X				
		Mehama to Fisherman's Bend	X	X	X				
		Fisherman's Bend to Mill City	X	X	X				
		Mill City to Gate's Bridge	X	X	X				
		Gate's Bridge to Packsaddle	X	X	X				
		Packsaddle to Minto Dam	X	X	X				
	Upstream of Minto Dam	Minto to Big Cliff Dam (not currently surveyed)			X	X	X	X	
	Little North Santiam				X	X	X	X	X
		Lunkers Bridge to Bear Creek Bridge	X	X	X				
		Bear Creek Bridge to Golf Bridge	X	X	X				
		Golf Bridge to Narrows	X	X	X				
		Narrows to Camp Cascade	X	X	X				
		Camp Cascade to Salmon Falls	X	X	X				
		Salmon Falls to Elkhorn Bridge	X	X	X				
South Santiam									X

Subbasin	River Section	Survey Reach (downstream to upstream extent)	Carcass Surveys	Redd Surveys	Peak Redd Count	Redd Density	pHOS	PSM	Escape-ment
	Downstream of Foster Dam	Downstream of Lebanon Dam			X	X	X	X	
		Sanderson's to Gill's Landing	X	X	X				
		Lebanon Dam to Foster Dam			X	X	X	X	
		Waterloo to McDowell Creek	X	X	X				
		McDowell Creek to Pleasant Valley	X	X	X				
		Pleasant Valley to Foster Dam	X	X	X				
	Upstream of Foster Dam				X	X	X	X	X
		River Bend Park to Shot Pouch Road	X	X	X				
		Shot Pouch Rd to High Deck Road	X	X	X				
		High Deck Rd to Cascadia Park	X	X	X				
		Cascadia Park to Moose Creek Bridge	X	X	X				
		Moose Creek Bridge to Gordon Creek Road	X	X	X				
		Gordon Cr. Rd to 2nd Trib. downstream of C.G.	X	X	X				
		2nd Trib. downstream of C.G. to Trout Creek C.G.	X	X	X				
		Trout Creek C.G. to Little Boulder Creek	X	X	X				
		Little Boulder Creek to Soda Fork	X	X	X				
		Soda Fork to Falls	X	X	X				
	Downstream of Leaburg Dam				X	X	X	X	X
		Leaburg Landing to Leaburg Dam	X	X	X				
	Upstream of Leaburg Dam						X		X
		Leaburg Dam to Forest Glen			X	X	X	X	
		Leaburg Lake to Helfrich	X	X	X				
		Ben & Kay to Rosboro Bridge	X	X	X				
McKenzie		Rosboro Bridge to Forest Glen	X	X	X				
		upstream of Forest Glen			X	X	X	X	
		Forest Glen to South Fork McKenzie	X	X	X				
		South Fork McKenzie to Hamlin	X	X	X				
		Hamlin to McKenzie Bridge	X	X	X				
		McKenzie Bridge to McKenzie Trail	X	X	X				
		McKenzie Trail to Paradise	X	X	X				
		Paradise to Belknap	X	X	X				
		Belknap to Olallie C.G.	X	X	X				

Subbasin	River Section	Survey Reach (downstream to upstream extent)	Carcass Surveys	Redd Surveys	Peak Redd Count	Redd Density	pHOS	PSM	Escape-ment
		Spawning Channel	X	X	X				
		Horse Creek							
		Mouth to Bridge	X	X	X				
		Bridge to Avenue Creek	X	X	X				
		Avenue Creek to Braids	X	X	X				
		Braids to Road Access	X	X	X				
		Road Access to Separation Creek	X	X	X				
		Separation Creek to Trail Bridge	X	X	X				
		Trail Bridge to Pothole Creek	X	X	X				
		Lost Creek							
		Mouth to Hwy Bridge	X	X	X				
		Hwy Bridge to Split Pt	X	X	X				
		Split Pt to Campground	X	X	X				
		Campground to Cascade	X	X	X				
		South Fork McKenzie downstream of Cougar Dam			X	X	X	X	
		Mouth to Bridge	X	X	X				
		Bridge to Cougar Dam	X	X	X				
	South Fork McKenzie River, upstream of Cougar Dam				X	X	X	X	X
		Reservoir to Hardy	X	X	X				
		Hardy Creek to Rebel Creek	X	X	X				
		Rebel Creek to Dutch Oven	X	X	X				
		Dutch Oven C.G. to Homestead C.G.	X	X	X				
		Homestead C.G. to Twin Springs C.G.	X	X	X				
		Twin Springs C.G. to Roaring River	X	X	X				
		Roaring River to Elk Creek	X	X	X				
		SF 1 mile upstream of confluence of Elk Creek	X	X	X				
Middle Fork Willamette	Jasper to Dexter Dam				X	X	X	X	X
		Jasper to Pengra	X	X	X				
		Pengra to Dexter Dam	X	X	X				
	Fall Creek				X	X	X	X	X
		Reservoir to Release Site	X	X	X				
		Release Site to Johnny Creek Bridge	X	X	X				
		Johnny Creek Bridge to Bedrock campground	X	X	X				

Subbasin	River Section	Survey Reach (downstream to upstream extent)	Carcass Surveys	Redd Surveys	Peak Redd Count	Redd Density	pHOS	PSM	Escape-ment
		Bedrock campground to Portland Creek	X	X	X				
		Portland Creek to NFD 1828 Bridge	X	X	X				
		NFD 1828 Bridge to Hehe Creek	X	X	X				
		Hehe Creek to Gold Creek	X	X	X				
		Gold Creek to Falls	X	X	X				
	Little Fall Creek				X	X	X	X	X
		Fish Ladder to NFD 1818 Bridge	X	X	X				
		NFD 1818 Bridge to NFD 1806 Bridge	X	X	X				
	North Fork Middle Fork Willamette				X	X	X	X	X
		Minute Creek to 2nd to last pullout	X	X	X				
		NFD 1944 Bridge to Minute Creek	X	X	X				
		Kiahanie Bridge to NFD 1944 Bridge	X	X	X				
		Release Site to Kiahanie Bridge	X	X	X				

Appendix 3: Survey reaches for upper Willamette subbasin prespawn mortality and spawner surveys

Subbasin	River	Description	Start River Mile	End River Mile	Total Distance	Comment
Santiam	**Santiam**	**Mouth to I-5 Bridge**	**0**	**6.4**	**6.4**	
Santiam	Santiam	I-5 Bridge to Jefferson	6.4	10	**3.6**	
Santiam	Santiam	Jefferson to Confluence	10	12.1	**2.1**	covered on N/S surveys
N. Santiam	**N. Santiam**	**Mouth/Jefferson to Green's Bridge**	**0**	**2.9**	**2.9**	**covers part of MS Santiam**
N. Santiam	N. Santiam	Green's Bridge to Shelburn	2.9	11.1	**8.2**	
N. Santiam	N. Santiam	Shelburn to Stayton	11.1	16.6	**5.5**	
N. Santiam	N. Santiam	Stayton to North Channel-Stayton Is	16.6	19.8	**3.2**	
N. Santiam	N. Santiam	Stayton to South Channel-Upper Bennett	19.8	23	**3.2**	
N. Santiam	N. Santiam	Upper Bennett to Powerlines	23	26.5	**3.5**	
N. Santiam	N. Santiam	Powerlines to Mehama	26.5	30	**3.5**	
N. Santiam	N. Santiam	Mehama to Fisherman's Bend	30	36.5	**6.5**	
N. Santiam	**Little N. Santiam**	**Mouth to NF Park**	**0**	**3**	**3**	
N. Santiam	Little N. Santiam	NF Park to Lunkers Bridge	3	7	**4**	
N. Santiam	Little N. Santiam	Lunkers Bridge to Bear Creek Bridge	7	8.9	**1.9**	
N. Santiam	Little N. Santiam	Bear Creek Bridge to Golf Bridge	8.9	12.3	**3.4**	
N. Santiam	Little N. Santiam	Golf Bridge to Narrows	12.3	13.2	**0.9**	
N. Santiam	Little N. Santiam	Narrows to Camp Cascade	13.2	14.4	**1.2**	
N. Santiam	Little N. Santiam	Camp Cascade to Salmon Falls	14.4	15.3	**0.9**	
N. Santiam	Little N. Santiam	Salmon Falls to Elkhorn Bridge	15.3	16.3	**1**	
N. Santiam	N. Santiam	Fisherman's Bend to Mill City	36.5	38.5	**2**	
N. Santiam	N. Santiam	Mill City to Gate's Bridge	38.5	42.3	**3.8**	
N. Santiam	N. Santiam	Gate's Bridge to Packsaddle	42.3	45.1	**2.8**	
N. Santiam	N. Santiam	Packsaddle to Minto Dam	45.1	45.3	**0.2**	
N. Santiam	**Breitenbush**	**Upper Arm Picnic Area to Byars Creek**	**0**	**1.4**	**1.4**	
N. Santiam	Breitenbush	Byars Creek to Humbug Creek	1.4	2.9	**1.5**	
N. Santiam	Breitenbush	Humbug Creek to Fox Creek	2.9	4.3	**1.4**	
N. Santiam	Breitenbush	Fox Cr. to Scorpion Cr	4.3	5.7	**1.4**	
N. Santiam	Breitenbush	Scorpion Cr. to Hill Cr	5.7	7.3	**1.6**	
N. Santiam	Breitenbush	Hill Cr. to SF Breitenbush	7.3	9.2	**1.9**	
N. Santiam	N. Santiam abv Detroit	Cooper’s Ridge to Misery Cr	73.8	76.2	**2.4**	river mile
N. Santiam	N. Santiam abv Detroit	Misery Cr. to Whitewater Cr.	76.2	78.4	**2.2**	
N. Santiam	N. Santiam abv Detroit	Whitewater Cr. to Pamelia	78.4	81.15	**2.75**	
N. Santiam	N. Santiam abv Detroit	Pamelia Creek to Minto Creek	81.15	83.95	**2.8**	
N. Santiam	N. Santiam abv Detroit	Minto Creek to Horn Creek	83.95	85.15	**1.2**	
N. Santiam	**Marion Creek**	**Mouth to Hatchery Weir**	**0**	**0.7**	**0.7**	
N. Santiam	**Horn Creek**	**Mouth to Hatchery Weir**	**0**	**0.5**	**0.5**	
N. Santiam	N. Santiam abv Detroit	Horn Creek to Bugaboo Creek	0.7	2.4	**1.7**	
N. Santiam	N. Santiam abv Detroit	Bugaboo to Straight Cr	2.4	5	**2.6**	

Subbasin	River	Description	Start River Mile	End River Mile	Total Distance	Comment
N. Santiam	N. Santiam abv Detroit	Straight Cr. to Parish Lake Road	5	8.5	**3.5**	
S. Santiam	**S. Santiam**	**Mouth/Jefferson to Sanderson's**	**0**	**10**	**10**	**Covers part MS Santiam**
S. Santiam	S. Santiam	Sanderson's to Gill's Landing/Lebanon	10	19.7	**9.7**	
S. Santiam	S. Santiam	Waterloo to McDowell Creek	19.7	24	**4.3**	
S. Santiam	S. Santiam	McDowell Creek to Pleasant Valley	24	29.4	**5.4**	
S. Santiam	S. Santiam	Pleasant Valley to Foster	29.4	33.9	**4.5**	
S. Santiam	S. Santiam abv Foster	River Bend Park to Shot Pouch Rd	46.6	48.9	**2.3**	river mile +2.6
S. Santiam	S. Santiam abv Foster	Shot Pouch Rd to High Deck Rd	48.9	50.6	**1.7**	
S. Santiam	S. Santiam abv Foster	High Deck Rd to Cascadia Park	50.6	52.2	**1.6**	
S. Santiam	S. Santiam abv Foster	Cascadia Park to Moose Creek Bridge	52.2	53.7	**1.5**	
S. Santiam	S. Santiam abv Foster	Moose Creek Bridge to Gordon Creek Rd	53.7	56.4	**2.7**	
S. Santiam	S. Santiam abv Foster	Gordon Creek Rd to 2nd Trib below C.G.	56.4	58.2	**1.8**	
S. Santiam	S. Santiam abv Foster	2nd Trib below C.G. to Trout Creek C.G.	58.2	59.7	**1.5**	
S. Santiam	S. Santiam abv Foster	Trout Creek C.G. to Little Boulder Creek	59.7	61.8	**2.1**	
S. Santiam	S. Santiam abv Foster	Little Boulder Creek to Soda Fork	61.8	63.6	**1.8**	
S. Santiam	S. Santiam abv Foster	Soda Fork to Falls	63.6	66.1	**2.5**	distance is estimated?
McKenzie	**McKenzie**	**Armitage to Hayden**	**4.1**	**14.3**	**10.2**	**4.1 to mouth**
McKenzie	McKenzie	Hayden to Bellinger	14.3	18.7	**4.4**	manually measured
McKenzie	McKenzie	Bellinger to Hendricks	18.7	24.2	**5.5**	manually measured
McKenzie	McKenzie	Hendricks to Dearhorn	24.2	31.8	**7.6**	
McKenzie	McKenzie	Dearhorn to Leaburg Landing	31.8	33.9	**2.1**	
McKenzie	McKenzie	Leaburg Landing to Leaburg Dam	33.9	39.9	**6**	
McKenzie	McKenzie	Leaburg Lake to Helfrich	39.9	44.3	**4.4**	
McKenzie	McKenzie	Ben & Kay to Rosboro Bridge	44.3	50.8	**6.5**	
McKenzie	McKenzie	Rosboro Bridge to Forest Glen	50.8	56.5	**5.7**	
McKenzie	McKenzie	Forest Glen to S.F. McKenzie	56.5	58.9	**2.4**	
McKenzie	**S. Fork McKenzie**	**Mouth to Bridge**	**0**	**2.1**	**2.1**	
McKenzie	S. Fork McKenzie	Bridge to Cougar Dam	2.1	4.4	**2.3**	
McKenzie	S. Fork McK abv Cougar	Cougar Reservoir to NFD 1980	9.1	11.1	**2**	river mile
McKenzie	S. Fork McK abv Cougar	NFD 1980 to Rebel Creek	11.1	13.8	**2.7**	
McKenzie	S. Fork McK abv Cougar	Rebel Creek to Dutch Oven C.G.	13.8	16.2	**2.4**	
McKenzie	S. Fork McK abv Cougar	Dutch Oven C.G. to Homestead C.G.	16.2	18.1	**1.9**	
McKenzie	S. Fork McK abv Cougar	Homestead C.G. to Twin Springs C.G.	18.1	20.2	**2.1**	
McKenzie	S. Fork McK abv Cougar	Twin Springs C.G. to Roaring River	20.2	22.3	**2.1**	
McKenzie	S. Fork McK abv Cougar	Roaring River to Elk Creek	22.3	25.1	**2.8**	
McKenzie	McKenzie	S.F. McKenzie to Hamlin	58.9	59.2	**0.3**	
McKenzie	McKenzie	Hamlin to McKenzie Bridge	59.2	67.5	**8.3**	
McKenzie	**Horse Creek**	**Mouth to Bridge**	**0**	**2.4**	**2.4**	
McKenzie	Horse Creek	Bridge to Avenue Creek	2.4	5.9	**3.5**	
McKenzie	Horse Creek	Avenue Creek to Braids	5.9	7.1	**1.2**	
McKenzie	Horse Creek	Braids to Road Access	7.1	9.2	**2.1**	
McKenzie	Horse Creek	Road Access to Separation Creek	9.2	10.7	**1.5**	

Subbasin	River	Description	Start River Mile	End River Mile	Total Distance	Comment
McKenzie	Horse Creek	Separation Creek to Trail Bridge	10.7	11.8	**1.1**	
McKenzie	Horse Creek	Trail Bridge to Pothole Creek	11.8	13.5	**1.7**	
McKenzie	McKenzie	McKenzie Bridge to McKenzie Trail	67.5	69.1	**1.6**	
McKenzie	McKenzie	McKenzie Trail to Paradise	69.1	70.6	**1.5**	
McKenzie	McKenzie	Paradise to Belknap	70.6	73.9	**3.3**	
McKenzie	**Lost Creek**	**Mouth to Hwy 126 Bridge**	**0**	**0.5**	**0.5**	
McKenzie	Lost Creek	Hwy 126 Bridge to Split Pt	0.5	1	**0.5**	
McKenzie	Lost Creek	Split Pt to Limberlost CG	1	2.5	**1.5**	
McKenzie	Lost Creek	Limberlost CG to Cascade	2.5	3	**0.5**	
McKenzie	Lost Creek	Cascade to Spring	3	5.3	**2.3**	
McKenzie	McKenzie	Belknap to Olallie C.G.	73.9	79.4	**5.5**	
McKenzie	McKenzie	to Spawning Channel	79.4	79.5	**0.1**	
M. Fork	**Fall Creek**	**Reservoir to Release Site**	**13.7**	**15**	**1.3**	**release site RM -1.3**
M. Fork	Fall Creek	Release Site to Johnny Creek Bridge	15	19.7	**4.7**	
M. Fork	Fall Creek	Johnny Cr Bridge to Bedrock campground	19.7	21	**1.3**	
M. Fork	Fall Creek	Bedrock campground to Portland Creek	21	22	**1**	RM for portland creek
M. Fork	Fall Creek	Portland Creek to NFD 1828 Bridge	22	23.7	**1.7**	
M. Fork	Fall Creek	NFD 1828 Bridge to Hehe Creek	23.7	25.5	**1.8**	
M. Fork	Fall Creek	Hehe Creek to Gold Creek	25.5	29	**3.5**	
M. Fork	Fall Creek	Gold Creek to Falls	29	30	**1**	
M. Fork	**Little Fall Creek**	**Fish Ladder to NFD 1818 Bridge**	**12.9**	**15.4**	**2.5**	**ladder RM measured manually**
M. Fork	Little Fall Creek	NFD 1818 Bridge to NFD 1806 Bridge	15.4	17.9	**2.5**	manually measured
M. Fork	Little Fall Creek	NFD 1806 Bridge to Trib below NFD 400	17.9	21.7	**3.8**	exact Loc'n?
M. Fork	M. Fork	Jasper to Pengra	195.1	200.3	**5.2**	topo RM
M. Fork	M. Fork	Pengra to Dexter	200.3	203	**2.7**	
M. Fork	**N. Fork M. Fork**	**1926 Bridge to Release Site**	**15.5**	**18.3**	**2.8**	
M. Fork	N. Fork M. Fork	Release Site to Kiahanie Bridge	18.3	22.8	**4.5**	
M. Fork	N. Fork M. Fork	Kiahanie Bridge to 1944 Bridge	22.8	28.2	**5.4**	
M. Fork	N. Fork M. Fork	1944 Bridge to Minute Creek	28.2	32.1	**3.9**	
M. Fork	N. Fork M. Fork	Minute Creek to 2nd to last pullout/RM 33.6	32.1	33.6	**1.5**	
M. Fork	N. Fork M. Fork	2nd to last pullout/RM 33.6 to Skookum Cr	33.6	36.4	**2.8**	

Appendix 4: Accounting of hatchery-origin Chinook salmon passing Willamette Falls

Location	Description	02 Totals	03 Totals	04 Totals	05 Totals	06 Totals	07 Totals	08 Totals	09 Totals	10 Totals	11 Totals	12 Totals	Comment
Willamette Falls	H ChS over W Falls	83,100	87,700	96,700	36,600	37,000	23,100	14,700	28,500	67,100	45,100	37,200	Raw Count of clipped ChS over W Falls
Willamette Falls	Net H ChS over W Falls w 6% fallback	78,114	82,438	90,898	34,404	34,780	21,714	13,818	26,790	63,074	42,394	34,968	From Schroeder floy tagging '98-2000
Below Detroit		326	680	338	329	259	494	226	281	461	599	557	
Below Foster		955	630	377	530	528	483	209	483	799	545	443	
Below Leaburg	Peak Redds	115	171	99	75	84	141	240	167	266	232	268	From basin-specific survey summaries. Peak redd counts from spawning ground surveys.
Above Leaburg		807	1,016	1,038	1,072	709	1,346	629	531	1,013	1,168	666	
Below Dexter		64	14	9	9	111	9	134	36	22	99	76	
Below Detroit		0.87	0.96	0.85	0.70	0.69	0.75	0.27	0.49	0.76	0.63	0.75	
Below Foster		0.86	0.87	0.82	0.80	0.84	0.82	0.50	0.38	0.96	0.79	0.84	
Below Leaburg	pHOS	0.80	0.93	0.94	0.50	0.58	0.78	0.83	0.73	0.91	0.59	0.83	From basin-specific survey summaries. pHOS estimates from counts of clipped and unclipped ChS carcasses, adjusted for otolith marks in unclipped fish.
Above Leaburg		0.35	0.39	0.38	0.18	0.17	0.16	0.16	0.26	0.45	0.25	0.16	
Below Dexter		0.96	0.96	0.83	0.89	0.57	0.72	0.62	0.77	0.90	0.85	0.87	
Below Detroit		709	1,632	718	576	447	926	153	344	876	945	1,044	
Below Foster		2,058	1,375	772	1,056	1,111	984	261	460	1,916	1,076	930	
Below Leaburg	HOS	231	398	233	94	121	276	497	303	605	345	555	Assumes 2.5 spawners per redd: Peak Redds * 2.5 * pHOS
Above Leaburg		710	1,001	996	472	300	548	247	339	1,145	730	266	
Below Dexter		153	33	19	20	158	16	209	70	50	209	166	
Below Detroit		0.60	0.72	0.77	0.51	0.17	0.41	0.32	0.32	0.40	0.33	0.36	
Below Foster		0.20	0.30	0.70	0.30	0.10	0.10	0.10	0.10	0.30	0.10	0.30	
Below Leaburg	PSM Rate	0.16	0.52	0.60	0.40	0.10	0.37	0.09	0.22	0.23	0.28	0.26	From basin-specific survey summaries. Prespawn mortality calculated from recovery of female carcasses. PSM rates of 1.0 were converted to 0.99 when redds were found but zero spawned-out females were sampled.
Above Leaburg		0.05	0.16	0.11	0.16	0.02	0.05	0.01	0.01	0.10	0.05	0.01	
Below Dexter		0.84	0.99	0.99	0.94	0.29	0.95	0.17	0.99	0.99	0.60	0.57	
Below Detroit		1,064	4,197	2,405	599	92	644	72	162	584	465	587	
Below Foster		515	589	1,801	453	123	109	29	51	821	120	399	
Below Leaburg	PSM Count	44	431	349	63	13	162	49	85	181	134	195	The number of hatchery-rorigin that died before spawning given that survival rate was (1 - PSM)
Above Leaburg		37	191	123	90	6	29	2	3	127	38	3	
Below Dexter		777	3,313	1,406	290	66	324	44	6,887	9,198	317	221	
Below Detroit		1,773	5,829	3,123	1,175	538	1,570	224	506	1,460	1,410	1,632	
Below Foster		2,573	1,964	2,573	1,509	1,235	1,093	290	511	2,737	1,196	1,329	
Below Leaburg		275	829	582	157	135	438	547	388	786	479	751	Basin-specific hatchery origin fish that spawned or died before spawning but were not harvested.
Above Leaburg		748	1,191	1,120	562	306	577	249	342	1,272	768	269	
Below Dexter	HOS + PSM	930	3,346	1,424	310	224	340	253	6,957	9,248	526	387	
Other (unsurveyed) Basins		389	233	278	180	205	56	22	75	227	64	150	Uses weak positive relationship between HOS (+PSM) and harvest rate to predict run size of hatchery fish based on reported havest in unsurveyed streams. Formula is 0.9022 * reported harvest with r-squared = 0.30
Minto		4,362	4,032	3,559	1,427	3,148	1,619	768	2,068	4,274	NA	NA	
Foster		6,293	5,751	8,746	2,826	3,674	1,473	2,226	3,167	8,973	8,993	8230	
McKenzie	Capture/Removal of Hatchery Fish	5,939	5,635	6,132	3,019	2,770	2,197	2,501	3,304	6,251	5,490	3,665	
Leaburg H/Dam		0	0	0	0	0	330	137	136	126	65	78	
Dexter		NA	NA	NA	NA	5,664	3,728	2,168	4,322	6,116	6,884	8,277	
Basinwide	Returns to Hatchery	31,194	28,384	36,948	15,821	16,949	10,145	8,705	14,820	28,408	23,646	21,959	From Joint staff report
Basinwide	HOS + PSM	6,687	13,392	9,100	3,891	2,643	4,074	1,585	8,779	15,729	4,443	4,517	Summed from above
Basinwide	Total Harvest	12,587	11,026	13,256	4,564	5,738	2,184	295	3,161	9,732	4,928	5,068	From harvest summaries
Basinwide	HOS + PSM + Harvest + Hatchery	50,468	52,802	59,304	24,276	25,330	16,403	10,585	26,760	53,869	33,017	31,544	Total hatchery fish accounted for by spawners, PSM, harvest, and hatchery return.
Unaccounted hatchery-origin fish using Joint Staff Report		**27,646**	**29,636**	**31,594**	**10,128**	**9,450**	**5,311**	**3,233**	**30**	**9,205**	**9,377**	**3,424**	**Net ChS over W Falls minus accounted fish**
Percent of net Willamette Falls		**35%**	**36%**	**35%**	**29%**	**27%**	**24%**	**23%**	**0%**	**15%**	**22%**	**10%**	

Appendix 5: Historical Chinook Salmon Outplanting Records

Year	Above Minto		Above Detroit		Above Foster		Above Cougar		Above Lookout Point	
	Females	Males	Females	Males	Females	Males	Females	Males	Females	Males
2000			243	690	579	1,054	695	811		
2001			290	778	579	1,381	765	1,290		
2002			942	1,735	2,450	3,094	1,726	2,516	1,387	2,378
2003			1,261	1,623	1,916	2,692	1,287	1,694	562	1,135
2004			891	1,584	3,956	4,606	1,147	2,018	1,225	1,478
2005			227	372	1,047	1,485	387	476	335	463
2006			693	1,150	1,147	1,769	243	775	414	413
2007			517	450	241	162	297	446	353	202
2008			20	218	248	438	288	586	180	333
2009			147	753	199	661	624	754	305	816
2010			1,143	1,335	2,546	3,798	250	260	572	850
2011			63	85	1,421	2,048	175	170	787	915
2012			121	136	1,349	1,869	250	179	1,257	1,433
2013	247	377	804	941	635	1,064	253	188	931	1,159
2014	349	438	547	884	483	674	401	141	463	602
2015	69	102	737	921	270	333	400	200	607	610
2016	214	315	804	434	109	168	324	151	309	378
2017	212	307	726	891	109	146	376	235	266	475