Work Completed for Compliance with the 2008 Willamette Project Biological Opinion, USACE funding: 2012 hatchery baseline monitoring

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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).

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 Chinook salmon (Williamson et al. 2010) 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 for integrated harvest augmentation as part of the Willamette Valley Hatchery Mitigation Program. These hatchery stocks, as well as all naturally spawned spring Chinook salmon in the Upper Willamette Basin, are included in the Upper Willamette River Evolutionary Significant Unit (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 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. 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. Summer steelhead were first introduced to the South Santiam River as mitigation for lost winter steelhead production in areas inundated by Foster and Green Peter reservoirs. The scope of work actually directed towards risks posed by summer steelhead is much smaller than that directed towards issues faced by spring Chinook. The Willamette Project Biological Opinion (BiOP; NMFS 2008) required the USACE to collect information to describe the nature and extent of these potential effects but beyond relatively small-scale studies often integrated into much larger studies involving spring Chinook, more focused work will only follow commitment of significantly more effort and funds.

This report fulfills a requirement under Task Order NWPPM-10-FH-06, covering activities of May 2012–June 2012, 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 2008). The Corps provided funding to continue ongoing monitoring activities and initiate long-term planning. The conceptual relationship between spring Chinook salmon prioritized objectives, RPAs, and 2012 work tasks is depicted in Figure 2. In future work, the intent is to expand the conceptual framework provided in Figure 2 and develop specific numerical goals in terms of, for example, adult returns desired per subbasin. A detailed list of tasks associated with the work is provided in Appendix 1.

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 and promoting their conservation and recovery. Progress towards that goal will follow achievement of three overarching objectives:

1. Develop and maintain hatchery broodstocks to meet to meet harvest goals and assist with implementation of the Upper Willamette Conservation and Recovery Plan for Chinook Salmon and Steelhead (National Marine Fisheries Service [NMFS] and ODFW 2011), 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.

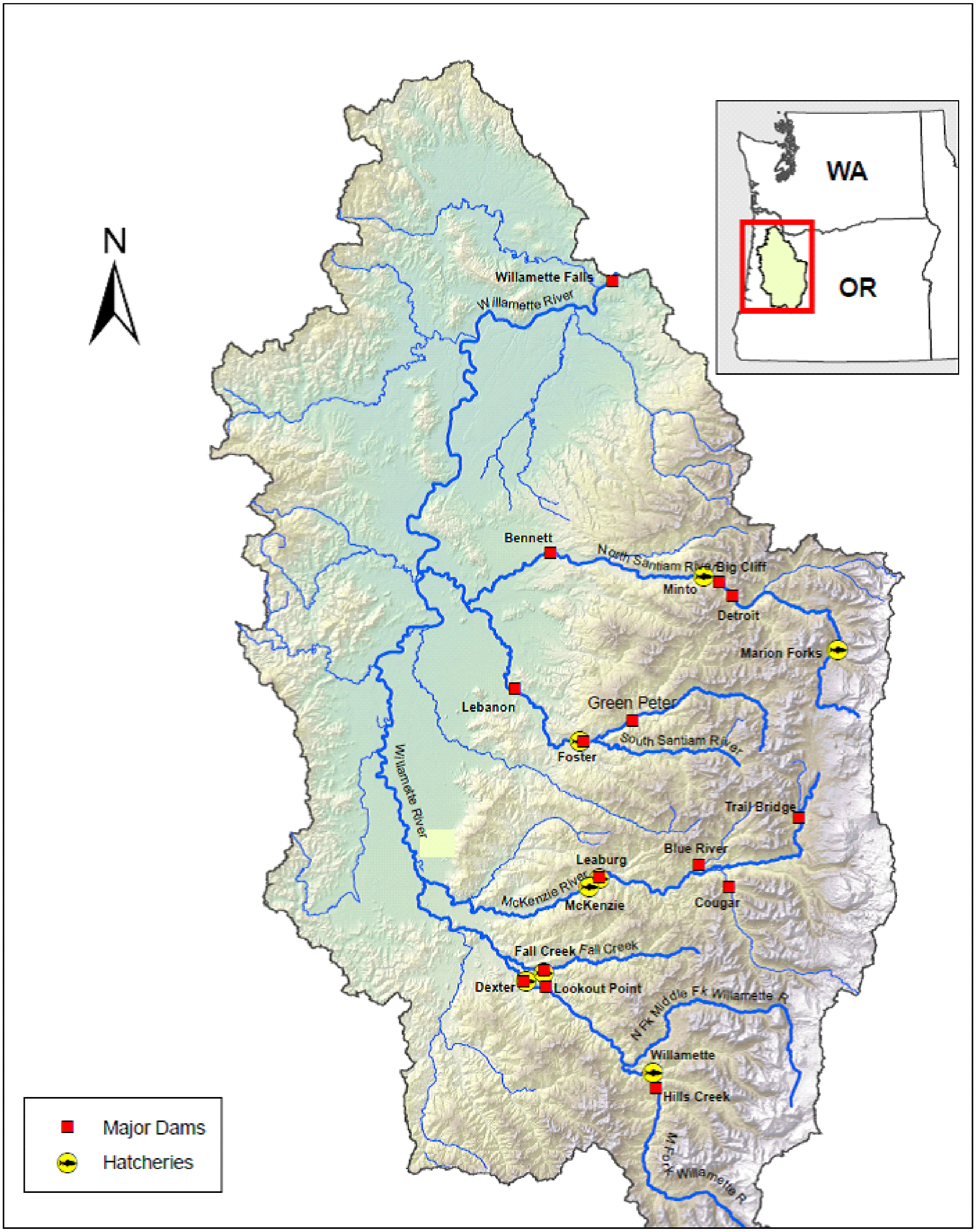

Figure 1. The Willamette Basin with major dams, hatcheries, and fish collection facilities.

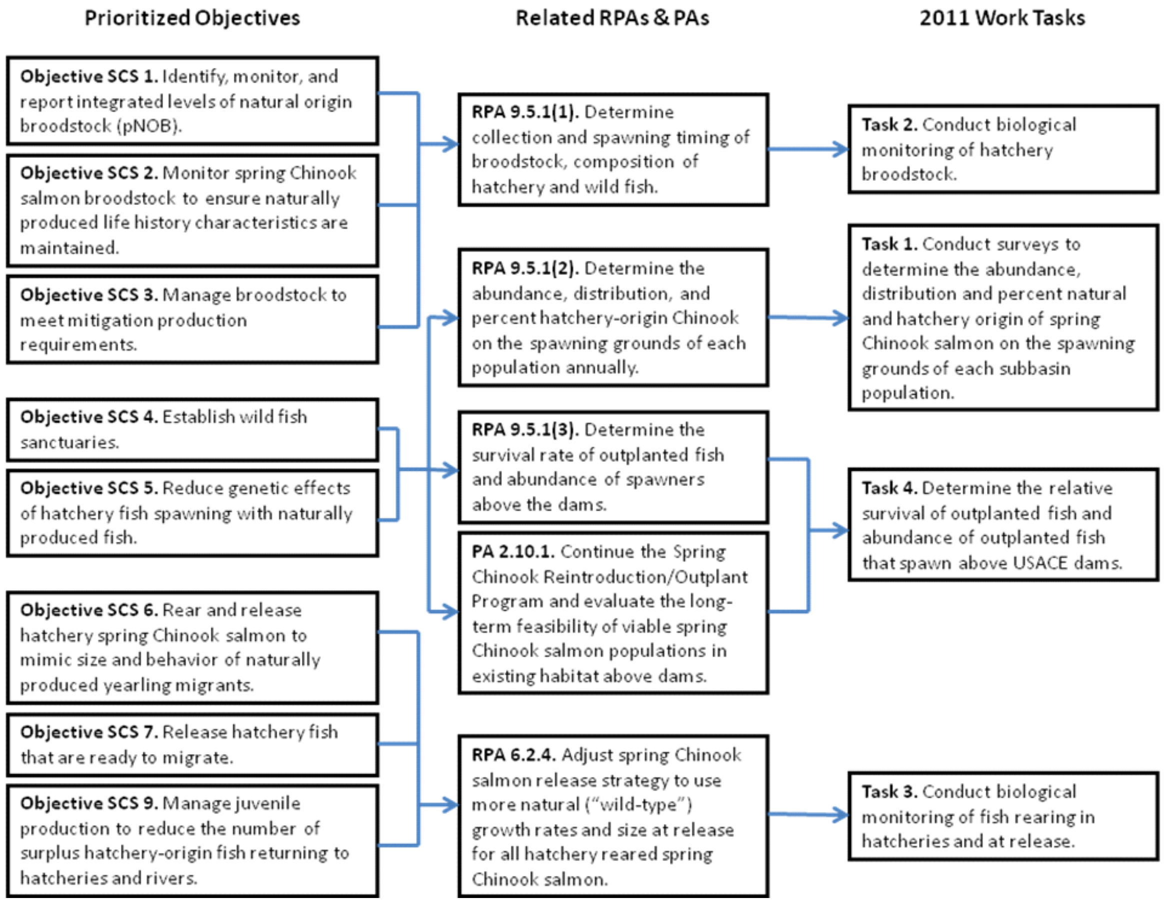

Figure 2. Relationship between Prioritized Objectives, Reasonable and Prudent Alternatives (RPAs), Proposed Actions (PAs), and Work Tasks conducted in 2012 for spring Chinook hatchery programs in the Upper Willamette Basin.

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). 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 the Hatchery Genetic Management Plans (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; SARS) 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 2013).

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 sufficient returning adults to support all mitigation 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.).

In 2012, adult collection began in May 2012 and occurred into October 2012 at all facilities. Collection protocols varied by hatchery. In the North Santiam subbasin, broodstock were collected in temporary traps at Upper and Lower Bennett dams and transported to McKenzie Hatchery for holding and spawning because the Minto Fish Collection Facility was under construction. In the South Santiam subbasin collection occurs at a trap in Foster Dam and fish are transported by truck to the nearby hatchery. In the McKenzie subbasin fish volunteer to the ladder on site at the hatchery. In the Middle Fork Willamette subbasin fish are captured at the Dexter Dam trap and transported by truck to the Willamette Hatchery further upstream. Adults at capture are generally anesthetized with CO_2 to facilitate handling except that the temporary protocols in place on the North Santiam did not permit use of anesthesia and fish were handled without anesthesia.

Spawning protocols are relatively uniform across hatcheries whereby adults are crowded, anesthetized with MS-222 or CO_2, and checked for ripeness. Unripe fish are returned to holding areas and ripe fish are killed and bled. Eggs are removed from females into spawning buckets and fertilized using a 1:1 sex ratio.

Incorporation of natural origin fish into the broodstock may ultimately be set at 5% or more per ongoing discussions and development of the HGMPs, but in 2012 the percentage of natural origin fish incorporated into broodstock varied widely by hatchery. In the North Santiam during 2012, natural origin fish were incorporated into the broodstock as part of an experiment to evaluate differences between hatchery- and natural-origin fish (Sharpe et al. *in review*). In the South Santiam subbasin, no natural-origin fish were incorporated into the brood because downstream juvenile survival at Foster Dam may be high enough that natural-origin adults are better off spawning above the dam. In the McKenzie River the natural-origin adults that volunteer to the hatchery were incorporated into the brood because most unclipped adults (presumed "wild" fish) that enter the hatchery are often unclipped hatchery fish. Returning all unclipped fish to the river would therefore increase pHOS among river spawners, an undesirable outcome. Natural-origin fish captured at Dexter Dam in the Middle Fork Willamette were all incorporated into brood at the Willamette Hatchery. Poor holding, spawning, and rearing conditions below Dexter Dam and recurrent high prespawning mortality rates above Lookout Point Dam, coupled with presumably poor downstream juvenile survival at Lookout Point and Dexter dams, led to the management decision to incorporate all unclipped (and thus a small number of naturally-produced) fish into brood in 2012.

Section 1.2.2: Outplanting and pHOS Protocols and Goals

Outplanting protocols vary widely throughout the subbasins. When the outplant goal is focused upon disposition of excess hatchery-origin fish (as in the North Santiam, McKenzie, 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 experimentally manipulate pHOS (McKenzie Hatchery: genetic pedigree study). When outplanting is focused upon the disposition of unclipped fish (South Santiam River and 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 the ultimate goal is to outplant with fish captured at the Minto Fish Collection Facility, but as construction continued at that facility in 2012, outplanted fish (adipose clipped only) were captured and trucked from the trap at Upper Bennett Dam with adults released in both 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. 2013). Outplanting in the Middle Fork Willamette subbasin is a complex procedure and includes 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, and into Little Fall Creek, a tributary entering 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. 2013; Mann et al. 2012). Finally, unclipped adults captured at the Fall Creek Dam trap are outplanted above Fall Creek Reservoir to continue 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). A summary of marks applied in 2012 appears in Table 1. 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 (2000 – 2010; Shaun Clements, ODFW, pers. comm.) with more than 100,000 tagged fish typically released from each hatchery.

Table 1. Marking of juvenile Chinook salmon released in 2012 with Coded Wire Tags (CWT), adipose clips (AD) and/or otolith marks (OT).

Stock	Tag Code	Release Date	Avg Weight (g)	CWT/AD/OT	AD/OT	Release Location
North Santiam (021)	090494	4/18/2012	41.09	18,628		North Santiam River
North Santiam (021)	090495	4/18/2012	41.09	18,628		North Santiam River
North Santiam (021)	090496	4/18/2012	41.09	18,628		North Santiam River
North Santiam (021)	090497	4/18/2012	41.09	18,629		North Santiam River
North Santiam (021)	090498	4/18/2012	41.09	18,645		North Santiam River
North Santiam (021)	090499	4/18/2012	41.09	18,645		North Santiam River
North Santiam (021)	090516	4/18/2012	41.09	18,646		North Santiam River
North Santiam (021)	090517	4/18/2012	40.35	18,645		North Santiam River
North Santiam (021)	090518	4/18/2012	40.07	18,663		North Santiam River
North Santiam (021)	090519	4/18/2012	40	18,663		North Santiam River
North Santiam (021)	090520	4/18/2012	40	18,663		North Santiam River
North Santiam (021)	090521	4/18/2012	40	18,663		North Santiam River
North Santiam (021)	090526	3/15/2012	37.89	54,858	172,780	North Santiam River
North Santiam (021)	090527	3/14/2012	36.08	55,279	172,801	North Santiam River
North Santiam (021)	090672	8/9/2012	9.44	98,645	1,401	Detroit Reservoir
North Santiam (021)	090673	8/9/2012	9.42	99,549	1,413	North Santiam River
South Santiam (024)	090372	2/14/2012	51.43	40,871	235,917	South Santiam River
South Santiam (024)	090373	2/21/2012	40.25	32,323	343,016	South Santiam River
South Santiam (024)	090374	2/29/2012	40.25	31,623	67,678	Molalla River
South Santiam (024)	090641	10/31/2012	57.2	52,255	241,041	South Santiam River
McKenzie (023)	090535	2/2/2012	38.31	196,575	3,467	McKenzie River
McKenzie (023)	090536	2/2/2012	36.46	198,699	559	McKenzie River
McKenzie (023)	090537	3/12/2012	50.74	211,353	194	Coast Fork Willamette River
McKenzie (023)	090538	3/12/2012	48.05	243,944	1,402	McKenzie River

Stock	Tag Code	Release Date	Avg Weight (g)	CWT/AD/OT	AD/OT	Release Location
McKenzie (023)	090674	11/2/2012	43.07	50,338	119,969	McKenzie River
McKenzie (023)	090675	11/2/2012	43.07	52,164	119,868	McKenzie River
MF Willamette (022)	090371	2/3/2012	39.03	31,583	687,544	MF Willamette River
MF Willamette (022)	090530	3/6/2012	30.75	100,301	257,119	MF Willamette River
MF Willamette (022)	090531	3/6/2012	60.4	93,621	114,113	MF Willamette River
MF Willamette (022)	090532	4/17/2012	54.85	110,457	129,668	MF Willamette River
MF Willamette (022)	090580	11/2/2012	55.93	27,644	108,563	MF Willamette River
MF Willamette (022)	090591	11/2/2012	55.93	51,790	108,939	MF Willamette River
			Total Tagged	2,057,618	2,887,452	

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. In 2012, 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 for profit, 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) in the Willamette Basin upstream of Willamette Falls (Figure 1) in 2012 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 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 recorded global positioning system (GPS) coordinates for each redd in a river section. 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), 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 adipose fin clips had CWTs, and in the McKenzie to determine if unclipped carcasses had a CWT. 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 and steelhead through ladders at the Bennett dams on the North Santiam River and the 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 by presumed hatchery or wild origin could be estimated. 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 Lower Bennett Dam was operated for the first time in 2012.

2.1.1.3.2 Video Monitoring at Leaburg Dam: Passage of spring Chinook salmon through the fishways at Leaburg Dam was monitored with video recording equipment. We recorded fish passage at both the left-bank and right-bank fish ladders.

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, 2008 through 2012, in the North Santiam, South Santiam and

McKenzie rivers. We used the redd count data for only 2008, 2011, and 2012 in the Middle Fork Willamette because not enough redds were counted in that subbasin in 2009 and 2010. 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 in 2012. Average spawn timing in the hatcheries was calculated as the weighted mean date of spawning, weighted by the number of fish spawned on each spawn date.

***2.1.2.3 Spawner Abundance Estimates**:* We used the peak count expansion method (more detail 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 = $Redd_{peak}/Redd_{female}$;

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

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 in 2012 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 (McKenzie, North and South Santiam, and Middle Fork Willamette rivers) and at hatcheries (McKenzie [McKenzie and N. Santiam brood] and Willamette Hatcheries). 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 following 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). For example, monitoring results in in the McKenzie River 2012 were typical of most years. Survey conditions were excellent throughout the survey season, many redds were counted and many carcasses were recovered. Carcasses were relatively easy to collect below Leaburg Dam. We counted 268 redds and collected 411 carcasses which equates to 1.5 carcasses/redd (411/268 = 1.5). In what are at present the two important natural spawning reaches above Leaburg Dam, Leaburg Dam to Cougar Dam and the mainstem and tributaries above the confluence with the South Fork McKenzie River, we estimated carcasses recovered/redd constructed at 0.3 and 0.2, respectively: it is much harder to recover carcasses in the upper river reaches. Our reach-specific pHOS estimates showed that pHOS in the lowest reach (83%; below Leaburg Dam) was much higher than in the two upper reaches (28% and 8%, respectively): hatchery fish are not evenly distributed throughout the basin. Therefore, the true basinwide pHOS estimate was derived by weighting the reach-specific pHOS estimates by the reach-specific indices of spawner abundance, in this case by:

$$\text{pHOS} = [(0.830*268)+(0.281*251)+(0.080*415)] / (268+251+415) = 0.349$$

The alterative grossly oversimplified method to estimate pHOS would be to simply divide the number of hatchery-origin carcasses by the total number of carcasses recovered (368/577 = 0.638), which results in an overestimate of pHOS in 2012 in the McKenzie.

We also used the otoliths to adjust estimates of the proportion of natural-origin brood (pNOB) in the hatcheries using the counts of non-thermally-marked unclipped broodstock (WILD_B), and the total number of broodstock (TOT_B) using the following equation:

$\text{pNOB} = \text{WILD}_B/\text{TOT}_B$.

We compared pHOS estimates between subbasins and between river reaches below dams within subbasins using contingency table analyses (G-tests) where observed values were the estimated counts of wild- and hatchery-origin carcasses.

***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 in 2012 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. For the purpose of discussion in this document we arbitrarily categorize PSM as “low”, “medium”, and “high” when estimates were less than 20%, from 20% to 50%, and above 50%, respectively. 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.

We conducted additional PSM monitoring in the South Santiam River for outplants above Foster Dam. All outplanted fish were tagged with a numbered Floy tag. For each tagged fish fork length (cm), outplant date, and outplant site (Caulkins Marina, Riverbend Park, or Gordon Road) was recorded. During PSM and spawning surveys we recorded spawner status of all recovered female carcasses. We used multiple logistic regression to test for associations between spawner status and fish size, outplant date and outplant site. The multiple regression included data from surveys conducted in 2009 through 2012.

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. The decimal codes of CWTs were read at ODFW’s Clackamas Fish Identification Laboratory to identify the hatchery stock and release site. We estimated the extent and origin of stray hatchery fish by expanding the number of recovered fish with a specific tag code to the percentage of fish in that release group that were tagged. For example, if one CWT from a McKenzie release was recovered in the South Santiam River when 10% of the McKenzie fish received CWTs, we assumed an additional nine McKenzie fish from that release strayed into the South Santiam River.

Section 2.2: Reintroduction Efforts

We intercepted salmon 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 Dam and the Upper and Lower Bennett dams. 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 and distribution based on spawner surveys (described below).

We collected biological data from all Chinook salmon that were outplanted. Data collected from spawned fish included fork length, sex, and presence or absence of an adipose fin clip. We collected tissue samples (small portion of a fin stored in 100% ethanol) from outplanted fish, and recorded sex along with presence or absence of a fin clip.

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 recorded at each hatchery by presence or absence of an adipose fin clip.

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. 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 in 2012 for both summer-run steelhead and Chinook salmon by querying HMIS for those data (Appendix 4). We also queried RMIS to obtain information on Chinook salmon liberation dates and release locations for CWT fish from Willamette hatcheries (Appendix 4). 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 2012 the total count of spring Chinook salmon ascending Willamette Falls was 37,213 (35,889 adults and 1,314 jacks). Fish arrived beginning on 21 February, peaking on 9 May and concluding 15 August (by convention, Chinook salmon counted after 15 August are considered fall Chinook salmon). The run at Willamette Falls was predominated by hatchery returns, with an estimated 76.6% of the 2012 run originating from Willamette hatcheries (ODFW/WDFW 2013) based on observed adipose mark rates.

In 2012, 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 South Santiam, McKenzie, and Dexter facilities. Collections at Upper Bennett Dam on the North Santiam River concluded in early August.

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. For each subbasin, 2012 summary data on redd counts, redd densities, and prespawning mortality rates are provided in the form of maps with pooling of the counts and rates across multiple sample reaches to illustrate general patterns of abundance and distribution. Redd density data for 2012 and earlier years' estimates are provided in Table 2. Figure 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 in 2012 (e.g. Little Fall Creek in the Middle Fork

Willamette) or where unusual management options were exercised in 2012 and detailed information on survey results in those tributaries might be of particular interest (e.g., the Little North Santiam River where no outplanting occurred in 2012). A description of how survey reaches were pooled for which metrics is presented in draft form in Appendix 2.

North Santiam River: The North Santiam River (Figures 5 through 8) was surveyed beginning 3 July and ending October 22, 2012. Redd construction was first observed August 6 but that observation represented a single redd; multiple redds were not counted in a single day until August 27. Peak redd counts were obtained between September 18 and October 11, depending on the particular river reach surveyed (Table 3). As in previous years, redd density in 2012 was highest in the section between the Bennett and Minto dams. Within that reach the highest redd densities were observed immediately below Minto Dam. Redd densities were significantly higher between Bennett and Minto dams (including redds in Little North Santiam) in 2012 (5.9 redds/km) compared to recent historical values (2002 – 2011: 4.1 ± 0.51 redds/km [mean ± SEM]; t = -3.498; df = 9; *P* = 0.007) for that reach (Table 2).

We estimated that for 2008-2012 the average spawn timing in the North Santiam River was September 28 (Figure 9) based on the inflection point on a sigmoid curve fitted to the cumulative redd counts observed in those years. In 2012 the mean date of spawning of North Santiam broodstock at McKenzie Hatchery was September 17. We conclude that spawning in the hatchery in 2012 preceded the average peak spawn time by about 11 d. Importantly, peak natural spawning in each subbasin in 2012 appeared to be somewhat earlier than the average calculated from 2008 through 2012 redd count data suggesting that while peak spawning at the hatcheries was earlier than the average, it may have been because spawning throughout the basin was slightly advanced in general.

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

		Redds/km										
Subbasin	Section	2012	2011	2010	2009	2008	2007	2006	2005	2004	2003	2002
North Santiam	Below Bennett Dams	0.3	1	1.7	1.1	0.1	3.8	0.7	0.9	0.9	0.6	0.9
	Bennett Dams to Minto	10.2	10.6	6.3	3.8	3.5	7.8	3.6	4.6	5.1	4.6	4.7
	Little North Santiam	3	3.6	2.1	1	3.8	2.8	1.3	2.3	1.9	1.1	1.1
	Above Detroit Reservoir	6.3	12.4	13.7	--	--	--	--	--	--	--	--
South Santiam	Lebanon Dam to Foster Dam	18.5	22.6	32.7	20.1	8.7	20.1	21.2	22.1	15.6	25.4	37.3
	Below Lebanon Dam	0	0.2	5.9	--	--	--	0.7	--	0.1	0.6	2.1
	Above Foster Dam	7.7	7.4	4.8	--	--	--	--	--	--	--	--
McKenzie	Below Leaburg Dam	25.7	22.9	27.4	17.4	24.5	14.7	7.5	7.8	10.3	17.8	12
	Leaburg - SF McKenzie	5.8	10	11.5	4.6	5.2	14.8	5.2	4.1	12.9	9.7	7.5
	S. Fork below Cougar Dam	9.5	13.6	7.4	9.7	11.9	16.6	12.2	12.2	20.2	12.1	15.3
	S. Fork above Cougar Dam	7	8.9	7.1	11	6.3	5.7	6.5	4.4	--	--	--
	Above S. Fork	4.5	11.1	8.6	4.8	5.7	13.2	6.9	12.6	7.9	9.2	7.4
Middle Fork Willamette	Below Dexter	5.3	6.9	1.5	2.5	9.3	0.6	7.7	0.6	0.6	1	4.4
	North Fork Middle Fork	6.9	4	4.2	--	--	--	--	--	--	--	--
	Fall Creek	2.2	2.2	2.6	1.4	3.5	1.1	8.3	5.1	8.1	3.8	8.1
	Little Fall Creek	3.8	6.7	--	--	--	--	--	--	--	--	--
	Above Hills Cr. Reservoir	16.3	--	--	--	--	--	--	--	--	--	--

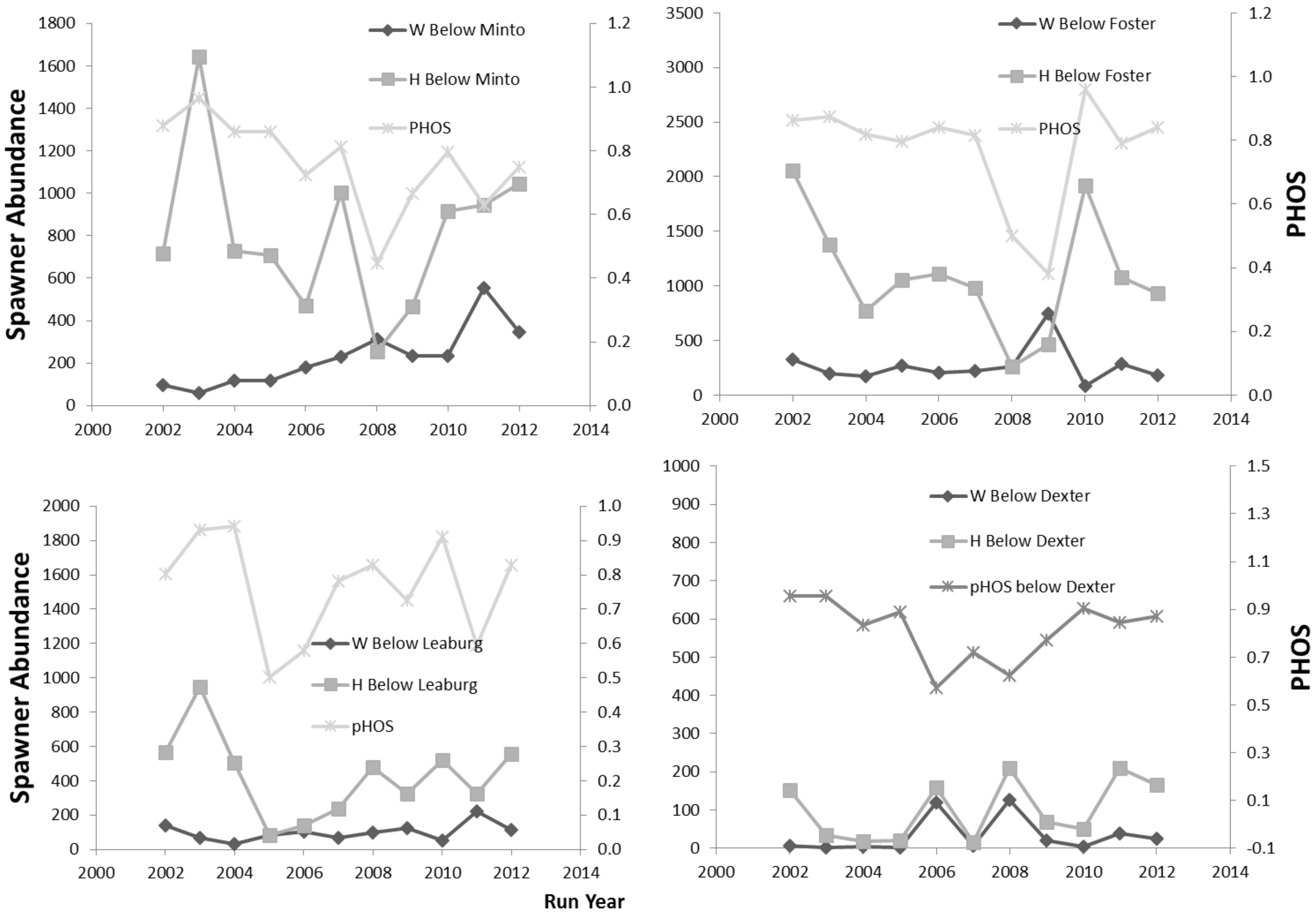


Figure 3. Spawner abundance estimates based on redd count expansion for reaches below dams. Note variable axes.

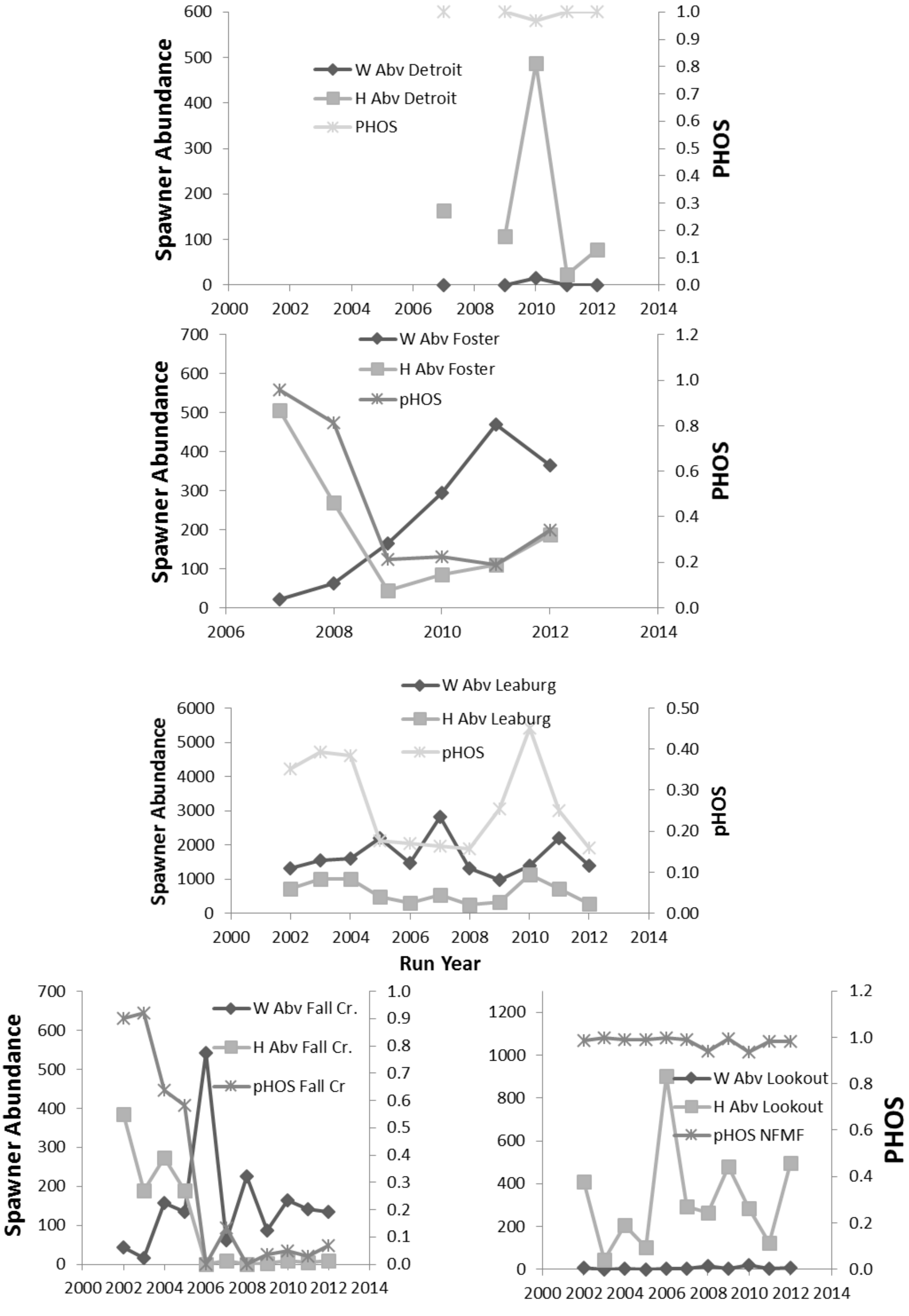
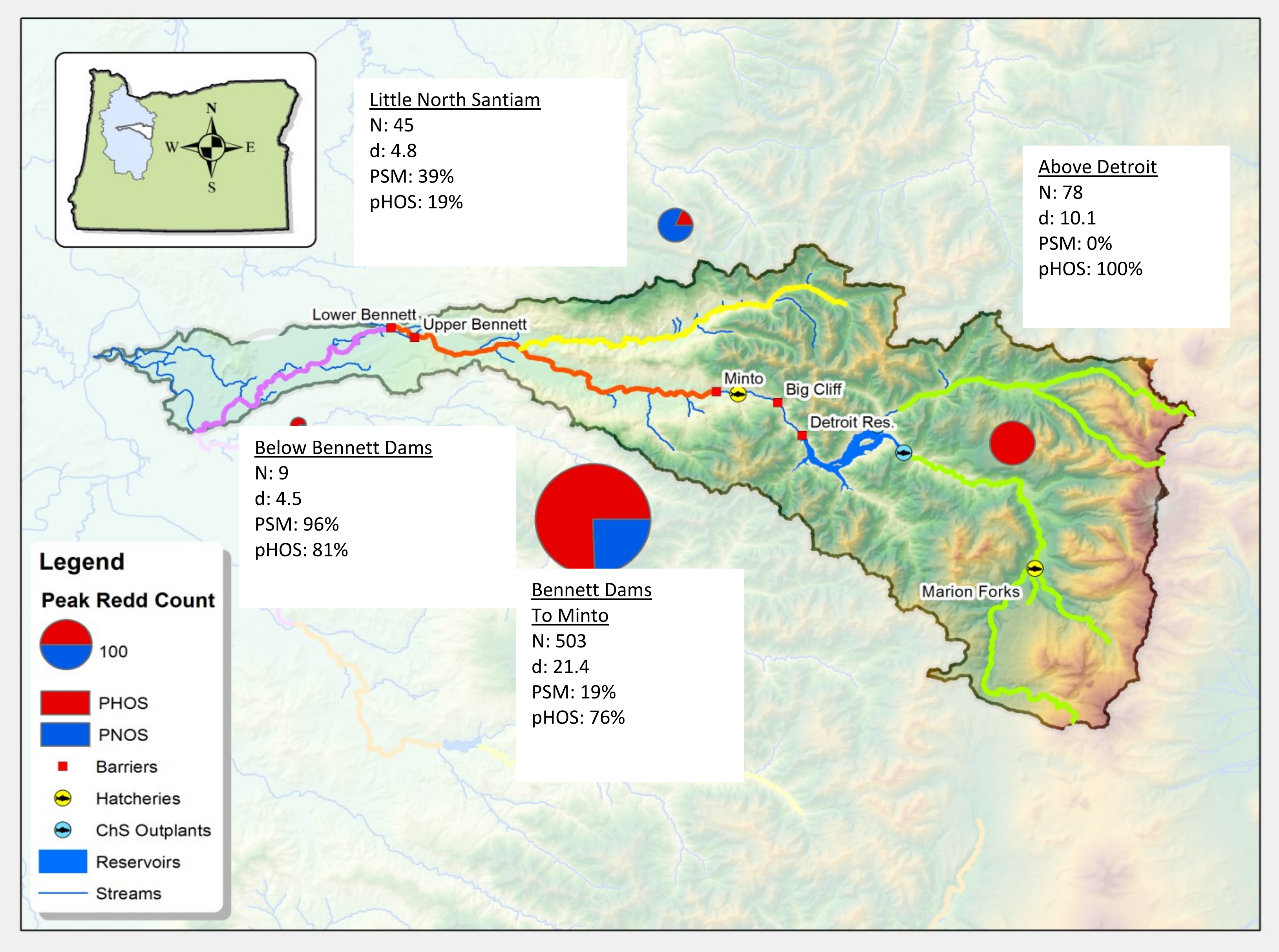


Figure 4. Spawner abundance estimates based on redd count expansion for reaches above dams. Note variable axes.

Table 3. Peak redd counts, date peak count was recorded, and number of surveys conducted by survey section in the North Santiam subbasin, 2012.

Subbasin	Survey Section	Peak Redd Count	Date of Peak Count	Number of Surveys
North Santiam Mainstem	Minto Dam to Packsaddle	39	10/3/2012	15
	Packsaddle to Gate's Bridge	192	9/28/2012	17
	Gate's Bridge to Mill City	142	9/28/2012	18
	Mill City to Fisherman's Bend	65	10/11/2012	17
	Fisherman's Bend to Mehama	55	10/11/2012	16
	Mehama to Powerlines	5	10/11/2012	15
	Powerlines to Upper Bennett	5	9/18/2012	12
	Upper Bennett to Stayton	5	10/11/2012	10
	Lower Bennett to Stayton	4	9/18/2012	5
	Stayton to Shelburn	0	N/A	7
	Shelburn to Green's Bridge	0	N/A	9
	Green's Bridge to Mouth	0	N/A	2
North Santiam Above Detroit	Parish Lake Road to Straight Cr	N/A	N/A	0
	Straight Cr to Bugaboo	N/A	N/A	0
	Bugaboo to Horn Cr	0	N/A	1
	Horn Cr	29	10/3/2012	4
	Marion Cr	19	9/18/2012	5
	Horn Cr to Minto Cr	7	10/3/2012	5
	Minto Cr to Pamelia Cr	21	9/18/2012	5
	Pamelia Cr to Whitewater Cr	N/A	N/A	0
	Whitewater Cr to Misery Cr	N/A	N/A	0
	Misery Cr to Cooper's Ridge	N/A	N/A	0
Breitenbush	S Fk Breitenbush to Hill Cr	0	N/A	2
	Hill Cr to Scorpion Cr	2	9/20/2012	2
	Scorpion Cr to Fox Cr	0	N/A	1
	Fox Cr to Humbug Cr	0	N/A	2
	Humbug Cr to Byars Cr	0	N/A	2
	Byars Cr to Picnic Area	0	N/A	1
Little North Santiam	Elkhorn Bridge to Salmon Falls	11	10/2/2012	5
	Salmon Falls to Camp Cascade	9	9/24/2012	5
	Camp Cascade to Narrows	16	10/9/2012	5
	Narrows to Golf Bridge	5	10/9/2012	5
	Golf Bridge to Bear Creek Bridge	4	10/2/2012	3
	Bear Creek Bridge to Lunkers Bridge	0	N/A	2



Little North Santiam
N: 45
d: 4.8
PSM: 39%
pHOS: 19%

Above Detroit
N: 78
d: 10.1
PSM: 0%
pHOS: 100%

Below Bennett Dams
N: 9
d: 4.5
PSM: 96%
pHOS: 81%

Bennett Dams
To Minto
N: 503
d: 21.4
PSM: 19%
pHOS: 76%

Figure 5. Spawner survey and carcass recovery results for the North Santiam River, 2012. Colored sections indicate major survey reaches. Pie charts indicate peak redd counts (also indicated by "N") by their size and proportion of hatchery-origin spawners.

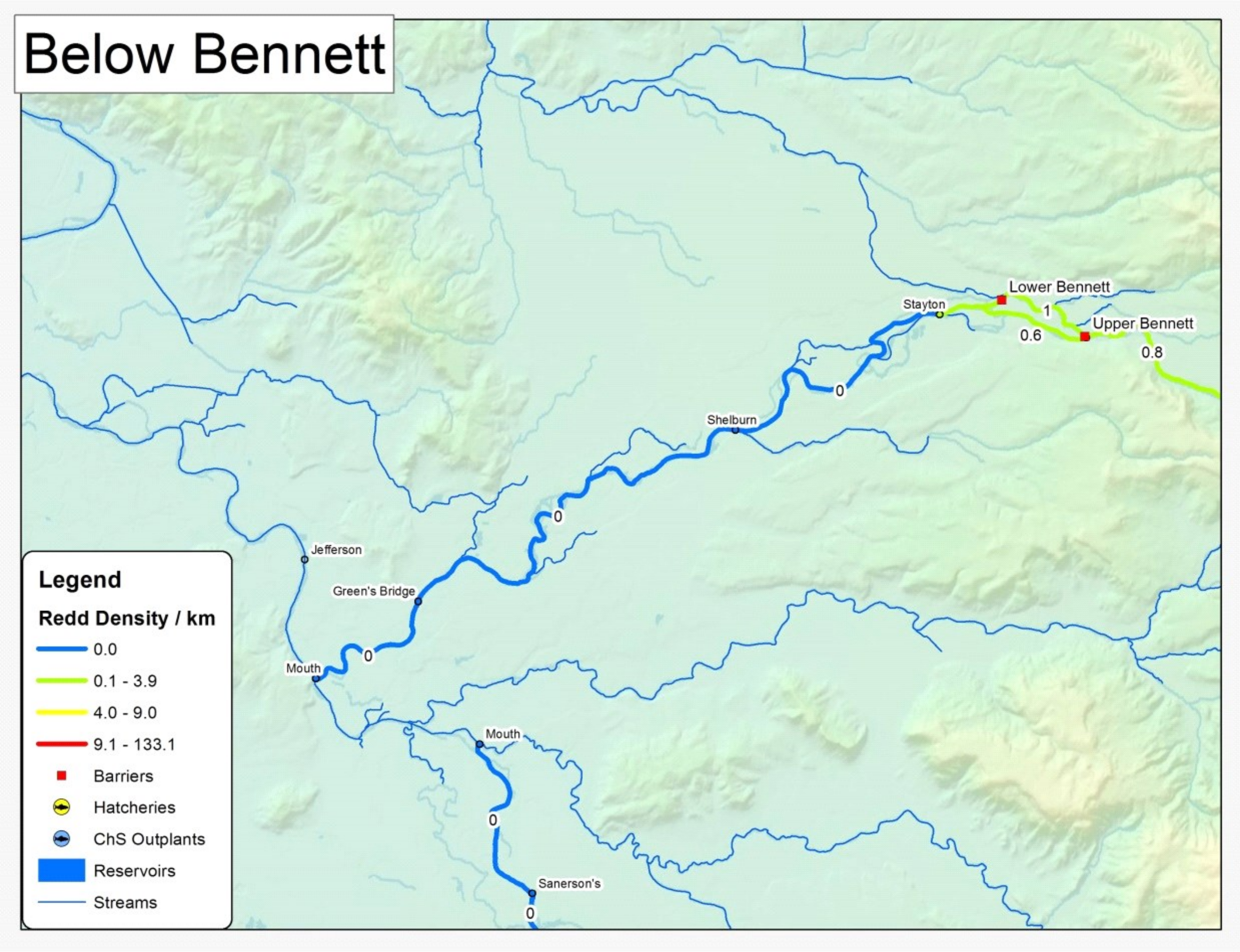


Figure 6. Spawning activity below Bennett dams in the North Santiam subbasin, 2012.

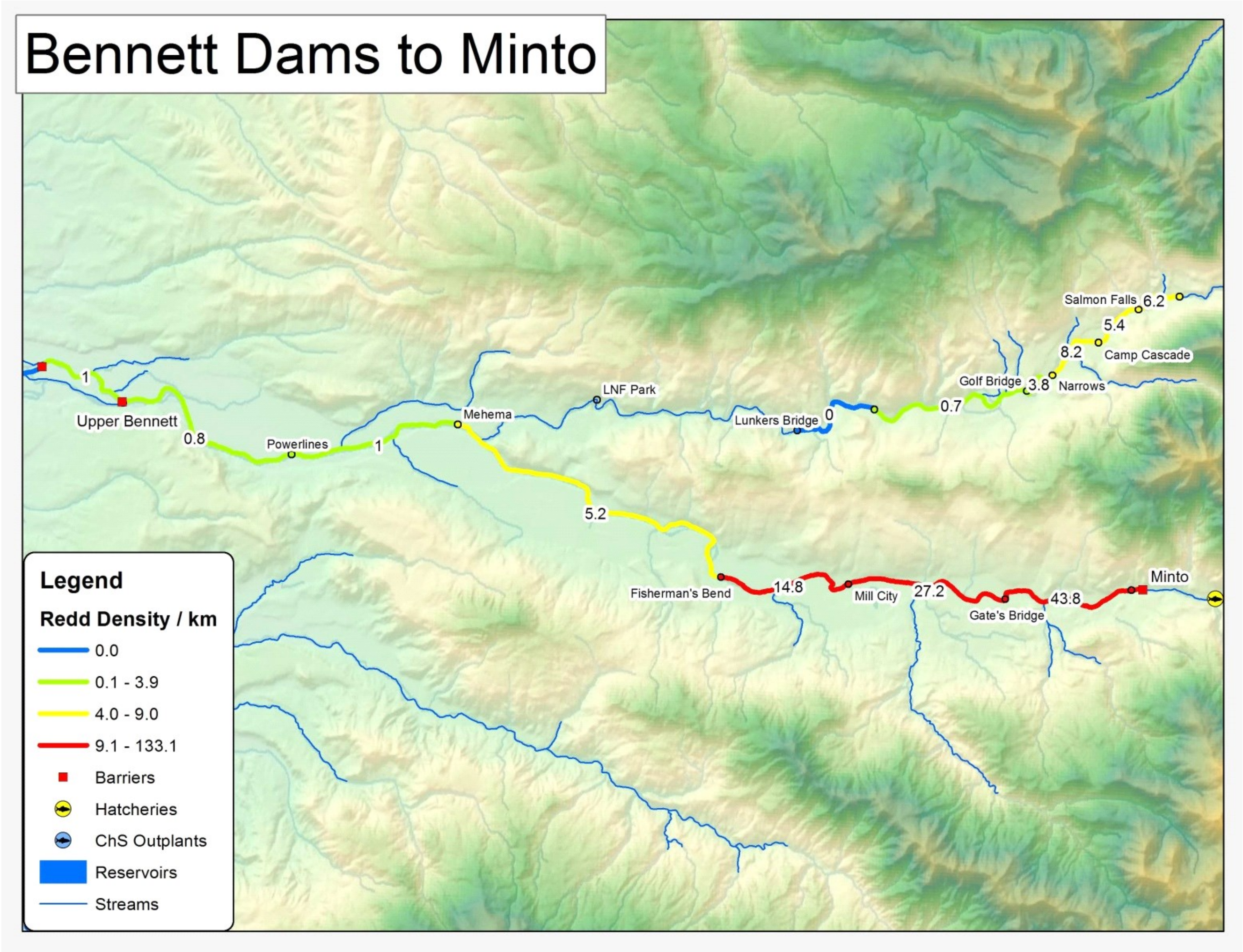


Figure 7. Spawning activity between Bennett dams and Minto Dam on the North Santiam subbasin, 2012.

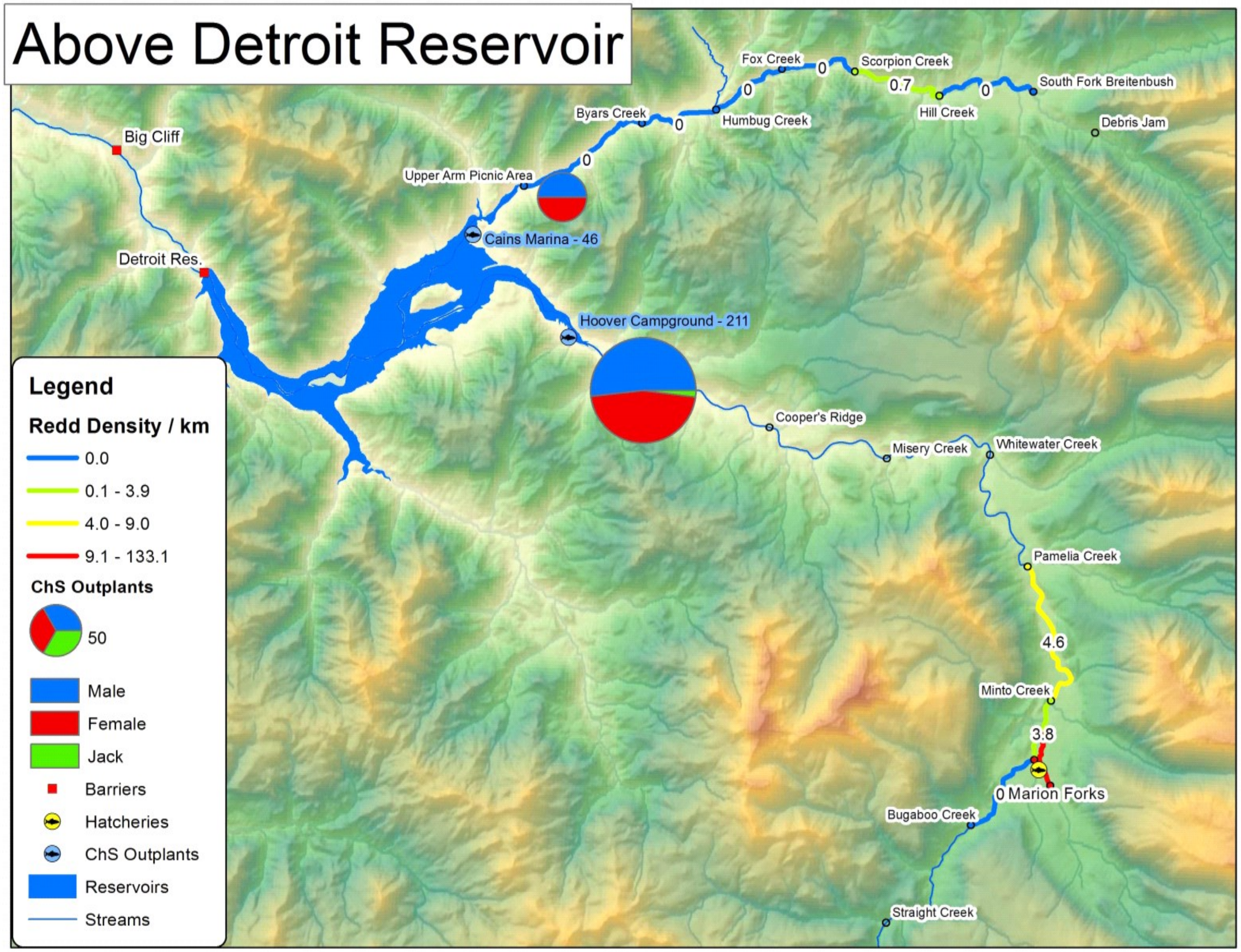


Figure 8. Outplanting of Chinook salmon and spawning activity above Detroit Dam in the North Santiam subbasin, 2012.

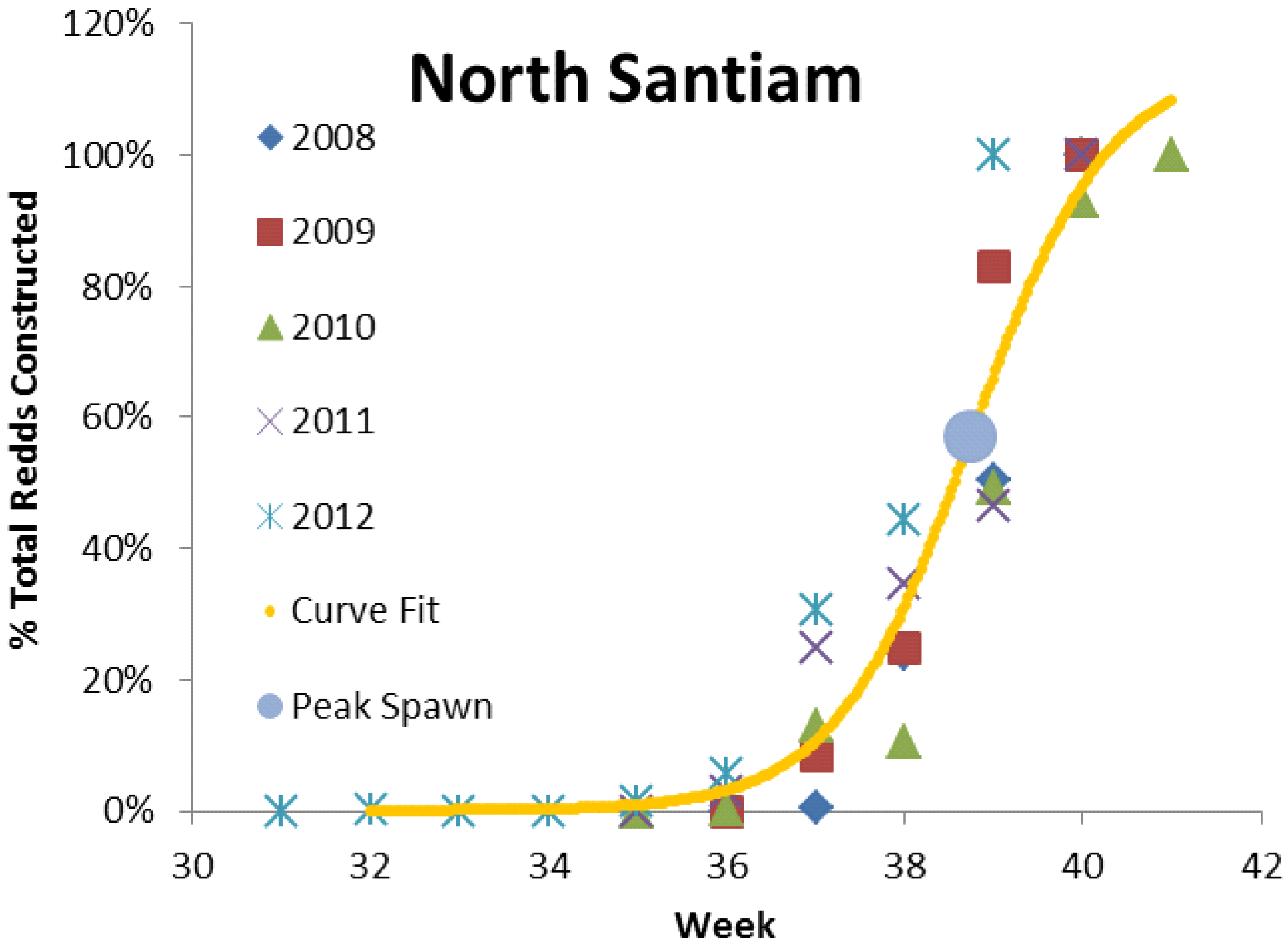


Figure 9. Estimated peak spawning date in the North Santiam subbasin.

South Santiam River: The South Santiam River (Figures 10-13) was surveyed beginning 2 July and ending 24 October, 2012. Redd construction was first observed August 29 and peak redd counts were obtained between September 17 and October 10, depending on the particular river reach surveyed (Table 4). As in previous years, the redd density in 2012 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. Redd counts and densities in 2012 (18.5 redds/km) were similar to recent historical redd densities (Table 2) above Lebanon Dam (2002 – 2011: 22.6 ± 2.5 redds/km [mean ± SEM]; t = 1.6; df = 9; $P = 0.143$). No redds were observed below Lebanon Dam in 2012 but redd densities in that reach have been uniformly low in the years between 2002 and 2011 when surveys were conducted (range: 0.1 to 2.1 redds/km).

We estimated that for 2008-2012 the average spawn timing in the South Santiam River was September 23 (Figure 14) based on the inflection point on a sigmoid curve fitted to the cumulative redd counts observed in those years. In 2012 the mean date of spawning of South Santiam broodstock was September 18. We conclude that spawning in the hatchery in 2012 preceded the average peak spawn time by about 5 d. Importantly, peak natural spawning in each subbasin in 2012 appeared to be somewhat earlier than the average calculated from 2008-2012 redd count data.

Table 4. Peak redd counts, date peak count was recorded, and number of surveys conducted by survey section in the South Santiam subbasin, 2012.

Subbasin	Survey Section	Peak Redd Count	Date of Peak Count	Number of Surveys
South Santiam Mainstem	Foster to Pleasant Valley	433	9/24/2012	25
	Pleasant Valley to McDowell Creek Rd	7	10/10/2012	19
	McDowell Creek Rd to Waterloo	3	10/10/2012	18
	Waterloo to Lebanon Dam	0	N/A	5
	Lebanon Dam to Gill's Landing	0	N/A	5
	Gill's Landing to Sanderson's	0	N/A	6
	Sanderson's to mouth	0	N/A	1
South Santiam Above Foster	Falls to Soda Fork	31	9/24/2012	6
	Soda Fork to Little Boulder Cr	26	10/8/2012	7
	Little Boulder Cr to Trout Cr C.G.	42	10/8/2012	9
	Trout Cr C.G. to 2nd Trib	11	9/17/2012	10
	2nd Trib to Gordon Cr Rd	46	10/8/2012	11
	Gordon Cr Rd to Moose Cr Bridge	27	9/18/2012	7
	Moose Cr Bridge to Cascadia	N/A	N/A	0
	Cascadia to High Deck	8	9/24/2012	8
	High Deck to Shot Pouch	3	10/8/2012	6
	Shot Pouch to Riverbend Park	28	9/24/2012	5
	Riverbend Park to Reservoir	0	N/A	1

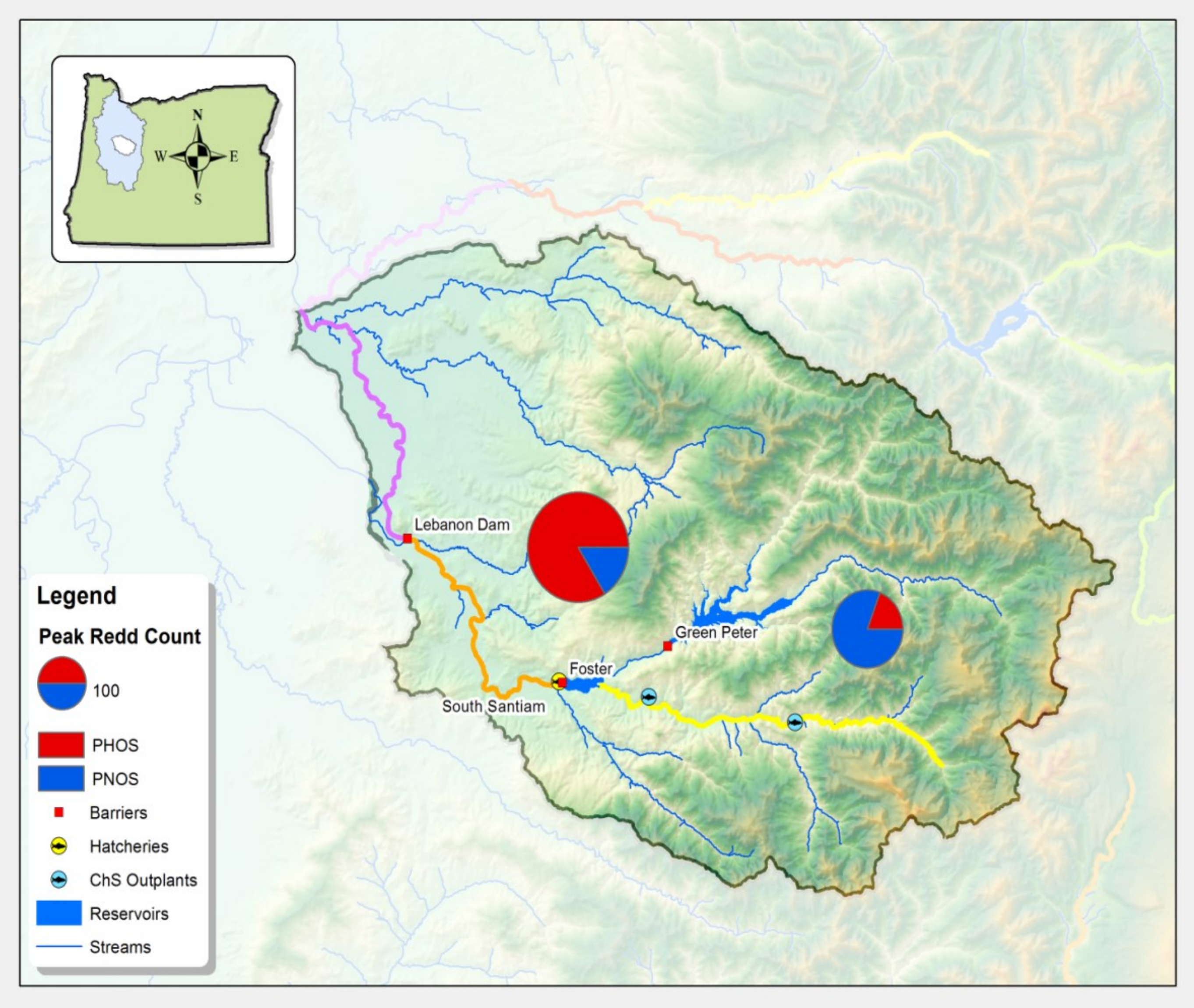


Figure 10. Spawner survey and carcass recovery results for the South Santiam River, 2012. Colored sections indicate major survey reaches. Pie charts indicate peak redd counts (also indicated by "N") by their size and proportion of hatchery-origin spawners (pHOS).

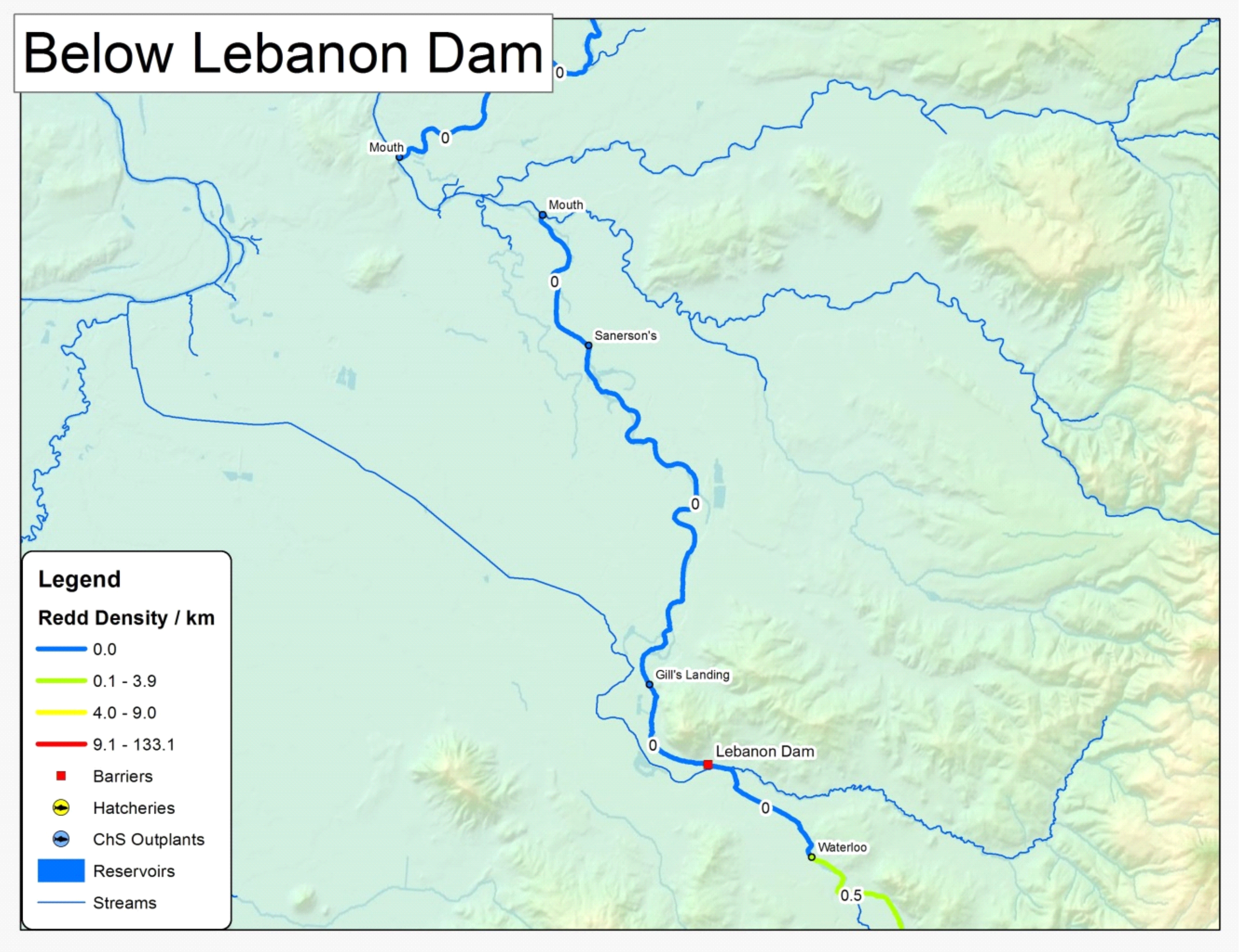


Figure 11. Spawning activity below Lebanon dam, 2012.

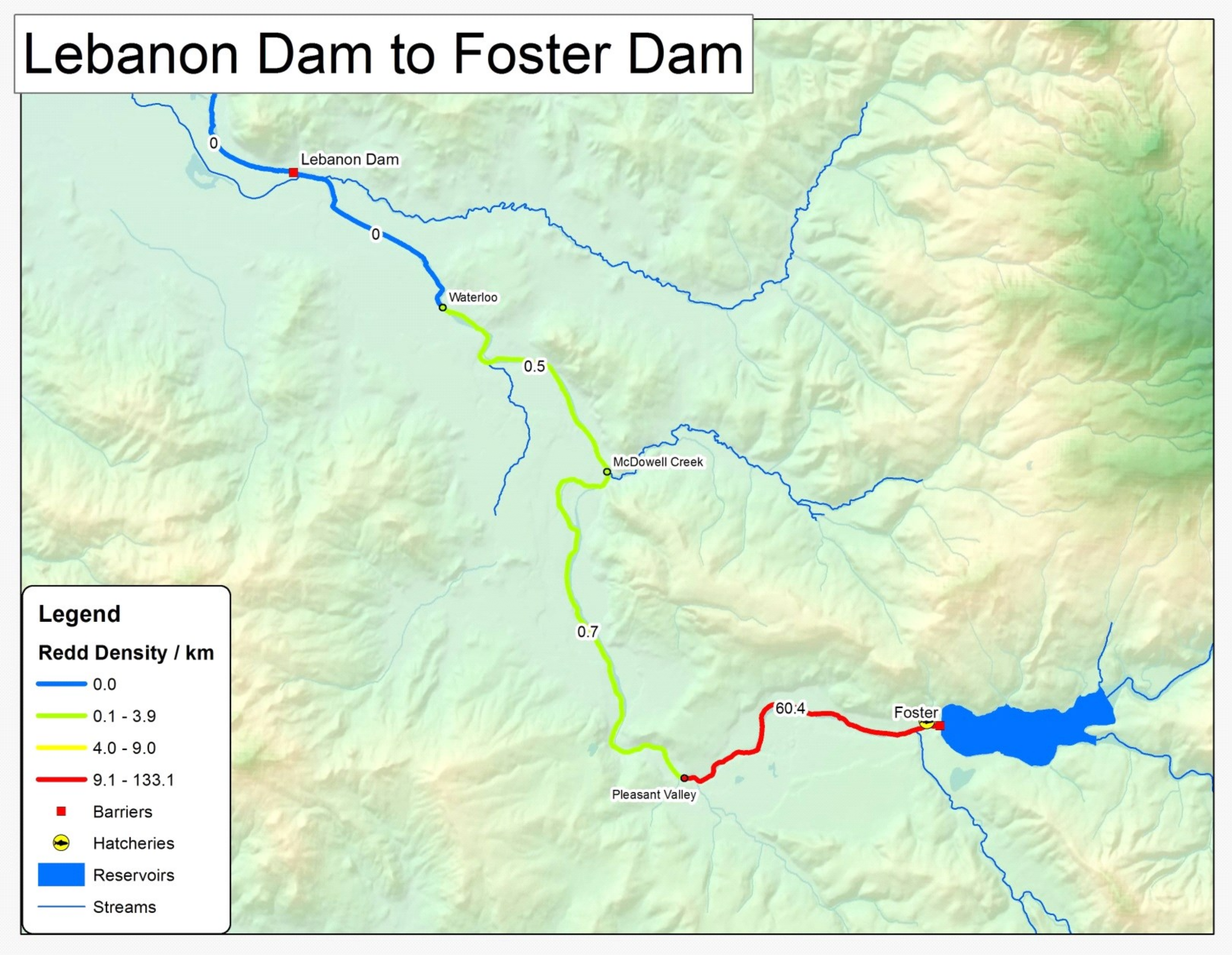


Figure 12. Spawning activity between Lebanon dam and Foster Dam, 2012.

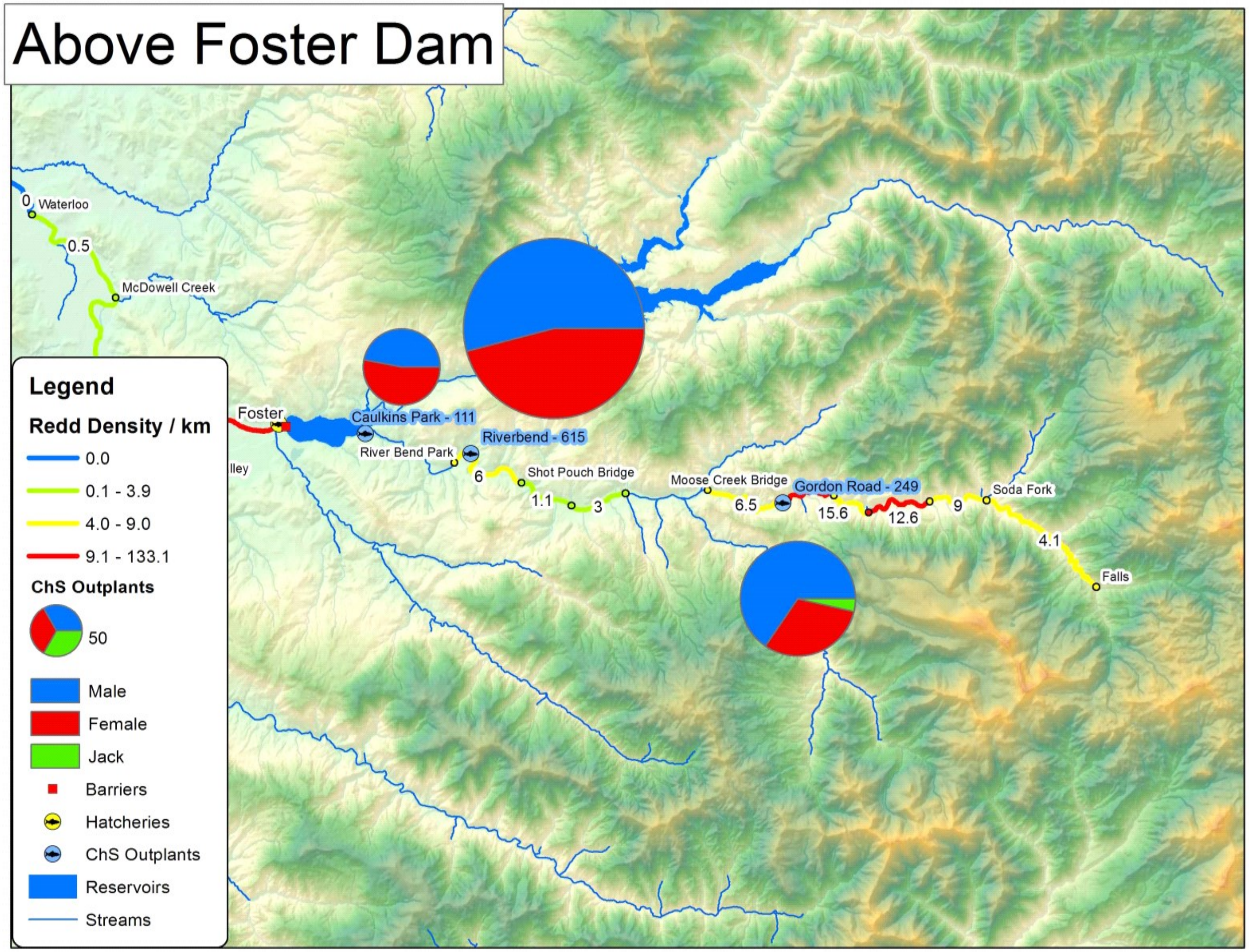


Figure 13. Outplanting and spawning activity above Foster Dam, 2012.

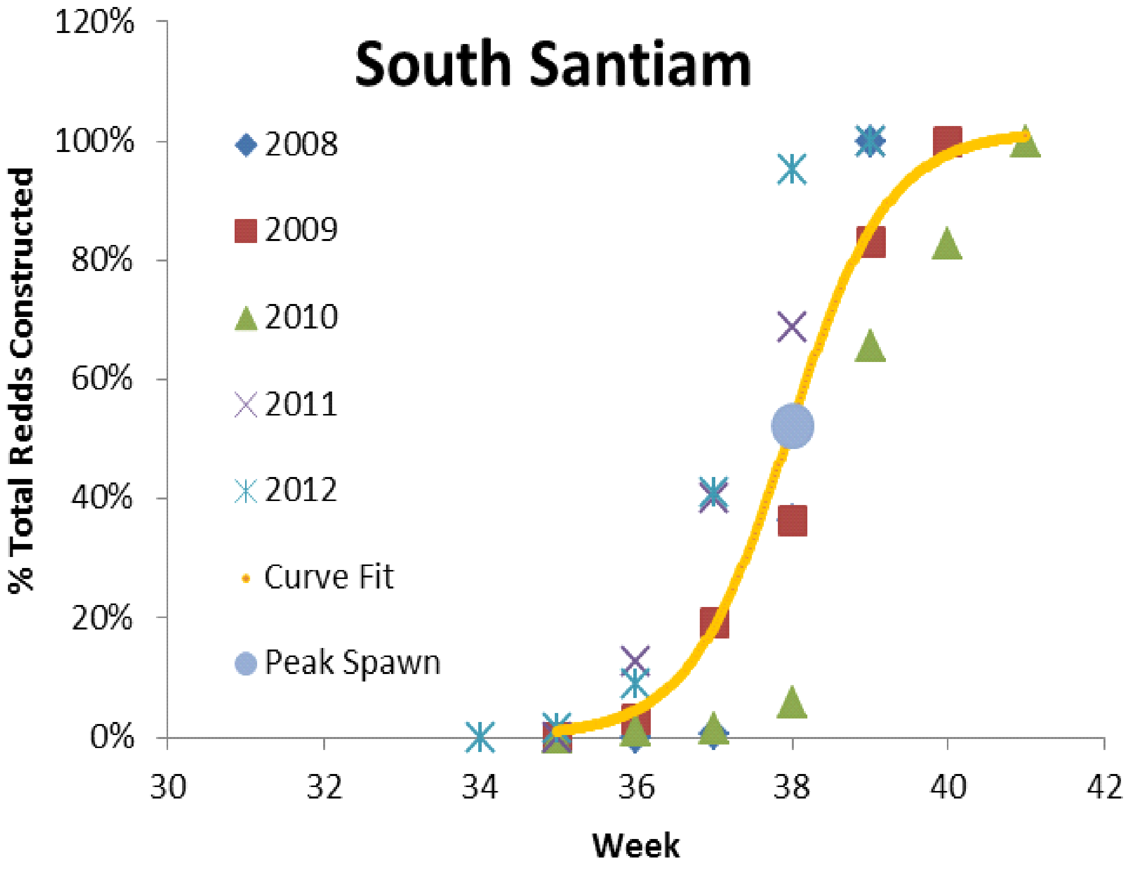


Figure 14. Estimated peak spawning date in the South Santiam subbasin.

McKenzie River: The McKenzie River (Figures 15-19) was surveyed beginning July 9 and ending October 25, 2012. Redd construction was first observed on August 29 and peak redd counts (Table 5) were observed between September 20 and October 15, depending on the particular river reach surveyed. As in previous years, the redd density in 2012 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 a decreasing trend in both PSM and pHOS upstream. Redd counts and densities were lower in 2012 (6.6 redds/km) compared with recent historical redd densities (Table 2) above Leaburg Dam (2002 – 2011: 9.3 + 2.6 redds/km [mean + SEM]; t = 3.275; df = 9; P = 0.010). In contrast, redd densities below Leaburg Dam were higher in 2012 (25.7 redds/km) compared to densities in recent years (2002 – 2011: 16.2 + 2.22 redds/km [mean + SEM]; t = -4.265; df = 9; P = 0.002).

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 2005-2012 but differed greatly for 2002-2004 (Figure 20).

We estimated that for 2008-2012 the average spawn timing in the McKenzie River was September 25 (Figure 21) based on the inflection point on a sigmoid curve fitted to the cumulative redd counts observed in those years. In 2012 the mean date of spawning of McKenzie broodstock was September 19. We conclude that spawning in the hatchery in 2012 preceded the average peak spawn time by about 6 d. Importantly, peak natural spawning in each subbasin in 2012 appeared to be somewhat earlier than the average calculated from 2008 through 2012 redd count data.

Table 5. Peak redd counts, date peak count was recorded, and number of surveys conducted by survey section in the McKenzie subbasin, 2012.

Subbasin	Survey Section	Peak Redd Count	Date of Peak Count	Number of Surveys
McKenzie Mainstem	Spawning Channel	44	10/8/2012	3
	Olallie C.G. to Belknap	54	9/26/2012	7
	Belknap to Paradise	28	9/26/2012	6
	Paradise to McKenzie Trail	19	9/26/2012	6
	McKenzie Trail to McKenzie Bridge	4	9/26/2012	8
	McKenzie Bridge to Hamlin	28	10/9/2012	8
	Hamlin to S.F. McKenzie	0	N/A	8
	S.F. McKenzie to Forest Glen	6	10/9/2012	7
	Forest Glen to Rosboro Bridge	103	10/1/2012	15
	Rosboro Bridge to Ben & Kay	38	10/9/2012	15
	Helfrich to Leaburg Lake	43	10/3/2012	15
	Leaburg Dam to Leaburg Landing	247	9/26/2012	18
	Leaburg Landing to Dearhorn	6	10/15/2012	10
	Dearhorn to Hendricks	15	10/15/2012	9
	Hendricks to Bellinger	0	N/A	2
South Fork McKenzie Below Cougar	Cougar Dam to Bridge	40	10/2/2012	14
	Bridge to Mouth	27	9/24/2012	15
South Fork McKenzie Above Cougar	Elk Cr. To Roaring River	3	9/30/2012	12
	Roaring River to Twin Springs C.G.	18	9/30/2012	10
	Twin Springs C.G. to Homestead	24	10/3/2012	13
	Homestead to Dutch Oven	58	10/3/2012	9
	Dutch Oven to Rebel Cr.	35	10/9/2012	14
	Rebel Cr. to NFD 1980	74	10/1/2012	14
	NFD 1980 to Reservoir	37	10/9/2012	15
Horse Creek	Pothole Creek to Trail Bridge	13	9/20/2012	2
	Trail Bridge to Separation Creek	2	9/20/2012	1
	Separation Creek to Road Access	15	10/4/2012	3
	Road Access to Braids	28	9/20/2012	4
	Braids to Avenue Creek	26	9/27/2012	6
	Avenue Creek to Bridge	64	9/27/2012	6
	Bridge to Mouth	47	9/27/2012	5
Lost Creek	Cascade to Campground	16	10/8/2012	4
	Campground to Split Pt	6	10/8/2012	4
	Split Pt to Hwy Bridge	12	10/8/2012	4
	Hwy Bridge to Mouth	3	9/27/2012	4

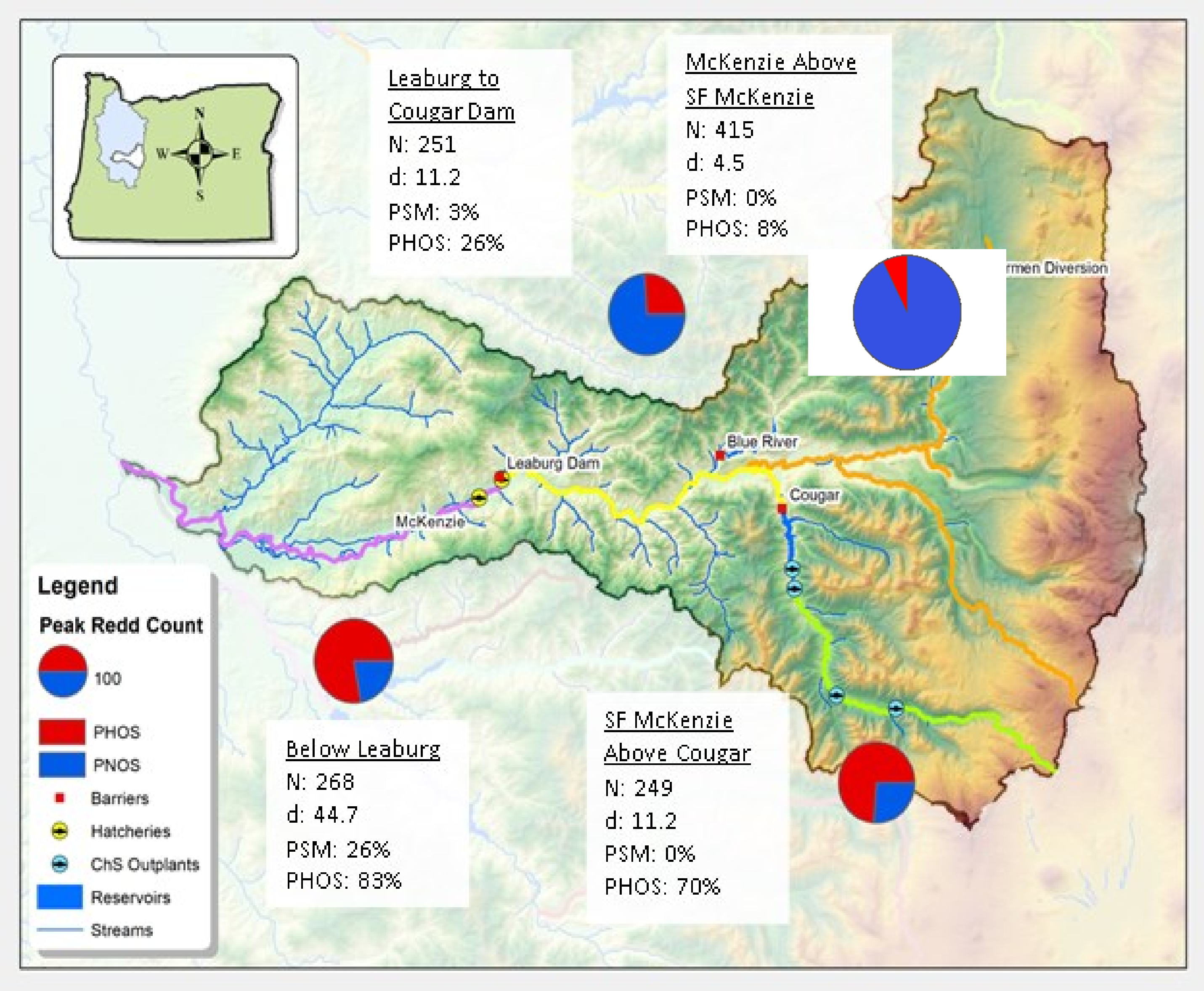


Figure 15. Spawner survey and carcass recovery results for the McKenzie River, 2012. Colored sections indicate major survey reaches. Pie charts indicate peak redd counts (also indicated by "N") by their size and proportion of hatchery-origin spawners (pHOS).

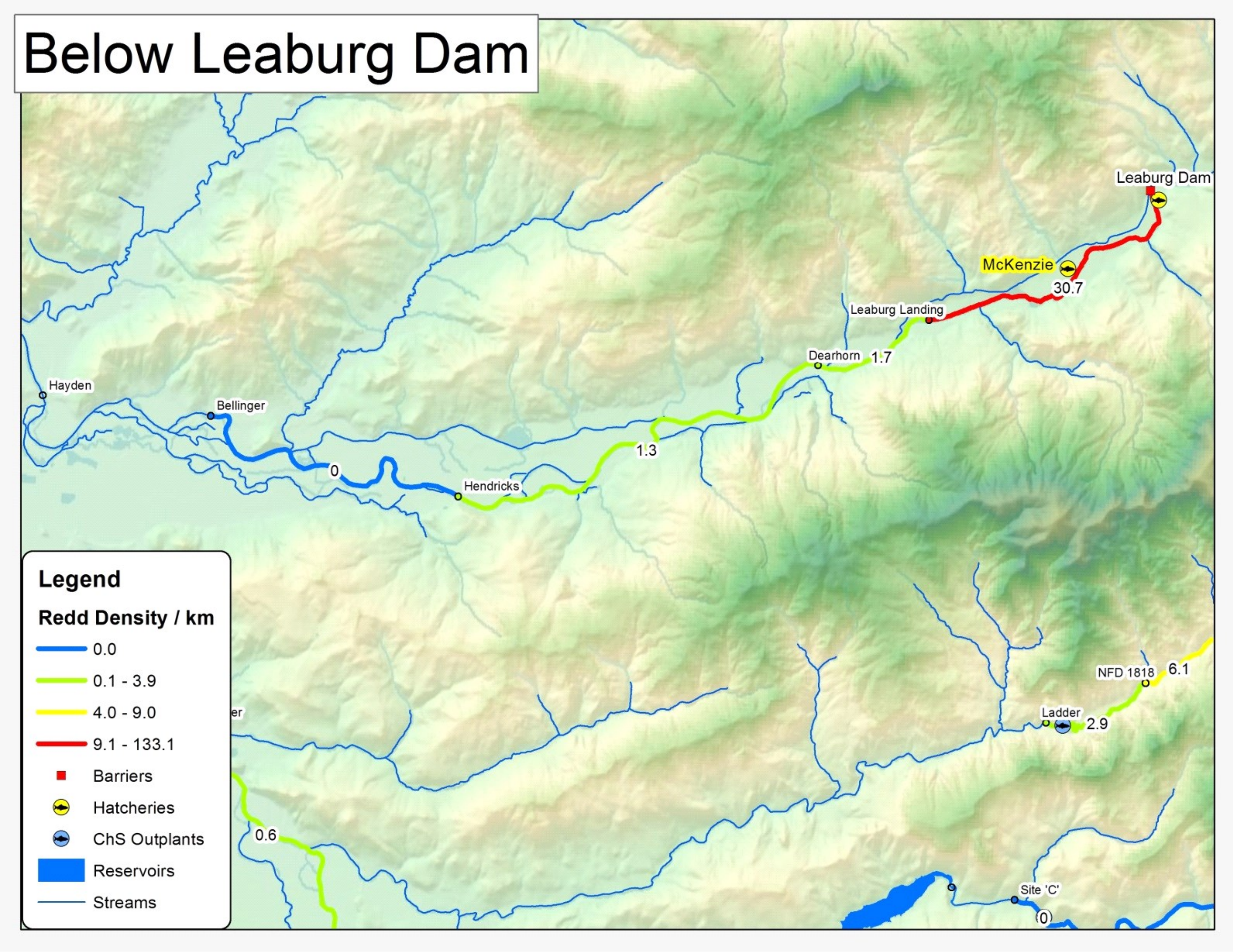


Figure 16. Spawning activity below Leaburg Dam, 2012.

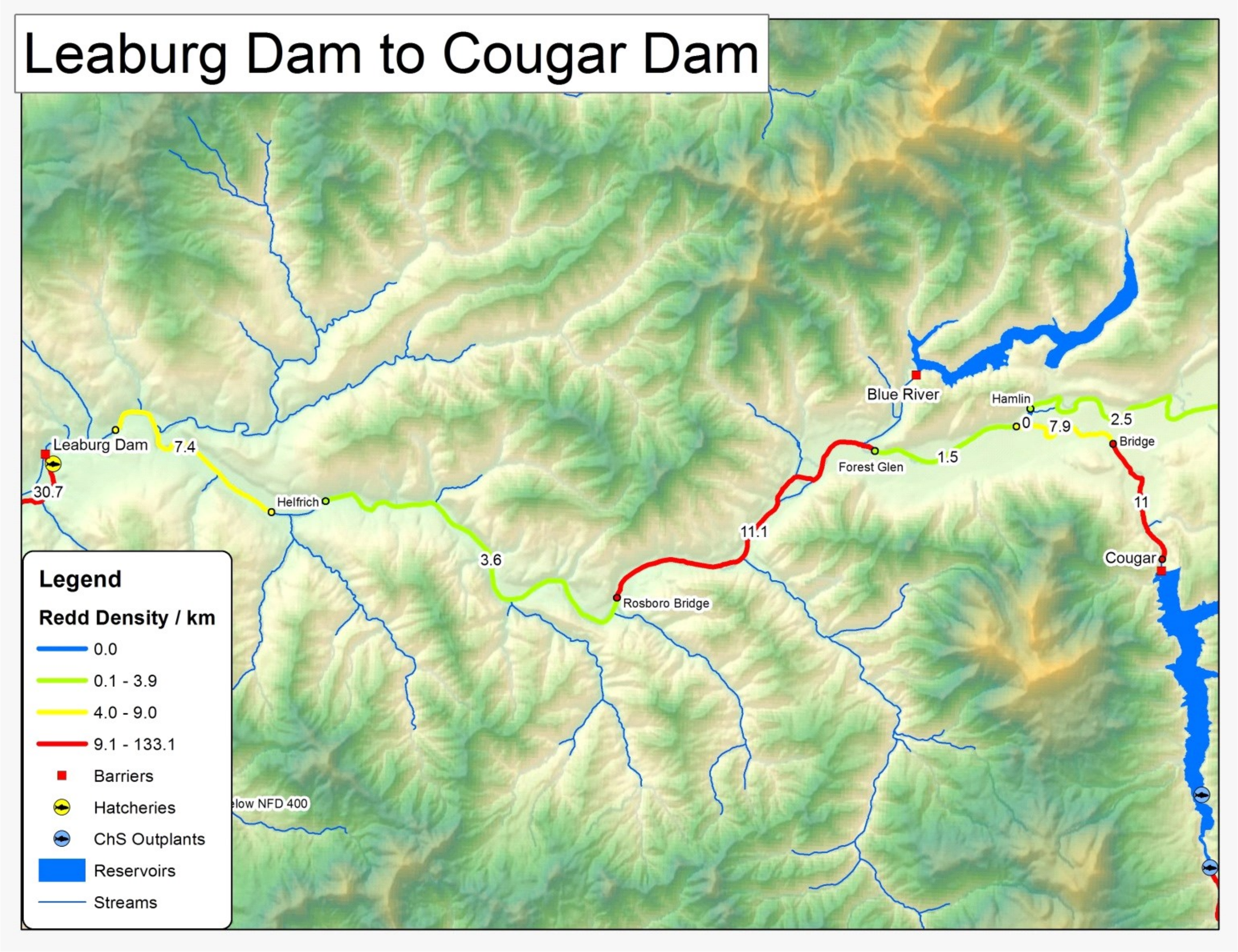


Figure 17. Spawning activity between Leaburg Dam and Cougar Dam, 2012.

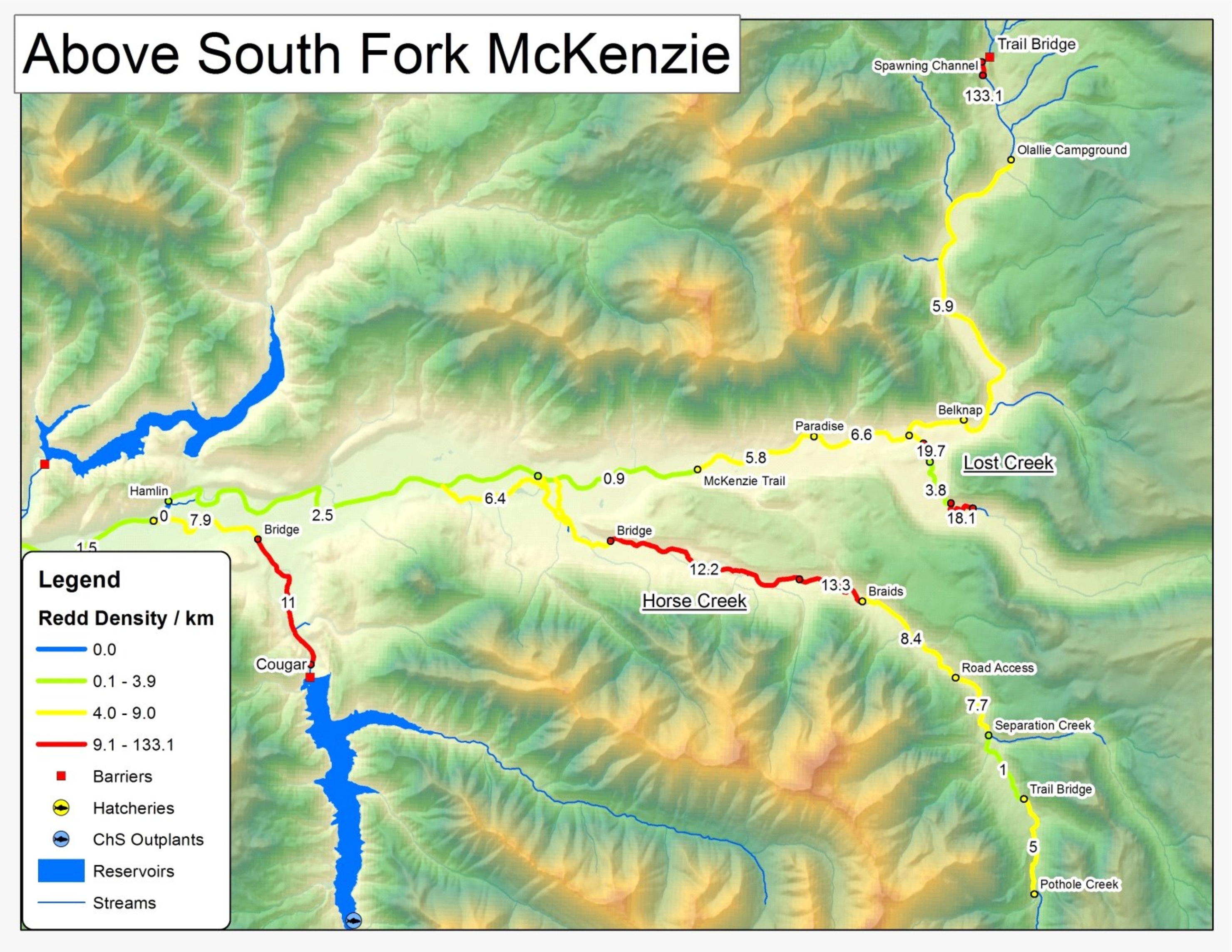


Figure 18. Spawning activity above the confluence of the South Fork McKenzie River, 2012.

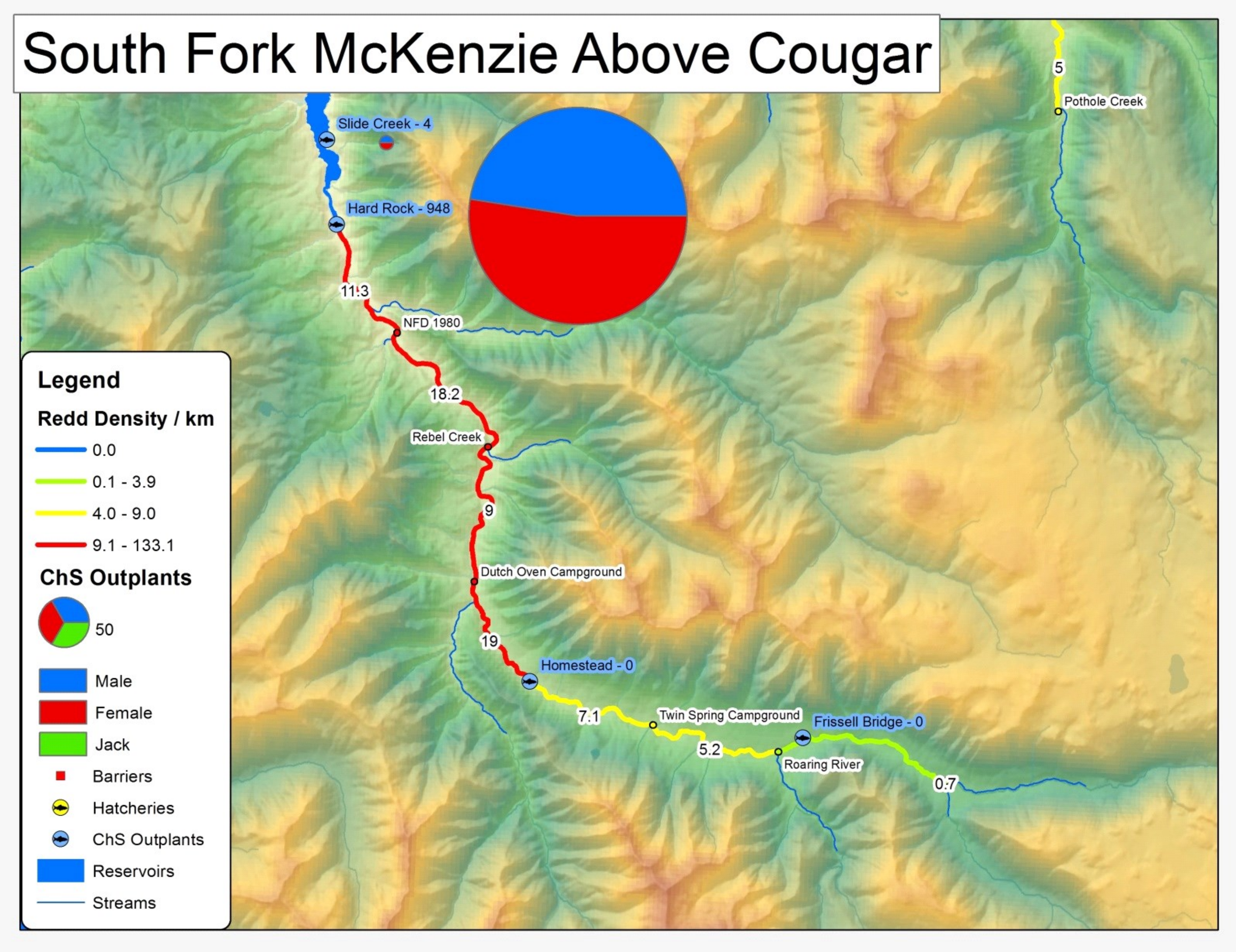


Figure 19. Outplanting and spawning activity above Cougar Dam, 2012. Size of pie chart indicates number of outplanted fish and slices indicate sex ratio.

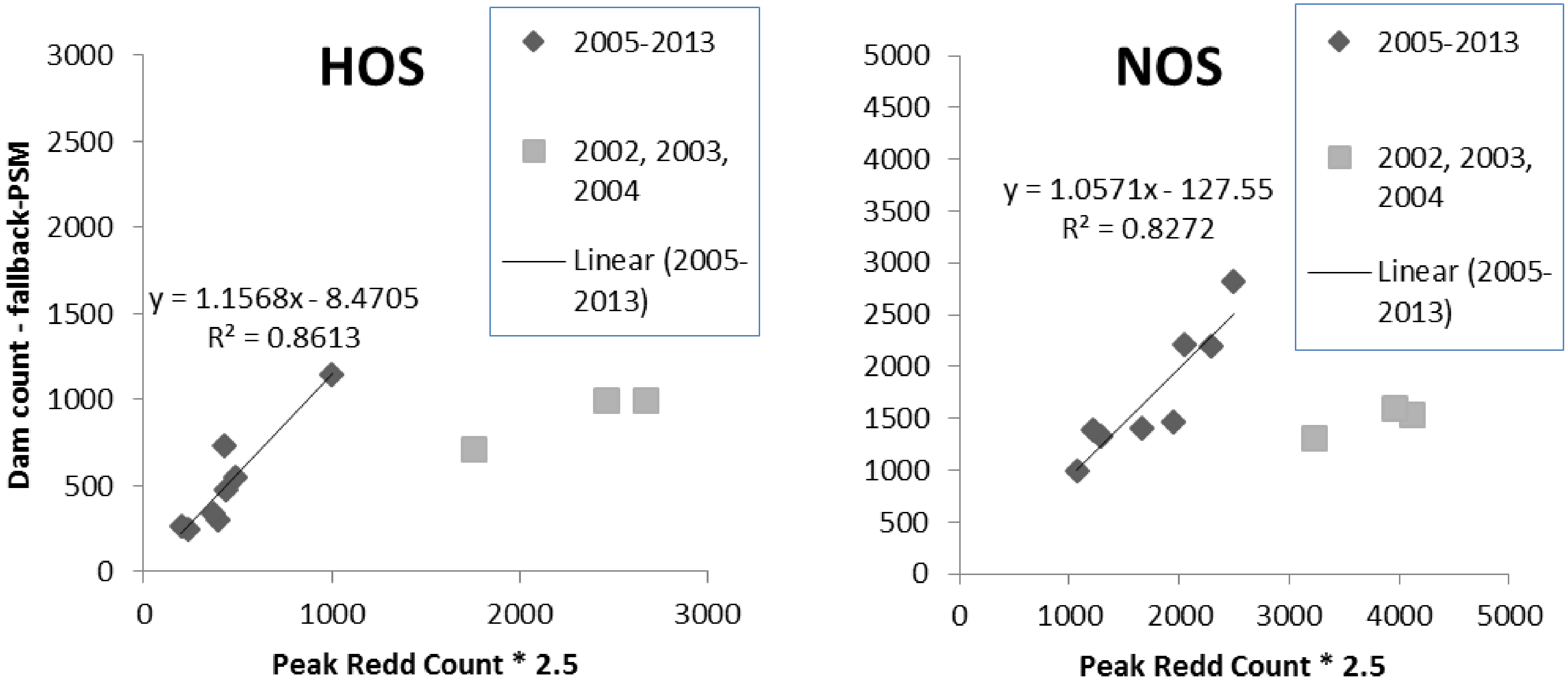


Figure 20. Relationships between spawner abundance estimates above Leaburg Dam, based on redd count expansion and dam counts. HOS and NOS indicate hatchery- and natural-origin spawners, respectively.

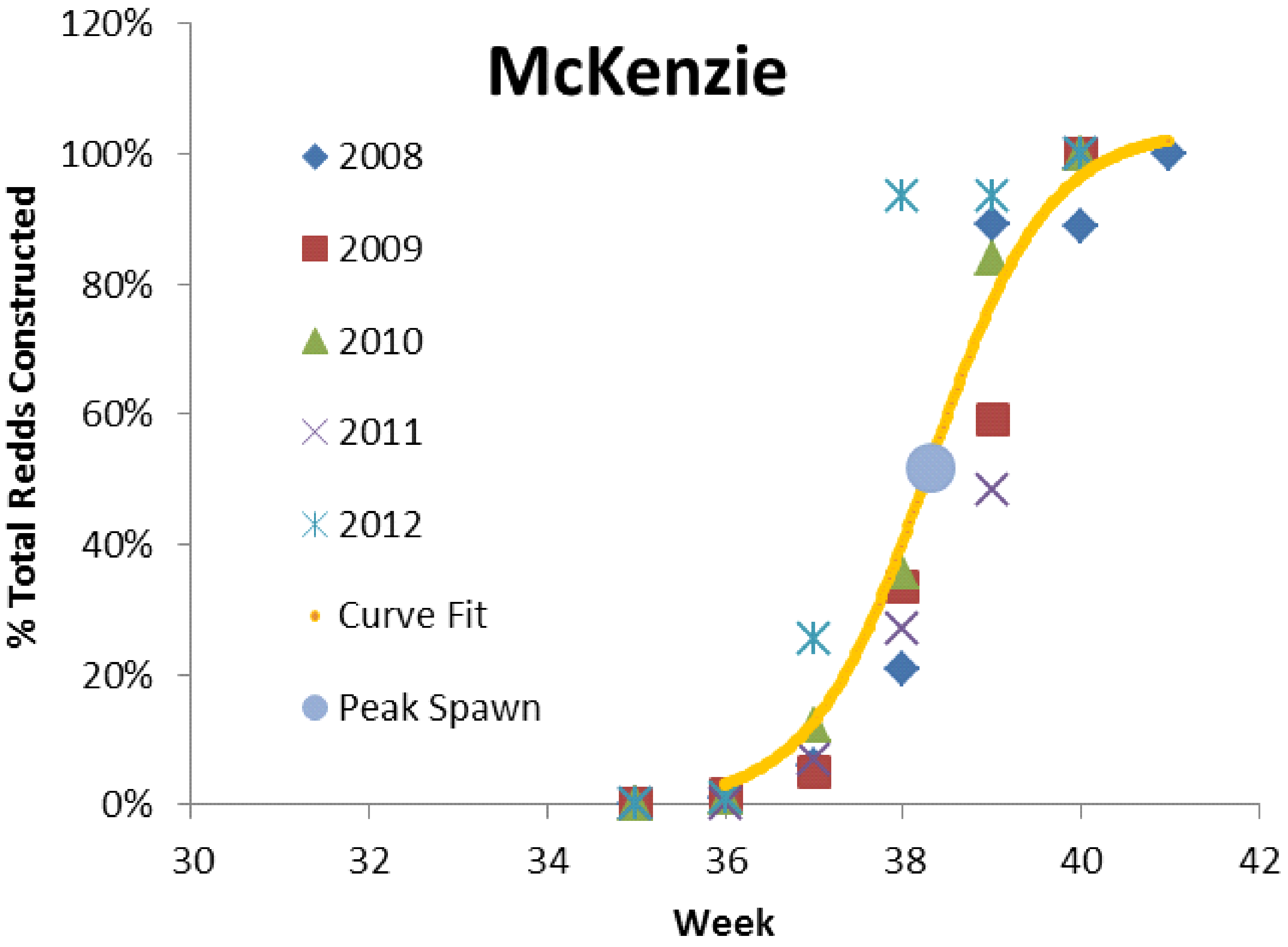


Figure 21. Estimated peak spawning date in the McKenzie subbasin.

Middle Fork Willamette River: The Middle Fork Willamette River (Figures 22-26) was surveyed beginning July 9 and ending October 17. Most redds below the dam were constructed in the reach immediately downstream of Dexter Dam. Redd construction was first observed on August 2 but that represented a single redd; multiple redds counted on a single day were not observed until August 27. Peak redd counts (Table 6) were obtained between September 18 and October 12, depending on the particular reach surveyed. Redd densities in 2012 (5.3 redds/km) were similar to recent historical redd densities (Table 2) below Dexter Dam (2002 – 2011: 3.5 + 1.1 redds/km [mean + SEM]; t = -1.67; df = 9; P = 0.129).

We estimated that for 2008, 2011, and 2012 the average spawn timing in the Middle Fork Willamette River was September 26 (Figure 27) based on the inflection point on a sigmoid curve fitted to the cumulative redd counts observed in those years. In 2012 the mean date of spawning of Middle Fork Willamette broodstock was September 16. We conclude that spawning in the hatchery in 2012 preceded the average peak spawn time by about 10 d.

Table 6. Peak redd counts, date peak count was recorded, and number of surveys conducted by survey section in the Middle Fork Willamette subbasin, 2012.

Subbasin	Survey Section	Peak Redd Count	Date of Peak Count	Number of Surveys
Middle Fork Mainstem	Dexter to Pengra	71	10/4/2012	14
	Pengra to Jasper	5	10/10/2012	14
Fall Creek	Johnny Creek Bridge to Big Pool campground	0	N/A	2
	Bedrock campground to Johnny Creek Bridge	0	N/A	3
	Portland Creek to Bedrock campground	0	N/A	3
	NFD 1828 Bridge to Portland Creek	7	10/12/2012	4
	Hehe Creek to NFD 1828 Bridge	9	10/11/2012	6
	NFD 1833 Bridge to Hehe Creek	9	9/27/2012	6
	Gold Creek to NFD 1833 Bridge	19	10/5/2012	5
	Falls to Gold Creek	14	10/4/2012	4
Little Fall Creek	Trib below NFD 400 to NFD 1806 Bridge	0	N/A	5
	NFD 1806 Bridge to NFD 1818 Bridge	21	9/20/2012	10
	NFD 1818 Bridge to Fish Ladder	10	9/20/2012	8
North Fork Middle Fork	Kiahanie Bridge to Release Site	118	10/9/2012	8
	NFD 1944 Bridge to Kiahanie Bridge	68	10/9/2012	1
	Minute Creek to NFD 1944 bridge	10	9/25/2012	1
	North Fork Trail #3666 trailhead to Minute Creek	6	9/18/2012	1
Middle Fork Above Hills Creek	Paddy's Valley to Beaver Cr.	245	10/8/2012	11
	Chuckle Springs to Echo Bridge	114	10/9/2012	7
	Echo Bridge to Young's Cr.	176	10/3/2012	9
	Young's Cr. to Reservoir	121	10/11/2012	7

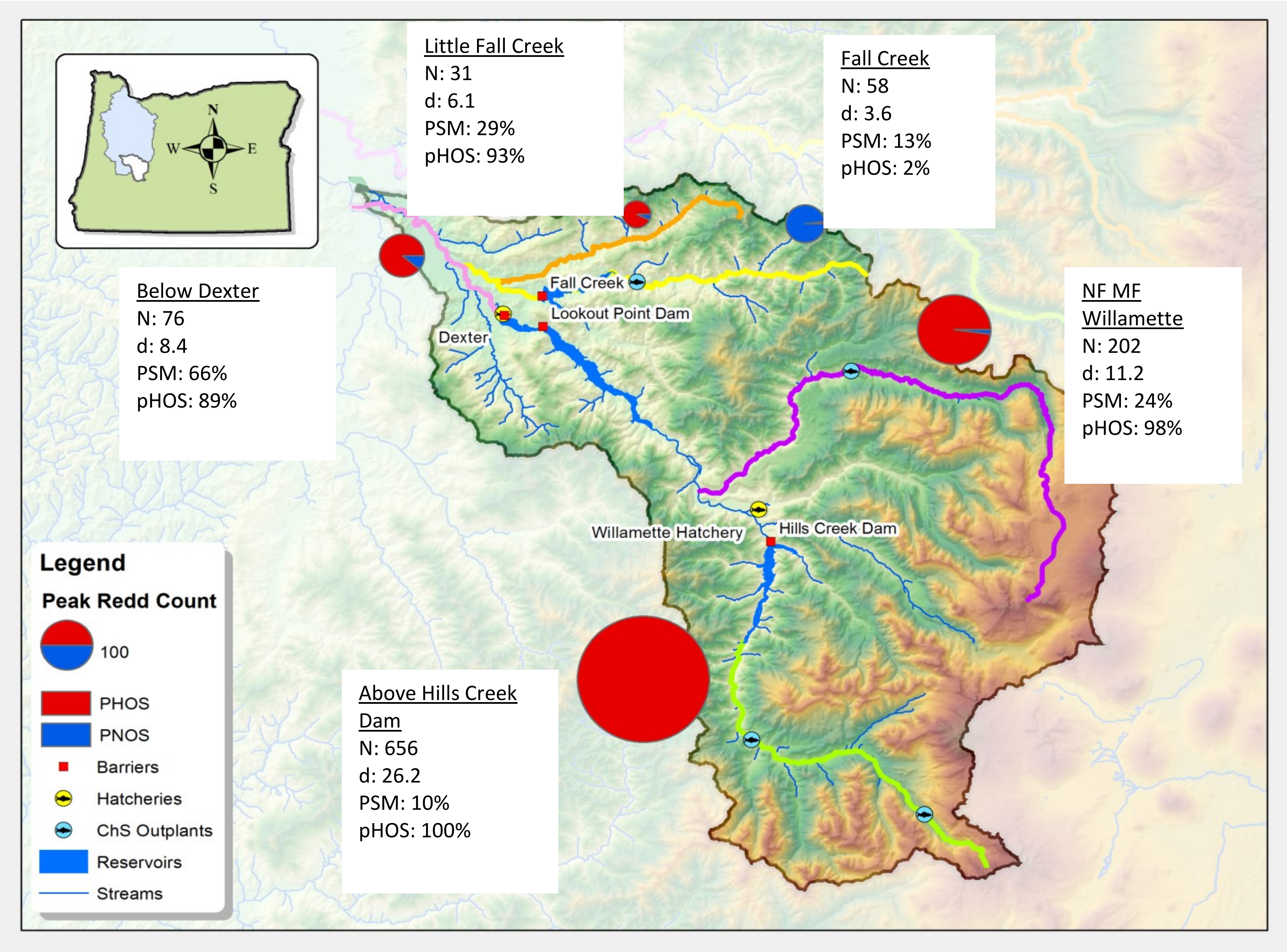


Figure 22. Spawner survey and carcass recovery results for the Middle Fork Willamette River, 2012. Colored sections indicate major survey reaches. Pie charts indicate peak redd counts (also indicated by "N") by their size and proportion of hatchery-origin spawn

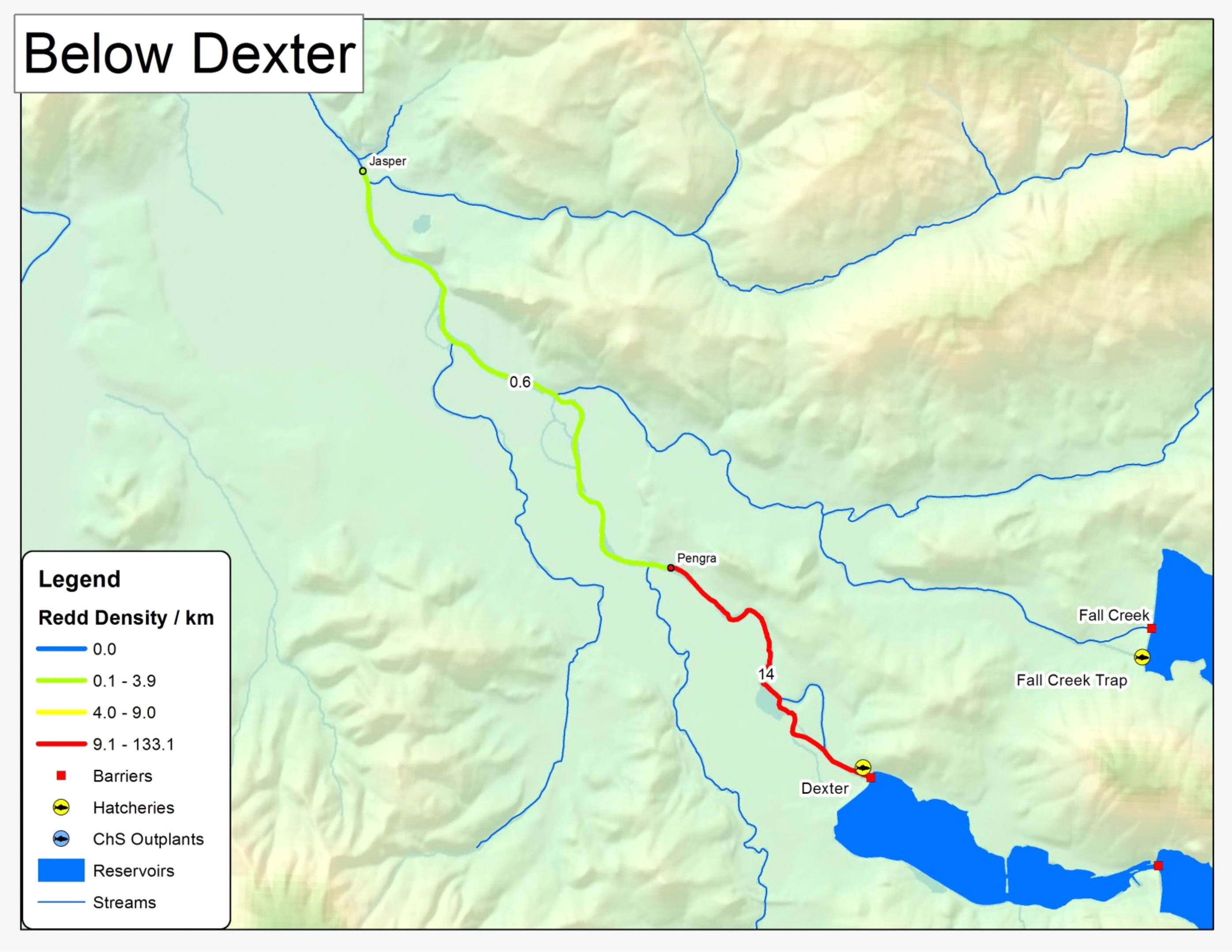


Figure 23. Spawning activity below Dexter Dam, 2012.

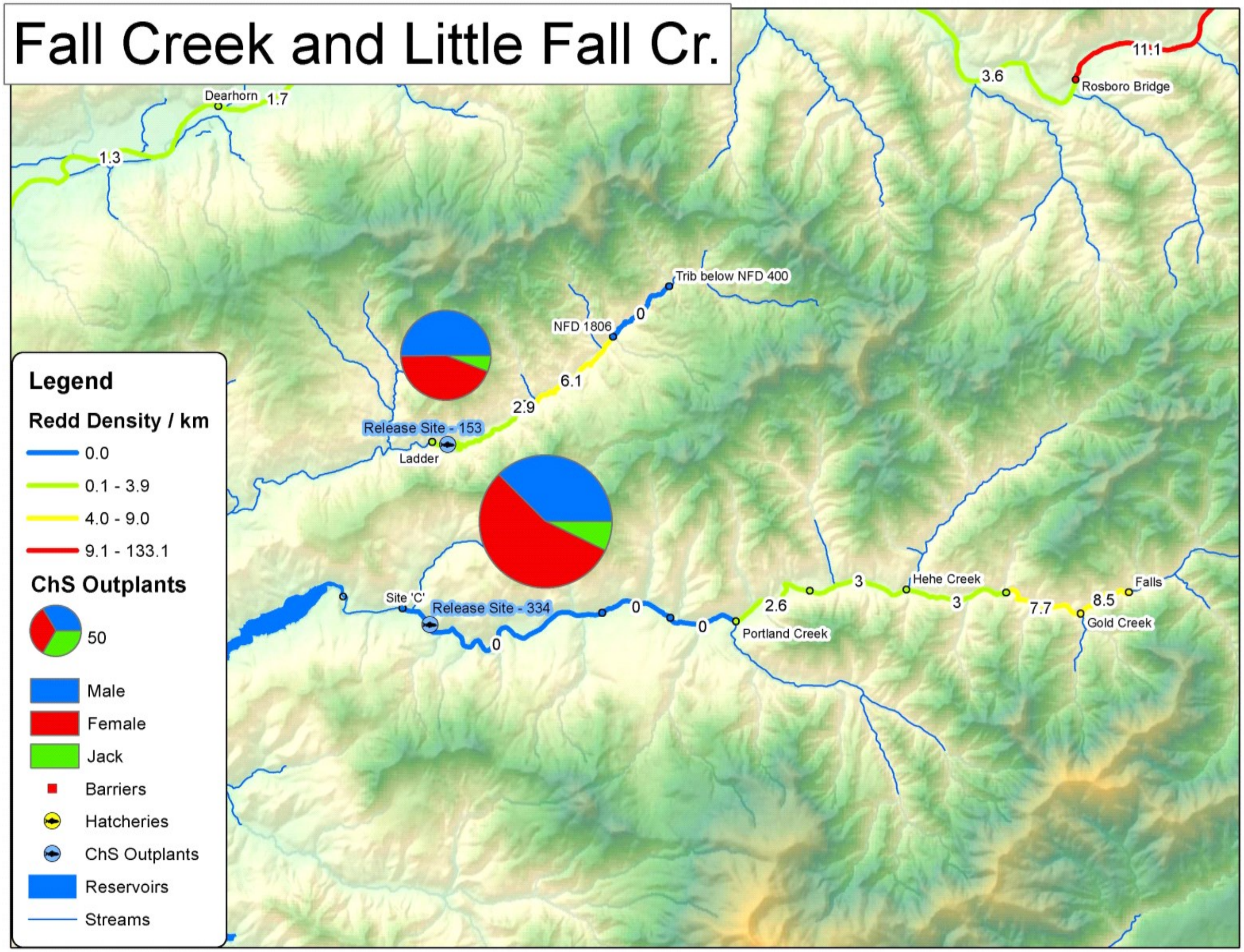


Figure 24. Outplanting and spawning activity in Fall Creek and Little Fall Creek, 2012.

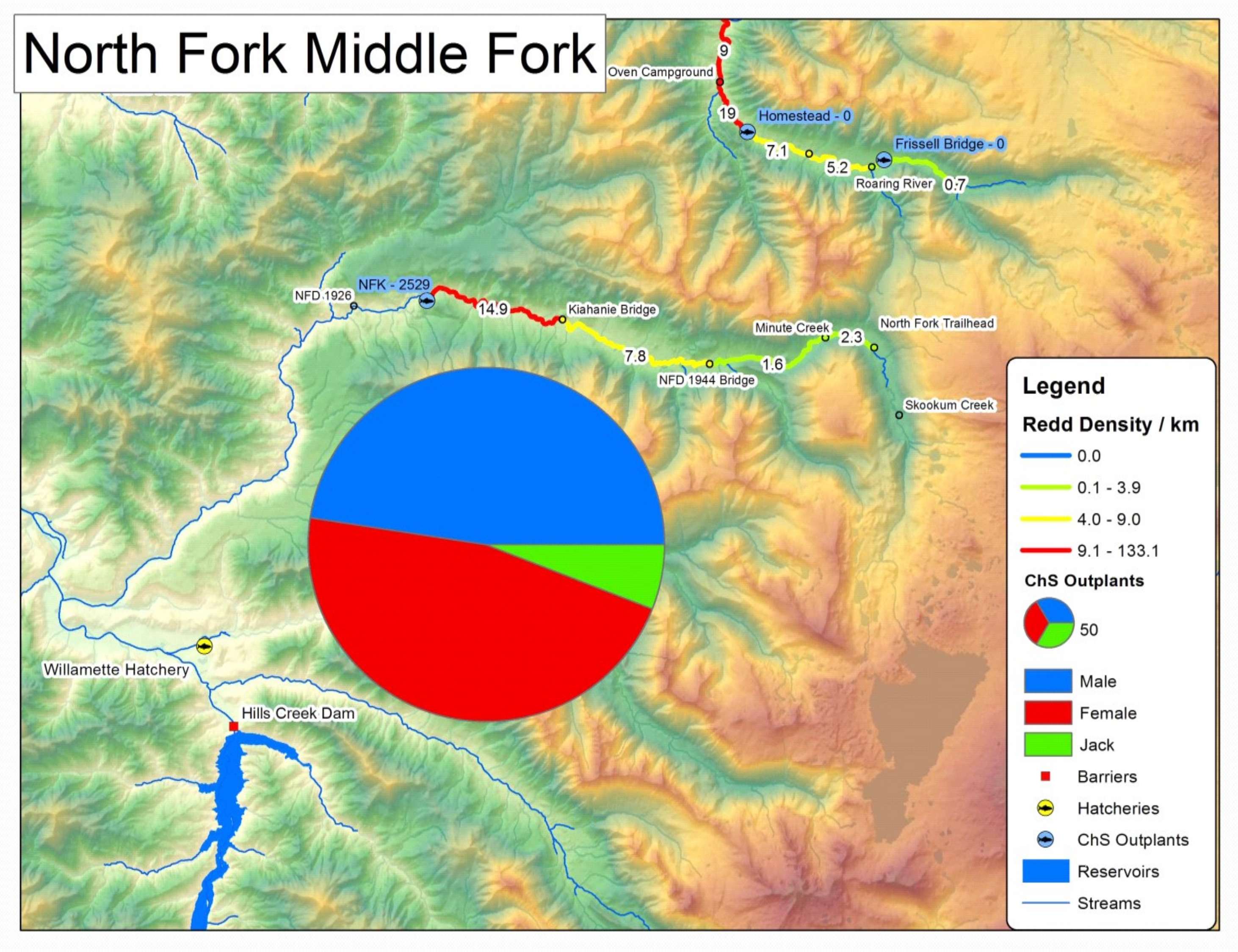


Figure 25. Outplanting and spawning activity in the North Fork Middle Fork Willamette River, 2012.

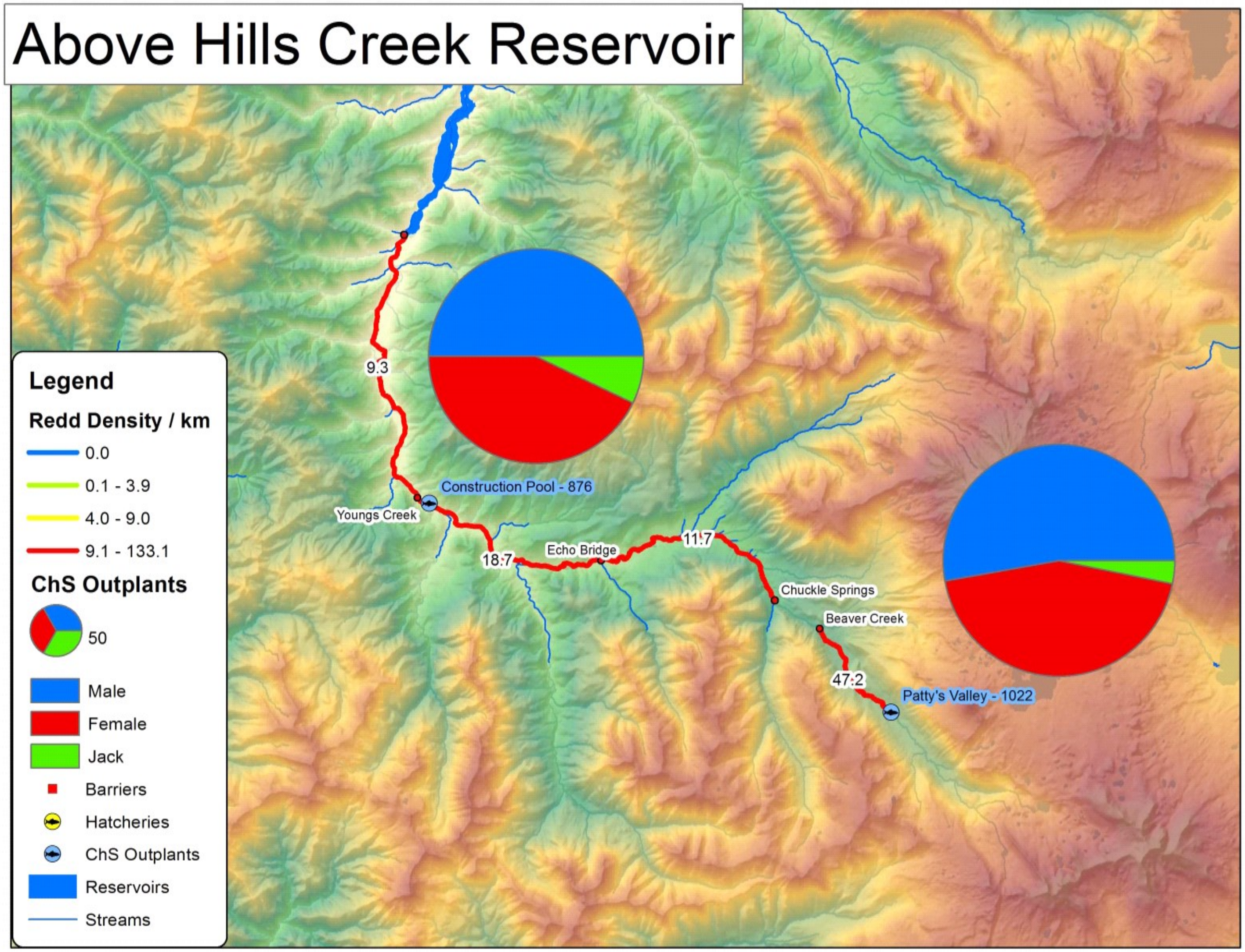


Figure 26. Outplanting and spawning activity in the Middle Fork Willamette River above Hills Creek Reservoir, 2012.

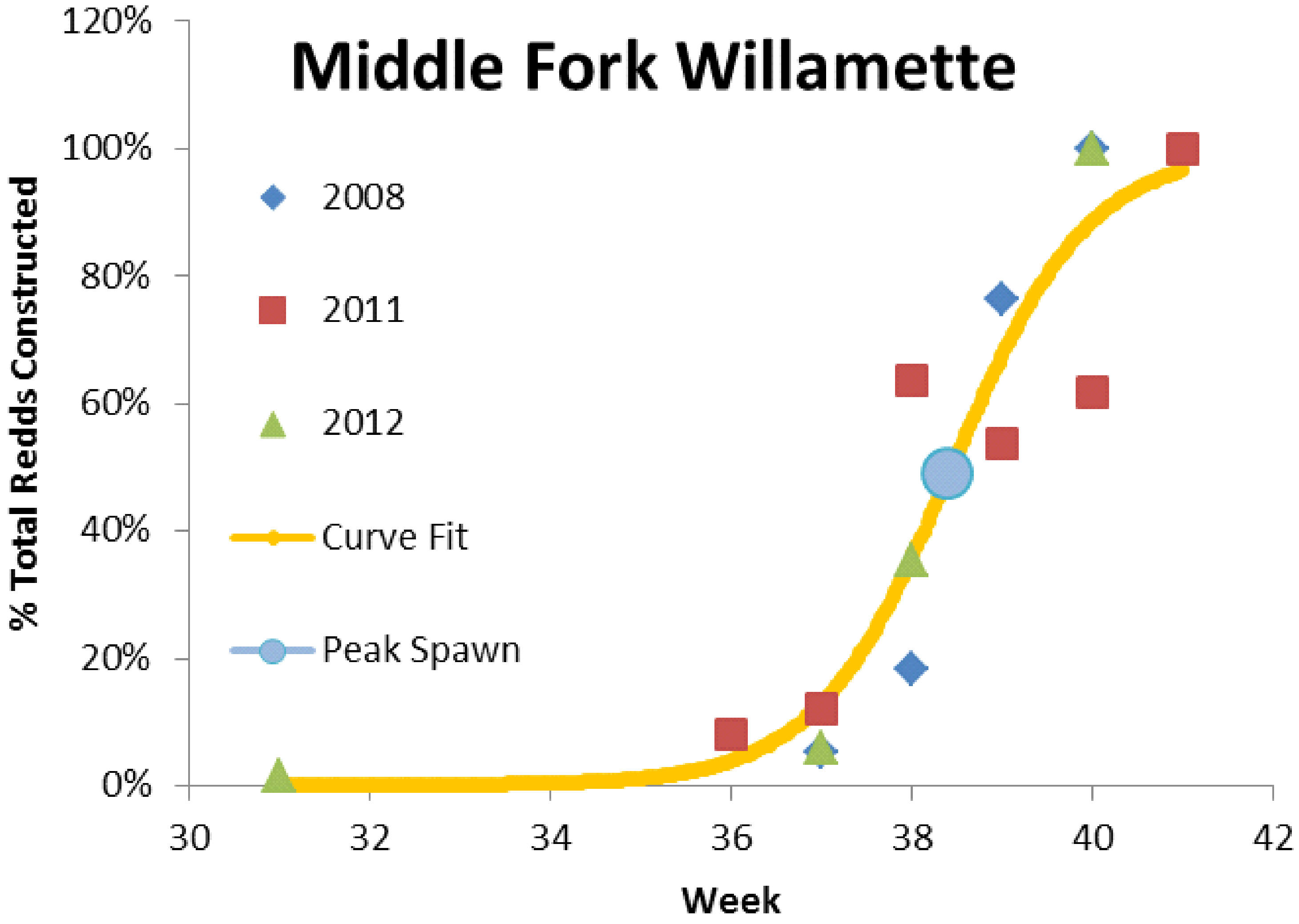


Figure 27. Estimates of peak spawning date in Upper Willamette subbasins based on cumulative redd counts.

Section 3.1.3 Age Structure and Size Distribution on Spawning Grounds:

The age structure of natural- and hatchery-origin fish collected in 2012 during spawner and carcass surveys, as determined from analysis of fish scales, is presented in Table 7. Historical age structure of natural and hatchery-origin fish, including the 2012 date is presented in Figure 28.

Size distribution of natural- and hatchery-origin fish collected during spawner and carcass surveys is shown in Table 8.

Table 7. Age structure of natural- and hatchery-origin Chinook salmon, 2012. Scales were collected during spawning ground surveys except for "S. Fk McK Outplants" where samples were collected from hatchery-origin fish at McKenzie Hatchery.

Subbasin	Natural-origin Age					Hatchery-origin Age					
	3	4	5	6	7	2	3	4	5	6	7
North Santiam	1	17	78	7	0	0	0	4	11	0	0
South Santiam	14	113	87	5	0	0	0	54	33	1	0
McKenzie	0	30	157	12	0	0	0	11	18	2	0
Middle Fork	7	52	11	0	0	0	3	72	27	0	0
S. Fk McK Outplants	0	0	0	0	0	1	3	121	173	11	1
North Santiam	1%	17%	76%	7%	0%	0%	0%	27%	73%	0%	0%
South Santiam	6%	52%	40%	2%	0%	0%	0%	61%	38%	1%	0%
McKenzie	0%	15%	79%	6%	0%	0%	0%	35%	58%	6%	0%
Middle Fork	10%	74%	16%	0%	0%	0%	3%	71%	26%	0%	0%
S. Fk McK Outplants	0%	0%	0%	0%	0%	0%	1%	39%	56%	4%	0%

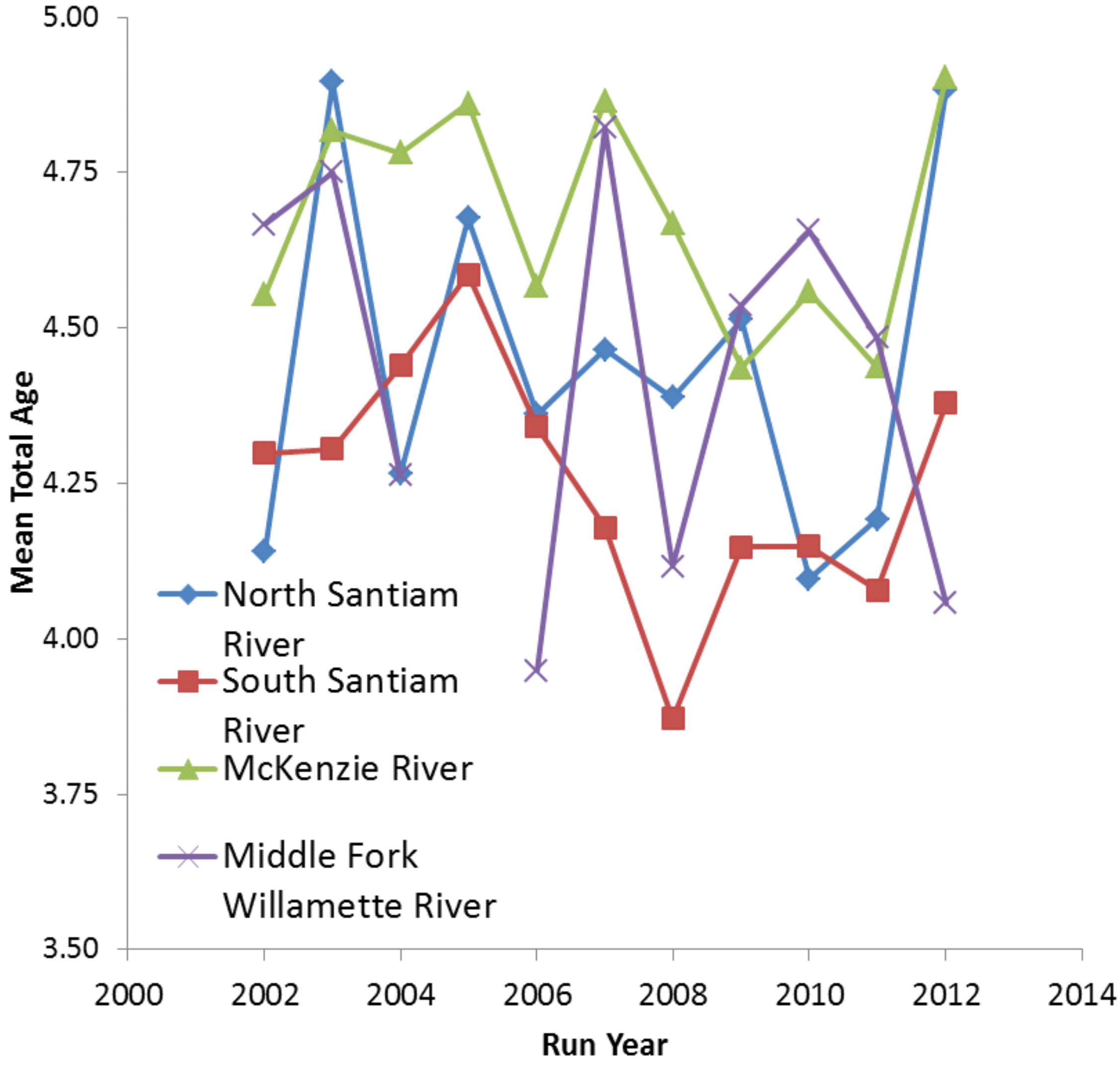


Figure 28. Recent historical mean age of natural-origin Chinook salmon in Upper Willamette subbasins.

Table 8. Size distribution of Chinook salmon collected during spawner and carcass surveys, 2012. NSNT, SSNT, McK and MFW indicate North Santiam, South Santiam, McKenzie, and Middle Fork Willamette rivers, respectively.

Fork Length (cm)	NSNT Wild	NSNT Hatchery	SSNT Wild	SSNT Hatchery	McK Wild	McK Hatchery	MFW Wild	MFW Hatchery
40	0	0	0	0	0	0	0	0
50	0	1	0	0	0	0	0	0
60	0	0	4	1	1	0	4	12
70	4	5	29	13	14	22	7	126
80	28	23	92	59	77	151	40	342
90	58	20	79	49	86	148	14	122
100	18	5	17	4	28	10	0	8
110	2	0	2	0	4	3	0	0
N	110	54	223	126	210	334	65	610
Mean	84	81	79	79	82	80	76	75
SEM	0.68	1.2	0.58	0.65	0.57	0.36	0.9	0.28
Median	84	80	79	80	82	80	76	75
Mode	81	88	82	80	79	79	76	74

Section 3.1.4 Spawner Abundance:

3.1.4.1: North Santiam River: We estimated that total spawner abundance in the North Santiam subbasin, based strictly on redd count expansion, was 1,588 fish of which 371 were natural-origin and 1,216 were hatchery-origin (Table 9). Spawner abundance above Detroit Dam (195 spawners) was low because of the small number of Chinook salmon we were able to trap and outplant from the Bennett Dam trap. We estimated that 83 and 29 natural- and hatchery-origin fish, respectively, spawned in the Little North Santiam River. Hatchery-origin fish must have strayed into that tributary because no outplanting of hatchery fish occurred there in 2012 but some of the wild origin spawners might have resulted from natural production there.

Table 9. Chinook salmon spawner abundance estimates for the North Santiam subbasin 2012. Estimates derived by redd count expansion were parsed into hatchery- and natural-origin using carcass counts after adjustment using otolith data.

Subasin, section	Peak Redd Count	Reach Length (km)	Redd Density (redds/km)	Spawner Abundance Estimate (redds*2.5)	pHOS	Hatchery-origin Abundance Estimate	Natural-origin Abundance Estimate
North Santiam							
Below Bennett	9	3.2	2.8	23	86.0%	19	3
Bennett Dams to Minto	503	37.8	13.3	1258	77.4%	973	285
Little North Santiam	45	15.0	3.0	113	25.9%	29	83
Above Detroit Reservoir	78	12.4	6.3	195	100.0%	195	0

3.1.4.2: South Santiam: We estimated that spawner abundance of natural-origin and hatchery-origin fish in the South Santiam subbasin was 542 and 1,120 fish, respectively (Table 9). The majority of natural-origin spawning occurred above Foster Dam; we estimated that spawner abundance there was 367 wild and 188 hatchery fish. We observed no redds and infer no spawning occurred below Lebanon Dam in 2012, 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.

Table 10. Chinook salmon spawner abundance estimates for the South Santiam River, 2012. Estimates derived by redd count expansion were parsed into hatchery- and natural-origin using carcass counts after adjustment using otolith data.

Subasin, section	Peak Redd Count	Reach Length (km)	Redd Density (redds/km)	Spawner Abundance Estimate (redds*2.5)	pHOS	Hatchery-origin Abundance Estimate	Natural-origin Abundance Estimate
South Santiam							
Lebanon Dam to Foster Dam	443	24.1	18.4	1108	84.2%	933	175
Below Lebanon Dam	0	15.3	0.0	0	100.0%	0	0
Above Foster Dam	222	29.0	7.7	555	33.9%	188	367

3.1.4.3: McKenzie: Total spawner abundance in the McKenzie subbasin was estimated at 2,378 spawners in 2012 (1,184 wild origin and 1,194 hatchery-origin; Table 11). By convention, the McKenzie subbasin is divided into four reaches of interest:

- Below Leaburg Dam, where we estimated spawner abundance of 114 and 556 wild- and hatchery-origin spawners respectively.

- Between Leaburg Dam and the confluence with the South Fork McKenzie River plus the South Fork McKenzie River up to Cougar Dam. We estimated spawners at 456 natural-origin and 171 hatchery-origin fish in that reach.

- The mainstem McKenzie River above the confluence with the South Fork McKenzie River. In this reach we estimated 960 natural-origin and 77 hatchery-origin spawners. That estimate does not include the spawners that might have resulted from the 2012 outplanting of 147 fish above Trail Bridge Dam (six unclipped and 141 clipped).

- 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. 2013; Banks et al. 2013). Our expansion of redd counts generated estimates of 189 natural-origin and 433 hatchery-origin spawners above Cougar Dam in 2012.

Table 11. Chinook salmon spawner abundance estimates for the McKenzie River, 2012. Estimates derived by redd count expansion were parsed into hatchery- and natural-origin using carcass counts after adjustment using otolith data.

Subasin, section	Peak Redd Count	Reach Length (km)	Redd Density (redds/km)	Spawner Abundance Estimate (redds*2.5)	pHOS	Hatchery-origin Abundance Estimate	Natural-origin Abundance Estimate
McKenzie							
Below Leaburg Dam	268	9.7	27.8	670	82.9%	556	114
Leaburg - SF McKenzie	184	29.1	6.3	460	29.1%	134	326
South Fork below Cougar Dam	67	6.9	9.7	168	22.2%	37	130
S Fork McKenzie Above Cougar	249	35.7	7.0	623	69.6%	433	189
Above South Fork McKenzie	415	92.6	4.5	1038	7.4%	77	960

3.1.4.4 Middle Fork Willamette: Results from our surveys indicated that 2,558 fish (176 natural-origin and 2,381 hatchery-origin; Table 12) spawned in the Middle Fork Willamette subbasin in 2012. The reaches of interest in the Middle Fork Willamette subbasin include:

- Below Dexter Dam. We estimated that 24 natural-origin and 166 hatchery-origin fish spawned below Dexter Dam in 2012.

- Little Fall Creek. Hatchery-origin fish were outplanted in Little Fall Creek in 2012 and we estimated that 78 hatchery-origin fish spawned there in 2012.

- Fall Creek. We estimated that 135 wild origin and 10 hatchery-origin fish spawned above Fall Creek Reservoir.

- North Fork Middle Fork. We estimated that five natural-origin and 282 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 nine natural-origin and 1,631 hatchery-origin fish spawned in the Middle Fork Willamette River above Hills Creek Reservoir.

Table 12. Chinook salmon spawner abundance estimates for the Middle Fork Willamette River, 2012. 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**	**Reach Length (km)**	**Redd Density (redds/km)**	**Spawner Abundance Estimate (redds*2.5)**	**pHOS**	**Hatchery-origin Abundance Estimate**	**Natural-origin Abundance Estimate**
Middle Fork Willamette							
Below Dexter	76	14.5	5.2	190	87.3%	166	24
North Fork Middle Fork	202	29.1	6.9	505	98.4%	497	8
Fall Creek	58	26.2	2.2	145	7.0%	10	135
Little Fall Creek	31	8.2	3.8	78	100.0%	78	0
Above Hills Creek Reservoir	656	40.2	16.3	1640	99.5%	1631	9

Section 3.1.5 Estimates of prespawning mortality:

Prespawning mortality varied widely among subbasins and among river reaches within subbasins. 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. We believe that pre-spawning mortality estimates of outplanted fish are affected by the following factors: the time of the year that fish are released upstream of dams, the quality of release sites, and water temperature. For those reasons we view our estimates of pre-spawning mortality in relative terms of low, medium or high corresponding to estimates of less than 20%, between 20 and 50%, and above 50%, respectively, rather than as absolute values.

3.1.5.1 North Santiam: The greatest rate of prespawning mortality in the North Santiam River was observed in the river reaches downstream of Upper Bennett Dam (Table 13). Of the 27 female carcasses examined, 26 had intact or nearly intact egg skeins (96% PSM). Prespawning mortality in the river reaches between Upper Bennett Dam and Minto and in the Little North Santiam River (19% and 39%, respectively) were considered low to moderate. We were unable to adequately estimate PSM above Detroit Reservoir because too few spawners were outplanted to permit useful sample sizes of female carcasses examined. The single female carcass that was recovered had spawned. For comparative purposes, we pooled spawned and unspawned female carcass counts in the mainstem above Bennett Dam with counts from Little North Santiam River and compared the pooled counts to those below Bennett Dam. The PSM rate was significantly greater below Bennett Dam ($G = 64.2$, $df = 1$, $P < 0.001$) when compared to PSM rates between Bennett and Minto dams.

3.1.5.2 South Santiam: The greatest prespawning mortality in the South Santiam River was observed in the river reaches downstream of Lebanon Dam (Table 13). Nine female carcasses were examined and all had intact or nearly intact egg skeins (100% PSM). Prespawning mortality in the river reaches between Lebanon Dam and Foster Dam and above Foster Dam

(27% and 15%, respectively) were considered moderate and low, respectively. For comparative purposes, we pooled spawned and unspawned female carcass counts in the mainstem South Santiam River and compared the pooled counts to those above Foster Dam. The PSM rate was significantly greater below Foster Dam (G = 9.95, df = 1, $P = 0.002$), in contrast to the results in 2011 when PSM was slightly but significantly higher above Foster Dam.

We also tested for association between probability of survival to spawning and year (2009 – 2012), fish size (fork length; cm), outplant site, and outplant timing (week). We found no significant differences at the alpha = 0.05 level in PSM between years and little influence of week, site, length, or an additive effect of all factors on prespawn mortality. Of all factors, year had the most (non-significant) influence, probably because of the relatively low PSM rate in 2011 and fish size had the least influence. There was a weak tendency for the probability of survival to spawning to decrease with timing of outplants. Table 14 provides details on tagged fish releases and recoveries. Table 15 provides the Akaike Information Criterion scores for the various models tested.

3.1.5.3 McKenzie: Prespawning mortality throughout the McKenzie was generally low but was moderate in the reaches below Leaburg Dam (Table 13). For comparative purposes, we pooled spawned and unspawned female carcass counts in the mainstem McKenzie River above Leaburg Dam (excluding the South Fork above Cougar Dam) and compared the pooled counts to those below Leaburg Dam. The PSM rate was significantly greater below Leaburg Dam (G = 41.6, df = 1, $P < 0.001$). Nineteen female carcasses were recovered during surveys above Cougar Dam and all had spawned.

3.1.5.1 Middle Fork Willamette: Prespawning mortality estimates were highly variable throughout the Middle Fork Willamette River (Table 13). The highest PSM was observed below Dexter Dam (66%). Rates were moderate in the North Fork Middle Fork (24%) and Little Fall Creek (29%). Rates were low in Fall Creek (13%) and apparently low in the Middle Fork above Hills Creek Reservoir (10%). However, the results from surveys above Hills Creek Reservoir should be viewed with caution because surveys did not begin in those reaches until August after many fish had been outplanted. Mortalities that occurred before surveys began might not have been available for sampling because of scavenging or decomposition and the PSM estimate might be biased low. We directly compared PSM rates between Little Fall Creek and the North Fork Middle Fork and, in contrast to results in 2011 when PSM in Little Fall Creek was lower, we found no statistically significantly difference (G = 0.3, df = 1, *P* = 0.58) in 2012.

Table 13. Prespawning mortality estimates, 2012. Estimates are derived exclusively from inspection of female carcasses.

Subbasin, section	Processed Carcasses	Males	Spawned Females	Unspawned Females	PSM	PSM Lower 95% CI	PSM Upper 95% CI
North Santiam							
Below Bennett	43	16	1	26	96%	89%	100%
Bennett Dams to Minto	380	132	200	48	19%	14%	24%
Little North Santiam	27	9	11	7	39%	16%	65%
Above Detroit Reservoir	1	0	1	0	0%	--	--
South Santiam							
Lebanon Dam to Foster Dam	443	106	247	90	27%	22%	32%
Below Lebanon Dam	10	1	0	9	100%	100%	100%
Above Foster Dam	254	137	100	17	15%	8%	21%
McKenzie							
Below Leaburg Dam	411	126	210	75	26%	21%	32%
Leaburg - SF McKenzie	55	29	25	1	4%	0%	12%
South Fork below Cougar Dam	18	3	15	0	0%	--	--
South Fork McKenzie Above Cougar	23	4	19	0	0%	--	--
Above South Fork McKenzie	94	37	57	0	0%	--	--
Middle Fork Willamette							
Below Dexter	55	23	11	21	66%	49%	86%
North Fork Middle Fork	551	267	216	68	24%	19%	29%
Fall Creek	100	55	39	6	13%	3%	24%
Little Fall Creek	30	6	17	7	29%	11%	50%
Above Hills Creek Reservoir	375	144	209	22	10%	6%	13%

Table 14. Releases of floy-tagged adult Chinook salmon above Foster Dam, 2009 – 2012, and recoveries of spawned and prespawn mortality females.

Year	Floy-tagged Adult Releases	Spawned Female Recoveries	Prespawn Mortality Female Recoveries	PSM
2009	310	12	1	8%
2010	728	21	2	9%
2011	1,210	56	14	20%
2012	1,040	58	17	23%

Table 15. Akaike Information Criterion (AIC) scores for PSM models tested in the South Santiam subbasin above Foster Dam.

Model	K	AIC_c	Δ AIC_c	Wi
Year	4	160.9	0	0.38
Year + Week	5	162.22	1.32	0.19
Year + Site	5	162.66	1.76	0.16
Year + Length	5	162.99	2.09	0.13
Intercept only	1	165.09	4.19	0.05
Week	2	165.97	5.07	0.03
Site	3	166.35	5.45	0.02
All	8	166.72	5.82	0.02
Length	2	166.75	5.85	0.02

Section 3.1.6 Origin on Spawning Grounds:

During surveys in 2012, we sampled unclipped Chinook salmon carcasses and collected 148 readable otoliths in the North Santiam River, 412 in the South Santiam River, 281 in the McKenzie River, and 101 in the Middle Fork Willamette River. 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 (Tables 16 and 17) allowed adjustments based on the proportions of unclipped hatchery-origin fish. Subbasin-wide pHOS estimates (all reaches above and below dams in each subbasin pooled) ranged from 55% (McKenzie) to 93% (Middle Fork). However, pHOS estimates in Fall Creek and the McKenzie River above the South Fork McKenzie were notably low (7.0% and 8.0%, respectively).

We also examined reach-specific pHOS estimates to describe spatial variation within subbasins. Clearly, hatchery-origin fish were not distributed evenly in each subbasin. In the North Santiam River hatchery fish were proportionately more abundant in the mainstem reaches and less so in the Little North Santiam ($G = 30.3$, $df = 1$, $P < .001$) where outplanting of hatchery fish did not occur in 2012. In the South Santiam, pHOS was significantly higher below Foster Dam than above ($G = 187.5$, $df = 1$, $P < .001$) because only unclipped fish captured at Foster dam are outplanted above the project. In the McKenzie River, hatchery fish were proportionately far more abundant in the lower reaches below Leaburg Dam than in all other surveyed reaches above Leaburg dam ($G = 206.6$, $df = 1$, $P < 0.001$). In the Middle Fork, excluding consideration of Fall Creek (described above), pHOS was lower below Dexter than above ($G = 15.9$, $df = 1$, $P < .001$), an outcome of course driven by the focused outplanting of adipose clipped fish into reaches above Dexter Dam.

3.1.6.1 North Santiam: As in previous years the pHOS estimates (Table 17) in the North Santiam River greatly exceeded the recovery goal of 10%. Only clipped Chinook salmon were outplanted above Detroit Dam in 2012 but because of difficulties encountered in operating the Upper Bennett Dam trap, few fish were outplanted, and we did not effectively remove hatchery-origin spawners from the reaches below Big Cliff Dam. We expect that when the Minto Facility is in operation in 2013, a larger proportion of hatchery spawners can be used for recovery efforts above Detroit and thereby lessen the immediate impact on wild spawners below Detroit Dam.

3.1.6.2 South Santiam: As in previous years the pHOS estimates (Table 17) in the South Santiam River greatly exceeded the recovery goal of 10%, both above and below. 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 (34.0%, based on thermal marks), pHOS targets were exceeded even there.

3.1.6.3 McKenzie: As in previous years the pHOS estimates (Table 17) in the McKenzie River exceeded the recovery goal of 10%. However, pHOS in the McKenzie is the lowest among the subbasins and, in the reaches above the confluence with the South Fork McKenzie River, the pHOS estimate was 7.0%.

3.1.6.4 Middle Fork Willamette: As in previous years the pHOS estimates (Table 17) in the Middle Fork Willamette River greatly exceeded the recovery goal of 10%. However, as in the South Santiam above Foster Dam, only unclipped fish are outplanted in Fall Creek. Four of the 59 otoliths collected from carcasses in Fall Creek were thermally marked, so pHOS in that portion of the subbasin (6.8%) meets recovery goals. The remainder of the subbasin was dominated by hatchery spawners.

Table 16. Analysis results for otoliths collected from spawning ground surveys in 2012 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	North Santiam	106	15	14.2%
	Little North Santiam	23	4	17.4%
	North Santiam Above Detroit	0	0	--
	Marion Forks Hatchery	24	5	20.8%
	North Santiam Total	**153**	**24**	**15.7%**
South Santiam River	South Santiam Below Foster	80	13	16.3%
	South Santiam Above Foster	238	81	34.0%
	South Santiam Total	**318**	**94**	**29.6%**
McKenzie River	McKenzie Below Leaburg	92	25	27.2%
	McKenzie Above Leaburg	75	7	9.3%
	South Fork McKenzie Below Cougar	11	0	0.0%
	South Fork McKenzie Above Cougar	7	0	0.0%
	Horse Creek	61	3	4.9%
	Lost Creek	0	0	--
	McKenzie Hatchery	53	24	45.3%
	McKenzie Total	**299**	**59**	**19.7%**
Middle Fork Willamette River	Middle Fork Below Dexter	10	4	40.0%
	Fall Creek	59	4	6.8%
	Little Fall Creek	4	4	100.0%
	North Fork Middle Fork	10	5	50.0%
	Middle Fork Above Hills Creek	1	0	--
	Willamette Hatchery	55	21	38.2%
	Middle Fork Total	**139**	**38**	**27.3%**

Table 17. Estimates of pHOS in 2012 based on counts of clipped and unclipped carcasses after adjustments following otolith analyses.

Subbasin, section	Processed Carcasses	Unclipped	Clipped	% Thermally Marked Otoliths	Wild Estimate	Hatchery Estimate	pHOS	pHOS Lower 95% CI	pHOS Upper 95% CI
North Santiam									
Below Bennett	43	8	35	20.0%	6	37	86%	76%	100%
Bennett Dams to Minto	380	99	281	13.5%	86	294	77%	73%	82%
Little North Santiam	27	24	3	17.4%	20	7	26%	9%	44%
Above Detroit Reservoir	1	0	1	0.0%	0	1	100%	100%	100%
South Santiam									
Lebanon Dam to Foster Dam	443	83	360	16.3%	70	373	84%	81%	88%
Below Lebanon Dam	10	0	10	0.0%	0	10	100%	100%	100%
Above Foster Dam	254	254	0	34.0%	168	86	34%	28%	40%
McKenzie									
Below Leaburg Dam	411	96	314	27.2%	70	340	83%	79%	87%
Leaburg - SF McKenzie	55	43	12	9.6%	39	16	29%	17%	42%
South Fork below Cougar Dam	18	14	4	0.0%	14	4	22%	3%	44%
South Fork McKenzie Above Cougar	23	7	16	0.0%	7	16	70%	51%	93%
Above South Fork McKenzie	94	92	2	6.0%	87	7	7%	2%	13%
Middle Fork Willamette									
Below Dexter	55	11	44	40.0%	7	48	87%	78%	99%
North Fork Middle Fork	551	18	533	50.0%	9	542	98%	97%	100%
Fall Creek	100	100	0	6.8%	93	7	7%	2%	12%
Little Fall Creek	30	4	26	100.0%	0	30	100%	100%	100%
Above Hills Creek Reservoir	375	2	373	0.0%	2	373	99%	99%	100%

Section 3.1.7 Straying:

We report straying as the incidence of hatchery-origin fish released as juveniles in one subbasin and recovered as adults in a different 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 18). The exception was for South Santiam stock fish that were reared at the Willamette Hatchery and released directly into the Molalla River; more straying from "Molalla" fish into the Santiam subbasins occurred in 2012. Recoveries at McKenzie hatchery are biased slightly low because an unknown, but probably small, number of CWT hatchery fish were captured at the hatchery but not sampled for CWTs. Instead, they were used to supplement low numbers of natural-origin fish that were passed above Cougar Dam. At other hatchery facilities CWT recovery rates were assumed to be 100%. The CWT recovery rates during spawning ground surveys are unknown but we are developing a method to estimate the recovery rate and will report our results later.

Section 3.1.8 Video Monitoring:

3.1.8.1 North Santiam (Upper and Lower Bennett Dams): Counts of spring Chinook salmon passing upstream of Upper Bennett Dam and Lower Bennett Dam in 2012 are provided in Tables 19 - 21. The first unclipped adult was observed the week of April 27 and the first clipped adult was noted the following week. The peak count for both unclipped and clipped adults occurred the week of July 13. The final observations of unclipped and clipped adults occurred the weeks of November 9 and October 19, respectively. 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 first, peak, and last jacks were observed the weeks of May 18, July 13, and September 28, respectively. A relatively small number of fish that were trapped at Upper Bennett Dam and subsequently passed upstream were included in counts to better reflect total passage even though they were not technically counted using the video system. The Lower Bennett video system was operated continuously beginning 5/2/2012 and ending 11/.16/2012 except for a 3 h (0600 – 0900) loss of video signal on 7/13/2012. Because few if any fish were moving at that time no adjustments to the counts were made. The Upper Bennett video system was operated continuously throughout the year except for a video signal loss for 37 h on 5/13/2012 and 5/14/2012. We estimated that seven Chinook salmon, seven winter steelhead, 20 summer steelhead and five unknown steelhead passed upper Bennett Dam during the video outage. These estimated expansions are included in the counts in Tables 19 -21.

3.1.8.2 McKenzie River (Leaburg Dam): Counts of spring Chinook salmon passing upstream of Leaburg Dam in 2012 are provided in Table 22. The first unclipped adult was observed the week of May 11 and the first clipped adult was noted the week of June 15. The peak count for unclipped adults occurred the week of July 6. Counts of clipped adults showed two peaks; one coincident with that of unclipped fish and the other the week of September 7. The final observations of unclipped and clipped adults occurred the weeks of November 9 and October 19, respectively. Adipose clips on jack salmon could not readily be discerned because of the size of the fish and fin so those counts were pooled. Only three jacks were observed, all passing the weeks of July 6 (N = 1) and 13 (N = 2). Sixty adipose clipped adult Chinook salmon were removed from the ladder and transported to McKenzie Hatchery between August 24 and September 28 to help reduce pHOS in the subbasin. Both left-bank and right-bank video systems were operated continuously from 1/1/2012 through 12/31/2012.

Table 18. Analysis of CWT recoveries during spawning ground surveys, at hatchery traps, and at hatcheries during 2012. Numbers in parentheses are expansions based on the proportion of the release group that received CWTs. Bold text indicates interbasin straying. Shaded cells indicate recoveries in the basins into which fish were released. Recovery locations in rivers indicate spawning ground survey recoveries. All other recoveries were from hatcheries or traps.

Recovery Location	CWT Recoveries (and expansions) by Release Location						
	North Santiam River	Detroit Res.	South Santiam River	McKenzie River	M. Fk Willamette River	Molalla River	Clackamas River
North Santiam River	3 (67)	23 (47)	0 (0)	0 (0)	0 (0)	**8 (28)**	0 (0)
Marion Forks Hatchery	15 (332)	32 (65)	0 (0)	**7 (7)**	0 (0)	**12 (43)**	**1 (3)**
South Santiam River	0 (0)	0 (0)	29 (246)	0 (0)	0 (0)	**2 (7)**[1]	0 (0)
South Santiam Hatchery	0 (0)	0 (0)	374 (3157)	0 (0)	0 (0)	**7 (24)**[1]	0 (0)
McKenzie River	0 (0)	0 (0)	0 (0)	80 (81)	0 (0)	0 (0)	0 (0)
McKenzie Hatchery	**1 (22)**	0 (0)	**1 (14)**	311 (320)	0 (0)	0 (0)	**1 (6)**
Middle Fk Willamette River	0 (0)	0 (0)	0 (0)	0 (0)	3 (17)	0 (0)	0 (0)
Dexter Ponds Trap	0 (0)	0 (0)	0 (0)	**6 (6)**	632 (4883)	0 (0)	0 (0)
Willamette Hatchery	0 (0)	0 (0)	0 (0)	0 (0)	308 (2409)	0 (0)	0 (0)

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[1] Some uncertainty as to how these fish are to be characterized because although they were released in the Molalla they are originally of South Santiam stock (reared at the Willamette Hatchery).

Table 19. Net number of marked and unmarked spring Chinook salmon and other species counted at Upper Bennett Dam by month, 2012. Counts of jacks are provided but were not differentiated between marked and unmarked.

	Steelhead			Chinook					
Month	**Clipped**	**Unclipped**	**Unknown Mark**	**Clipped**	**Unclipped**	**Unknown Mark**	**Jacks**	**Coho**	**Lamprey**
January	0	9	2	0	0	0	0	5	0
February	0	58	18	0	0	0	0	0	0
March	2	262	27	0	0	0	0	0	0
April	56	430	94	0	0	1	0	0	0
May	376	51	58	189	65	4	0	0	0
June	905	9	2	1,078	348	5	16	0	14
July	358	2	0	1,062	314	1	20	0	0
August	86	1	3	389	135	2	26	0	108
September	80	10	0	54	38	-1	7	27	1
October	297	24	41	0	5	0	0	340	0
November	71	18	9	0	1	0	0	76	3
December	3	1	3	0	0	0	0	7	1
Total 2012	2,234	875	257	2,772	906	12	69	455	127

Table 20. Net number of marked and unmarked spring Chinook salmon and other species counted at Lower Bennett Dam by month, 2012. Counts of jacks are provided but were not differentiated between marked and unmarked.

	Steelhead			Chinook					
Month	**Clipped**	**Unclipped**	**Unknown Mark**	**Clipped**	**Unclipped**	**Unknown Mark**	**Jacks**	**Coho**	**Lamprey**
May	276	47	-1	43	19	4	2	0	0
June	969	5	3	71	30	-2	7	0	0
July	392	0	4	27	7	0	0	0	11
August	11	0	0	4	0	0	2	0	20
September	66	0	0	6	6	0	4	14	-3
October	151	0	11	1	47	0	2	209	2
November	11	0	0	0	1	0	2	44	1
Total 2012	1,876	52	17	152	110	2	19	267	31

Table 21. Net movement of fish counted on video at Upper and Lower Bennett dams combined on the North Santiam River in 2012. Note that Lower Bennett Dam was only in operation May through December.

	Steelhead			**Chinook**					
Month	**Clipped**	**Unclipped**	**Unknown Mark**	**Clipped**	**Unclipped**	**Unknown Mark**	**Jacks**	**Coho**	**Lamprey**
January	0	9	2	0	0	0	0	5	0
February	0	58	18	0	0	0	0	0	0
March	2	262	27	0	0	0	0	0	0
April	56	430	94	0	0	1	0	0	0
May	652	98	57	232	84	8	2	0	0
June	1,874	14	5	1,149	378	3	23	0	14
July	750	2	4	1,089	321	1	20	0	11
August	97	1	3	393	135	2	28	0	128
September	146	10	0	60	44	-1	11	41	-2
October	448	24	52	1	52	0	2	549	2
November	82	18	9	0	2	0	2	120	4
December	3	1	3	0	0	0	0	7	1
Total 2012	4,110	927	274 0	2,924	1,016	14	88 0	722 0	158

Table 22. Net number of marked and unmarked spring Chinook salmon, steelhead trout and lamprey counted at Leaburg Dam by month, 2012.

Month	Unmarked Steelhead	Hatchery Summer Steelhead	Unclipped ("Wild") Chinook	Hatchery Chinook	Lamprey
January	0	4	0	0	0
February	2	0	0	0	0
March	2	0	0	0	0
April	0	10	0	0	0
May	7	124	14	0	0
June	34	367	559	37	3
July	26	292	733	101	50
August	9	131	173	31	81
September	9	20	164	89	1
October	6	38	11	0	1
November	0	0	0	0	0
December	0	0	0	0	0
Total 2012	95	986	1,654	258	136

Section 3.2: Reintroduction Efforts

Section 3.2.1 Number of Chinook Salmon Released Upstream of Dams:

3.2.1.1 North Santiam: Outplanting of adult Chinook salmon above Detroit Dam in the North Santiam in 2012 (Table 23) was confounded by the need to capture adults at Upper Bennett Dam because the Minto trapping facility was under construction. The original design of the trap at Upper Bennett Dam did not appear to allow operation as intended. Adult fish have to turn right out of the fish ladder and volunteer through a fyke entry into the trap chamber. We think that the fish were reluctant to enter into the trap; instead, we think that they were easily able to back out of the fyke. We were not successful at capturing enough fish for broodstock and the full complement of fish for outplanting above Detroit. The original goal for the level of outplanting was 1,500 adipose-clipped adults above Detroit, split between the North Santiam (900) and the Breitenbush (600) rivers. Only 257 fish (132 males, 121 females and four jacks) were outplanted. All were sampled for DNA. We anticipate that when the Minto Fish Collection Facility is in operation in 2013, a larger number of hatchery-origin fish will be available for outplanting.

3.2.1.2 South Santiam: Outplanting operations at Foster Dam were successful in 2012. All unclipped fish captured in the trap were DNA sampled and trucked to release sites above Foster Dam. Although only unclipped Chinook salmon are outplanted, 34.0% of otoliths collected from carcasses during spawner surveys above Foster Dam indicated the fish were unclipped hatchery adults. A summary of outplanting activities is provided in Table 23

3.2.1.3 McKenzie: Outplanting activities in the McKenzie subbasin were successful in 2012. 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 in numbers roughly equal to natural-origin spring Chinook salmon outplanted from a trapping operation below Cougar Dam (Table 23).

3.2.1.4 Middle Fork Willamette: Outplanting efforts in the Middle Fork Willamette River were successful in 2012. Adult spring Chinook salmon (2,249 males, 2,058 females and 256 jacks) 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 (153 fish) were outplanted in Little Fall Creek and we continued spawning surveys in that tributary to assess the potential for recovery of the species there. Outplanting in Fall Creek was conducted by USACE staff, and involved transportation of 334 fish above Fall Creek Reservoir. A summary of outplanting activities in the Middle Fork Willamette River is provided in Table 23.

Table 23. Adult Chinook salmon outplanted, 2012.

Subbasin	Release Site Name	# Chinook Salmon Outplanted Males	Females	Jacks	Total
North Santiam	Cains Marina	23	23	0	46
	Hoover Campground	109	98	4	211
South Santiam	Caulkins Park	52	59	0	111
	Gordon Road	163	77	9	249
	Riverbend	330	281	4	615
South Fork McKenzie	Frissell Bridge	0	0	0	0
	Hard Rock	446	493	9	948
	Homestead	0	0	0	0
	Slide Creek	2	2	0	4
Middle Fork Willamette	Fall Creek	125	185	24	334
	Little Fall Creek	77	67	9	153
	Construction Pool	511	437	74	1022
	Paddy's Valley	540	448	33	1021
	North Fork Middle Fork Willamette	1198	1173	149	2520

Section 3.2.2 Origin of Chinook Salmon Released Upstream of Dams:

3.2.2.1 North Santiam: Only adipose-clipped adult Chinook salmon were outplanted above Detroit Reservoir in the North Santiam River; pHOS was 100% (Table 17).

3.2.2.2 South Santiam: Only adipose intact fish were outplanted from the Foster Dam trap to the South Santiam River above the dam. Analyses were conducted on otoliths collected during pre-spawning mortality and spawner surveys. We found thermal marks on 81 of the 238 readable otoliths from carcasses sampled during prespawn mortality and spawner surveys. Therefore, we estimate that pHOS above Foster Dam in 2012 was 34.0% (Table 17).

3.2.2.3 McKenzie: A mixture of adipose clipped and adipose intact fish were released above Cougar Dam in the South Fork McKenzie River. We recovered seven readable otoliths from unclipped carcasses during prespawn mortality and spawner surveys and none were thermally marked. We recovered 16 clipped carcasses. Therefore, the pHOS estimate based strictly on carcass recoveries above Cougar Dam in 2012 was 70% (Table 17). However, because the sample size of recovered carcasses was low, we suspect that the actual pHOS above Cougar Reservoir was approximately 47%, based on the outplanting of clipped vs. unclipped fish. Outplanted Chinook salmon from the Cougar Dam facility involved transport of 505 non-clipped fish and 17 adipose-clipped fish. An additional 430 adipose-clipped fish were outplanted from McKenzie Hatchery.

3.2.2.4 Middle Fork Willamette: Ten otoliths were recovered from unclipped carcasses above Dexter Dam in the North Fork Middle Fork Willamette River, five of which were thermally marked. Given that we recovered 18 unclipped and 533 clipped carcasses we estimate that pHOS was 98%. Surveys above Hills Creek Dam on the Middle Fork Willamette recovered two unclipped and 373 clipped carcasses. The one readable otolith from unclipped fish was not thermally marked and we therefore estimate that pHOS was 99% (Table 17). In Fall Creek only unclipped fish were trucked upstream of Fall Creek Dam but otolith analyses indicated that 7% of the unmarked fish were of hatchery origin (Table 17).

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 in the Upper Bennett Dam trap in 2012 because the Minto Dam trap further upriver was under construction. The majority of broodstock were clipped hatchery fish (Table 24) but some unclipped fish were collected and transported to McKenzie Hatchery for spawning to accommodate an ongoing study of experimental crosses of hatchery- and natural-origin fish (C. Sharpe*, in review*). Thermal marks on otoliths from unclipped fish indicated that 5% (5 thermal marks / 95 otoliths read) of the unclipped fish were actually of hatchery origin. Overall, in 2012 the PNOB was 0.17 in the North Santiam Hatchery program (Table 28).

3.3.1.2 South Santiam: All broodstock for the South Santiam Hatchery program were collected at the Foster Dam trap. Only adipose clipped fish are incorporated into the South Santiam broodstock (Table 25). Therefore, in 2012 PNOB was zero (Table 25).

3.3.1.3 McKenzie: A mixture of adipose clipped and unclipped fish were incorporated in to the McKenzie Hatchery program (Table 26). Thermal marks on otoliths from unclipped fish that volunteered to the McKenzie Hatchery indicated that 40.2% (39 thermal marks/97 otoliths read) of the unclipped fish were actually of hatchery origin (Table 25); PNOB was 0.04.

3.3.1.4 Middle Fork Willamette: A mixture of adipose clipped and unclipped fish were incorporated in to the Willamette Hatchery program (Table 24). Thermal marks in otoliths from the unclipped fish indicated that 60.8% were actually unclipped hatchery fish and PNOB was therefore 0.02 (Table 28).

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

3.3.2.1 North Santiam: Collection and disposition of broodstock for the North Santiam hatchery program is provided in Figure 29. Importantly, broodstock collection in 2012 occurred at upper Bennett Dam. When construction at the Minto Fish Collection Facility is complete, broodstock collection will likely occur later. Size distributions of the North Santiam broodstock by sex are provided in Figure 30: females tended to be larger than males (Mann-Whitney Test; U = 909.5, T = 2134.5; $P = 0.019$). We compared age structure between NOB and HOB among North Santiam broodstock (Figure 31) and found that HOB broodstock tended to be older (Mann-Whitney Test; U = 3083.5, T = 6086.5; $P = 0.021$). Similarly, we compared sizes of NOB and HOB fish (Figure 32) but did not detect a significant difference.

3.3.2.2 South Santiam: Collection timing of broodstock for the South Santiam Hatchery program, used by convention as a proxy for run timing, is provided in Figure 29. We compared age structure between HOB and natural-origin fish collected during spawner surveys (NOB fish are not used in the South Santiam program) (Figure 33) and found that HOB broodstock tended to be older (Mann-Whitney Test; U = 10606.0, T = 16862.0; $P = 0.003$). Size distributions of the South Santiam broodstock, by sex, are provided in Figure 30: males tended to be larger than females (Mann-Whitney Test; U = 844, T = 1834.0; $P = 0.020$). Similarly, we compared sizes of natural-origin spawners on the spawning grounds and HOB fish at the hatchery (Figure 34) and found that the natural-origin fish tended to be larger (Mann-Whitney Test; U = 10049.5, T = 12677.5; $P = 0.011$).

3.3.2.3 McKenzie: Collection timing of broodstock for the McKenzie Hatchery program, used by convention as a proxy for run timing, is provided in Figure 29. Size distributions of the McKenzie broodstock by sex are provided in Figure 30: males tended to be larger than females (Mann-Whitney Test; U = 809.5, T = 2529.5; $P = 0.004$). We compared age structure between HOB and NOB fish (Figure 35) and found that HOB broodstock tended to be older (Mann-Whitney Test; U = 2046.5, T = 3642.5; $P < 0.001$). Similarly, we compared sizes of NOB and HOB fish at the hatchery (Figure 36) and found that the natural-origin fish tended to be larger (Mann-Whitney Test; U = 1978, T = 5610; $P = 0.011$).

3.3.2.4 Middle Fork Willamette: Collection timing of broodstock for the Middle Fork Willamette Hatchery program, used by convention as a proxy for run timing, is provided in Figure 29. Size distributions of the Middle Fork Willamette broodstock by sex are provided in Figure 30. We found no statistically significant difference in size between sexes (Mann-Whitney Test; U = 1007, T = 1910; $P = 0.141$). We compared age structure between HOB and NOB fish (Figure 37) and found no statistically significant difference (Mann-Whitney Test; U = 519.5, T = 1118.5; $P = 0.196$). Similarly, we compared sizes of NOB and HOB fish at the hatchery (Figure 38) and found no statistically significant difference (Mann-Whitney Test; U = 553, T = 1187; $P = 0.272$).

Table 24. Collection and spawning of marked and unmarked Chinook salmon adults in the North Santiam subbasin, 2012.

	Broodstock at Bennett						Spawned					
	(ad clipped)			*(no mark)*			*(ad clipped)*			*(no mark)*		
Date	*M*	*F*	*J*	*M*	*F*	*J*	*M*	*F*	*J*	*M*	*F*	*J*
5/31/2012	9	9	0	0	0	0	--	--	--	--	--	--
6/1/2012	13	9	0	1	0	0	--	--	--	--	--	--
6/5/2012	12	7	1	0	0	0	--	--	--	--	--	--
6/12/2012	23	11	0	0	0	0	--	--	--	--	--	--
6/20/2012	15	15	1	1	1	0	--	--	--	--	--	--
6/22/2012	30	25	0	3	3	0	--	--	--	--	--	--
6/25/2012	22	17	0	3	2	0	--	--	--	--	--	--
6/28/2012	39	28	0	4	1	0	--	--	--	--	--	--
7/1/2012	51	32	0	4	3	2	--	--	--	--	--	--
7/2/2012	41	44	1	2	3	0	--	--	--	--	--	--
7/3/2012	17	21	0	5	0	0	--	--	--	--	--	--
7/8/2012	13	16	1	2	2	0	--	--	--	--	--	--
7/15/2012	17	17	0	7	10	0	--	--	--	--	--	--
7/19/2012	12	6	0	1	1	0	--	--	--	--	--	--
7/21/2012	28	18	0	5	4	1	--	--	--	--	--	--
7/24/2012	17	17	0	3	3	0	--	--	--	--	--	--
7/25/2012	10	15	1	4	1	1	--	--	--	--	--	--
7/30/2012	16	11	0	6	1	0	--	--	--	--	--	--
8/10/2012	5	5	0	3	1	0	--	--	--	--	--	--
9/12/2012	--	--	--	--	--	--	84	84	0	4	3	0
9/19/2012	--	--	--	--	--	--	152	152	0	0	0	0
9/26/2012	--	--	--	--	--	--	22	32	0	17	0	0

Table 25. Collection and spawning of marked and unmarked Chinook salmon adults in the South Santiam subbasin, 2012.

	Broodstock at Foster						Spawned					
	(ad clipped)			*(no mark)*			*(ad clipped)*			*(no mark)*		
Date	*M*	*F*	*J*	*M*	*F*	*J*	*M*	*F*	*J*	*M*	*F*	*J*
5/29/2012	3	0	0	--	--	--	--	--	--	--	--	--
6/4/2012	13	11	0	--	--	--	--	--	--	--	--	--
6/6/2012	25	11	0	--	--	--	--	--	--	--	--	--
6/12/2012	0	1	0	--	--	--	--	--	--	--	--	--
6/19/2012	9	8	0	--	--	--	--	--	--	--	--	--
6/22/2012	49	65	6	--	--	--	--	--	--	--	--	--
6/26/2012	40	36	0	--	--	--	--	--	--	--	--	--
7/10/2012	26	42	0	--	--	--	--	--	--	--	--	--
7/19/2012	63	48	0	--	--	--	--	--	--	--	--	--
8/2/2012	58	59	2	--	--	--	--	--	--	--	--	--
8/21/2012	85	0	1	--	--	--	--	--	--	--	--	--
9/12/2012	--	--	--	--	--	--	117	118	1	--	--	--
9/13/2012	25	65		--	--	--	--	--	--	--	--	--
9/18/2012	8	27		--	--	--	--	--	--	--	--	--
9/19/2012	--	--	--	--	--	--	107	109	2	--	--	--
9/25/2012		24		--	--	--	--	--	--	--	--	--
9/26/2012	--	--	--	--	--	--	113	115	2	--	--	--

Table 26. Collection and spawning of marked and unmarked Chinook salmon adults in the McKenzie subbasin, 2012.

	Broodstock at McKenzie			Spawned					
	Broodstock not segregated			*(ad clipped)*			*(no mark)*		
Date	*M*	*F*	*J*	*M*	*F*	*J*	*M*	*F*	*J*
6/1/2012	82	57	3	--	--	--	--	--	--
6/4/2012	112	91	0	--	--	--	--	--	--
6/13/2012	50	23	2	--	--	--	--	--	--
6/19/2012	283	210	15	--	--	--	--	--	--
6/21/2012	189	163	5	--	--	--	--	--	--
6/28/2012	84	83	3	--	--	--	--	--	--
7/2/2012	274	195	15	--	--	--	--	--	--
7/9/2012	76	88	4	--	--	--	--	--	--
7/12/2012	219	130	11	--	--	--	--	--	--
7/17/2012	39	41	2	--	--	--	--	--	--
7/25/2012	109	98	7	--	--	--	--	--	--
8/7/2012	53	42	11	--	--	--	--	--	--
8/22/2012	54	34	3	--	--	--	--	--	--
9/6/2012	217	58	10	--	--	--	--	--	--
9/10/2012	99	49	2	132	138	2	8	2	0
9/17/2012	135	118	3	341	352	3	20	9	0
9/21/2012	41	59	3	--	--	--	--	--	--
9/24/2012	12	37	1	180	195	4	18	5	0
9/25/2012	12	10	0	--	--	--	--	--	--
10/1/2012	16	25	0	77	98		24	3	0

Table 27. Collection and spawning of marked and unmarked Chinook salmon adults in the Middle Fork Willamette subbasin, 2012.

	Broodstock at Willamette						Spawned					
	(ad clipped)			*(no mark)*			*(ad clipped)*			*(no mark)*		
Date	*M*	*F*	*J*	*M*	*F*	*J*	*M*	*F*	*J*	*M*	*F*	*J*
6/13/2012	282	303	8	7	2	0	--	--	--	--	--	--
6/14/2012	279	305	0	4	2	0	--	--	--	--	--	--
6/19/2012	340	295	0	1	2	0	--	--	--	--	--	--
7/18/2012	13	9	0	2	1	0	--	--	--	--	--	--
7/25/2012	7	9	0	5	4	0	--	--	--	--	--	--
8/1/2012	8	14	0	1	2	0	--	--	--	--	--	--
8/9/2012	18	17	0	14	7	0	--	--	--	--	--	--
8/23/2012	22	24	1	24	6	0	--	--	--	--	--	--
8/30/2012	30	16	0	25	4	0	--	--	--	--	--	--
9/11/2012	--	--	--	--	--	--	278	293	2	16	3	0
9/18/2012	--	--	--	--	--	--	204	216	0	13	1	0
9/25/2012	--	45	0	0	0		69	74	0	5	0	0
9/28/2012	--	--	--	--	--	--	8	8	0	0	0	0
10/2/2012	--	8	0	0	0	0	22	22	0	0	0	0

Table 28. Estimates of integration of natural-origin spawners as broodstock in Willamette hatcheries, 2012. Note that in 2012 North Santiam broodstock were held and spawned at McKenzie Hatchery because of the Minto facility construction.

Stock	Hatchery	# Clipped Spawners	# Unclipped Spawners	Otoliths Read	Unclipped Thermal Marks	pNOB
North Santiam	McKenzie	452	96	96	5	0.17
South Santiam	South Santiam	696	0	NA	NA	0.0
McKenzie	McKenzie	1,462	97	97	39	0.04
M. Fk Willamette	M. Fk Willamette	1,363	74	74	45	0.02

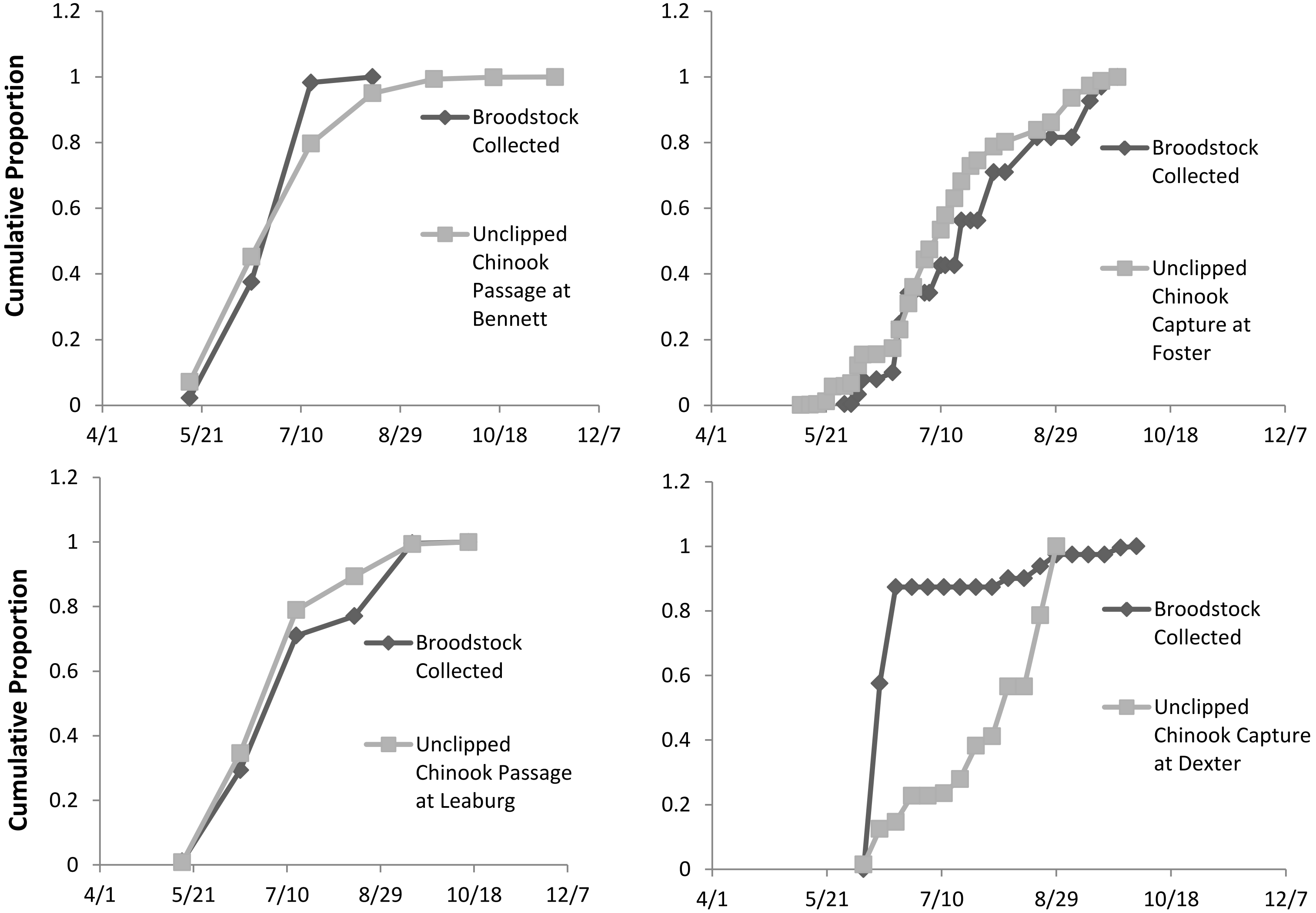

Figure 29. Comparison of broodstock collection timing to run timing of unclipped Chinook salmon.

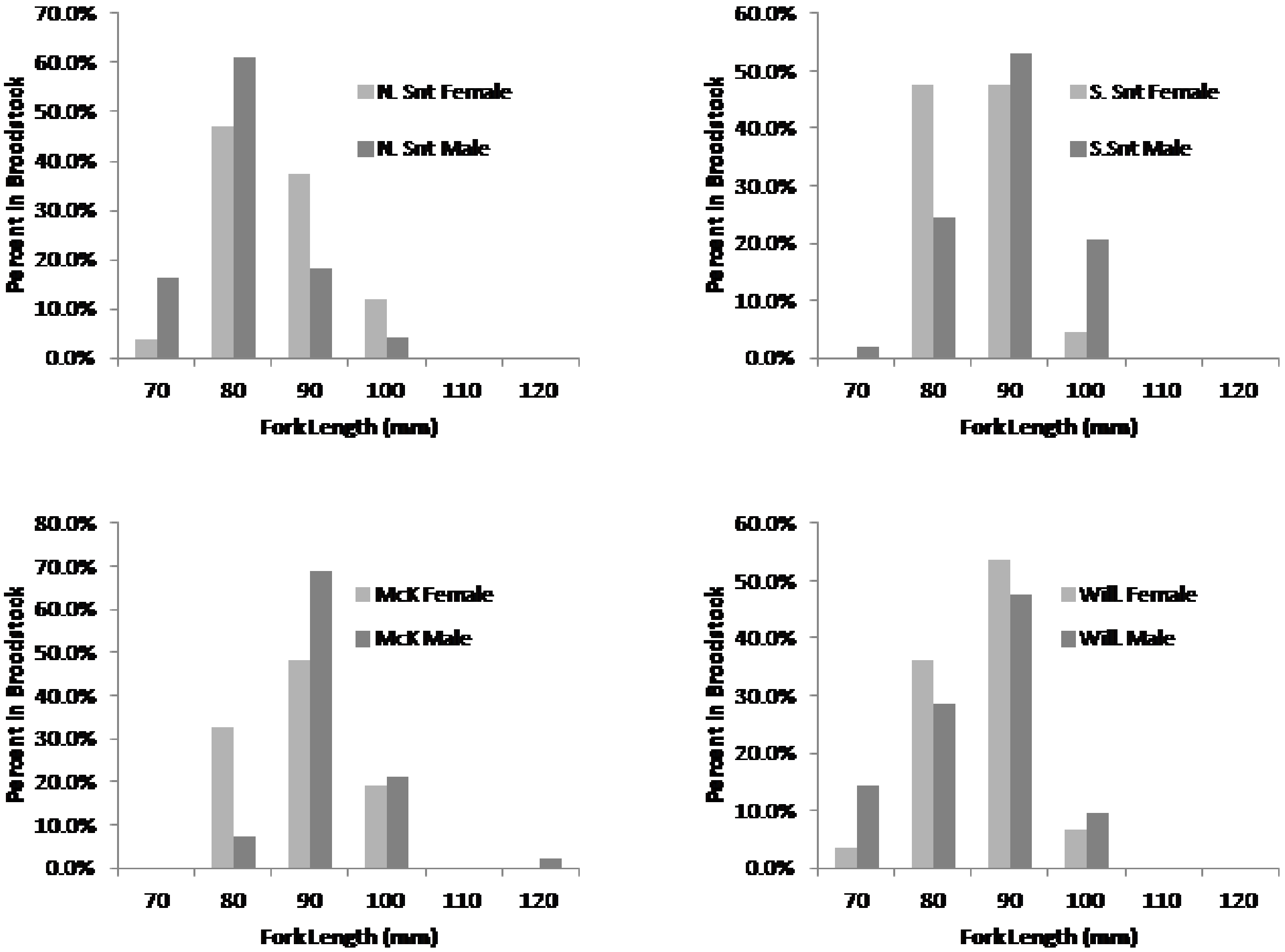

Figure 30. Size frequency of male and female Chinook salmon used in broodstock, 2012. Data from N = 100 at each hatchery; jacks were excluded (only 3 jacks among samples taken, all at South Santiam).

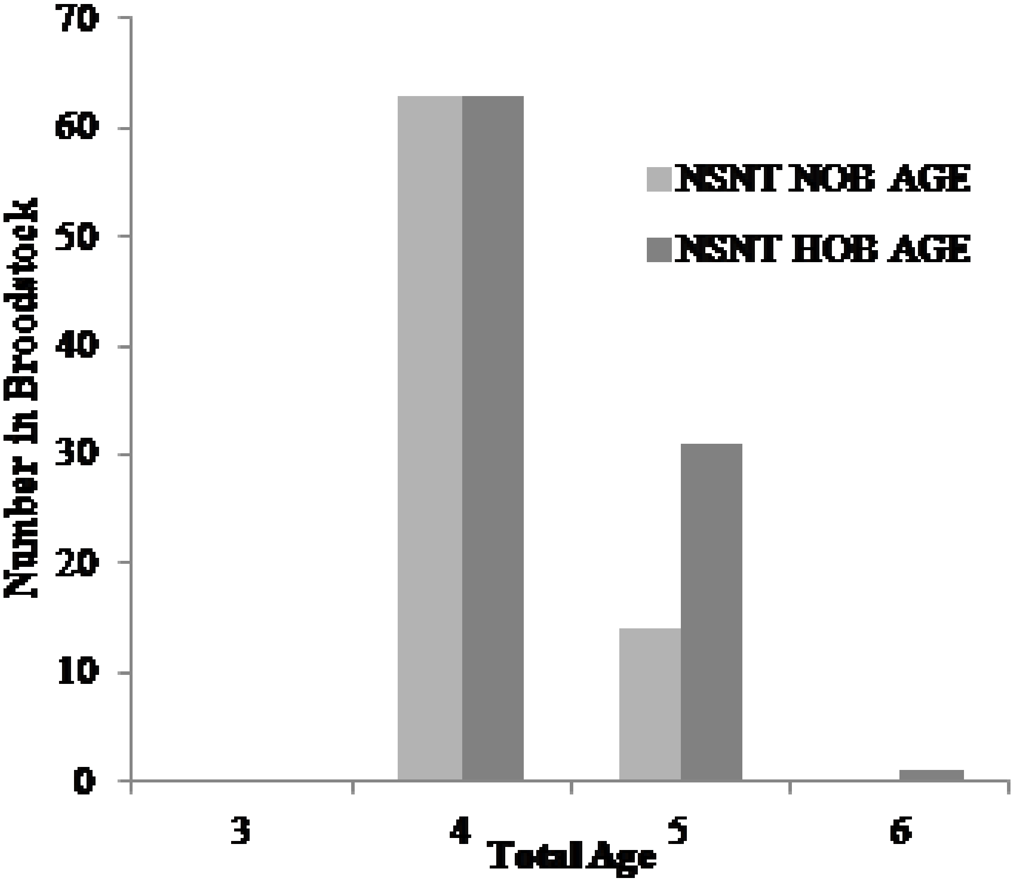

Figure 31. Age structure of Chinook salmon used for North Santiam broodstock, 2012. Sample sizes (readable scales) were 77 and 95 for NOB and HOB, respectively.

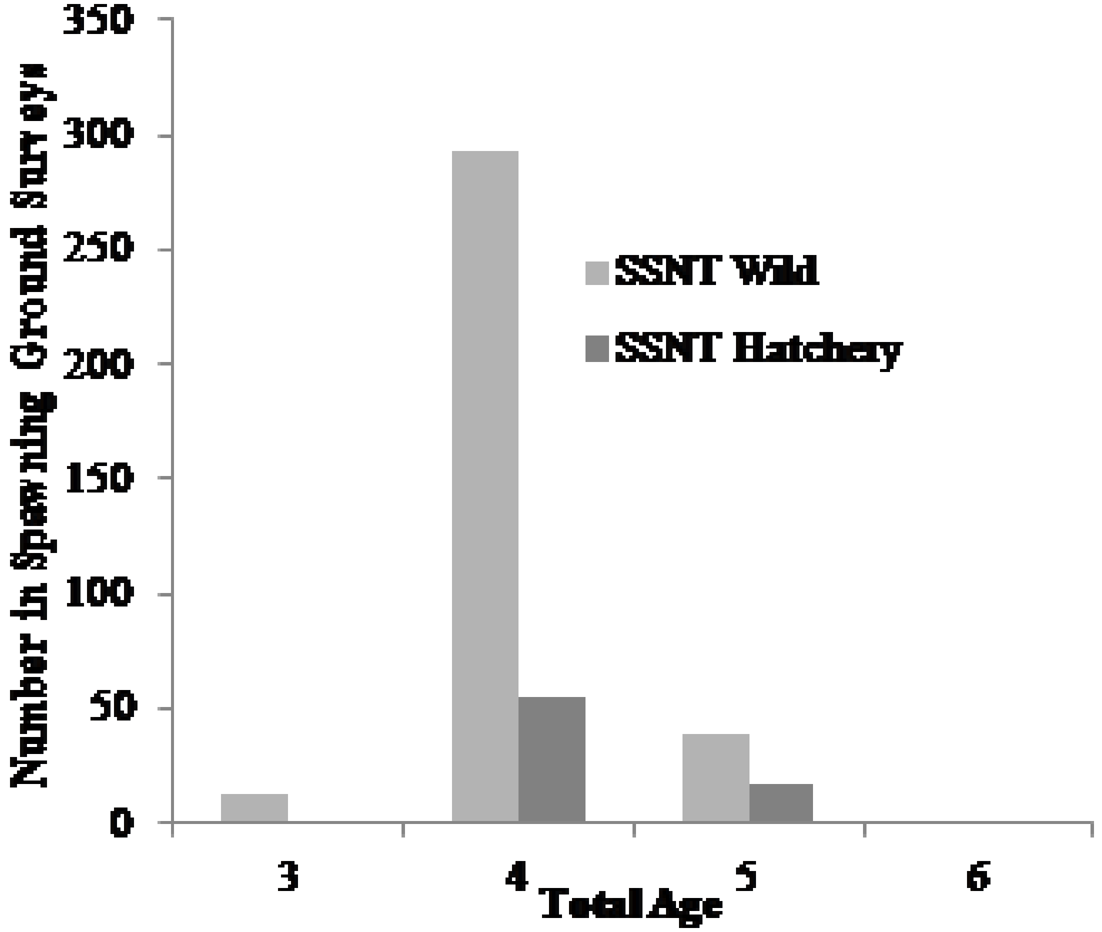

Figure 32. Size comparison of North Santiam Chinook salmon broodstock used for spawning, 2012.

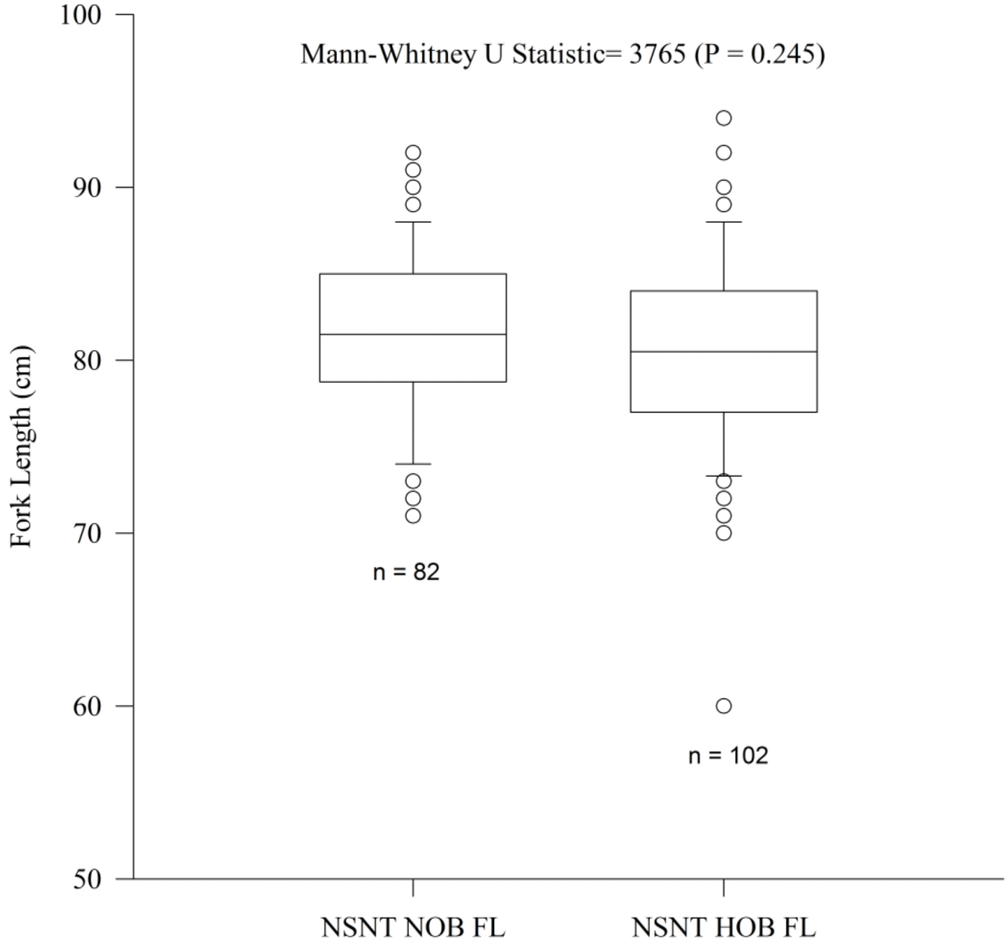

Figure 33. Age structure of wild- and hatchery-origin Chinook salmon in the South Santiam River, 2012. Note natural-origin Chinook salmon were not integrated into broodstock there in 2012 and the figure compares sizes of fish sampled on the spawning grounds.

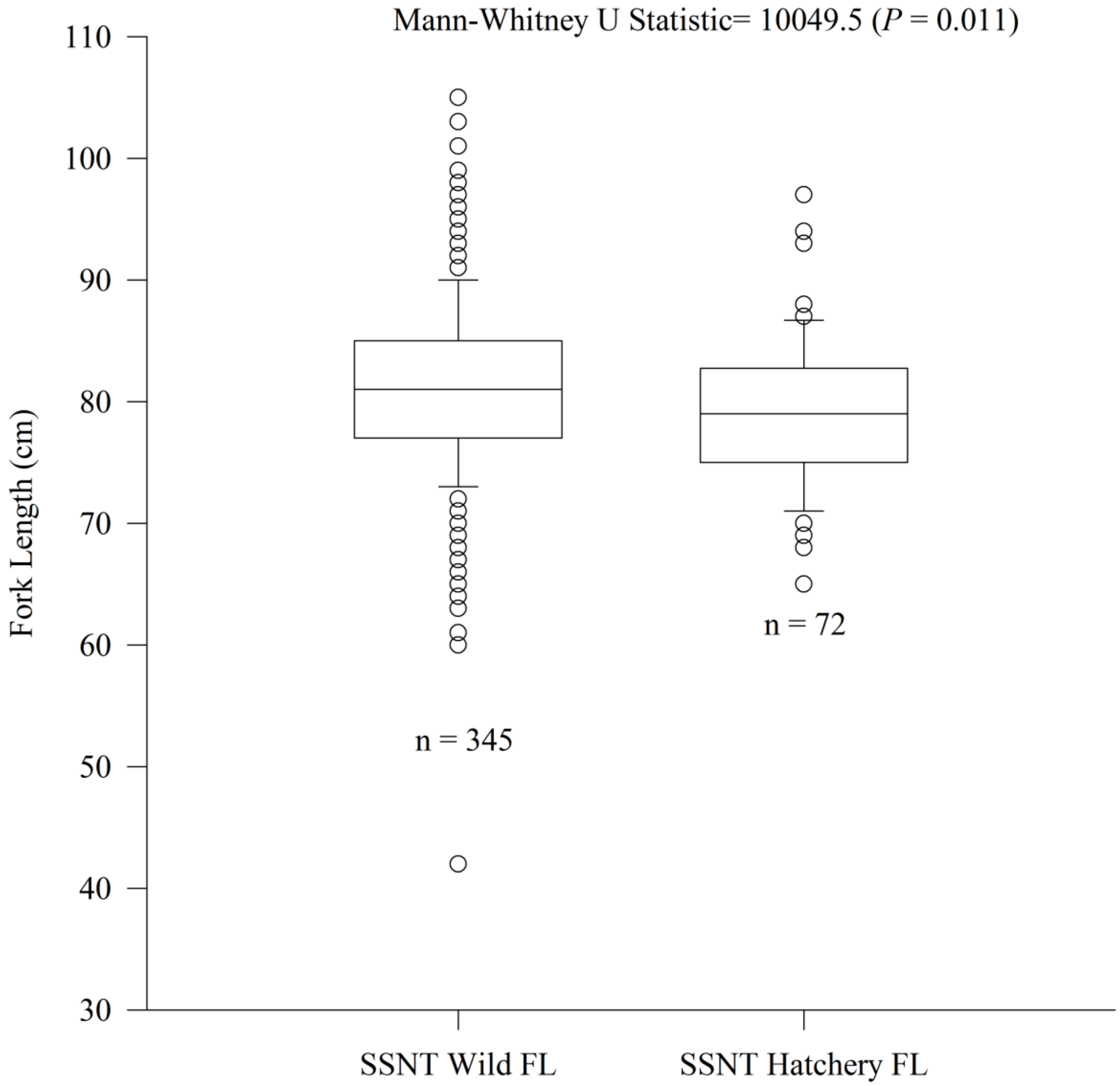

Figure 34. Fork length of hatchery- and natural-origin Chinook salmon in the South Santiam River, 2012. Note natural-origin Chinook salmon were not integrated into broodstock there in 2012 and the figure compares sizes of hatchery-origin broodstock to natural-origin broodstock.

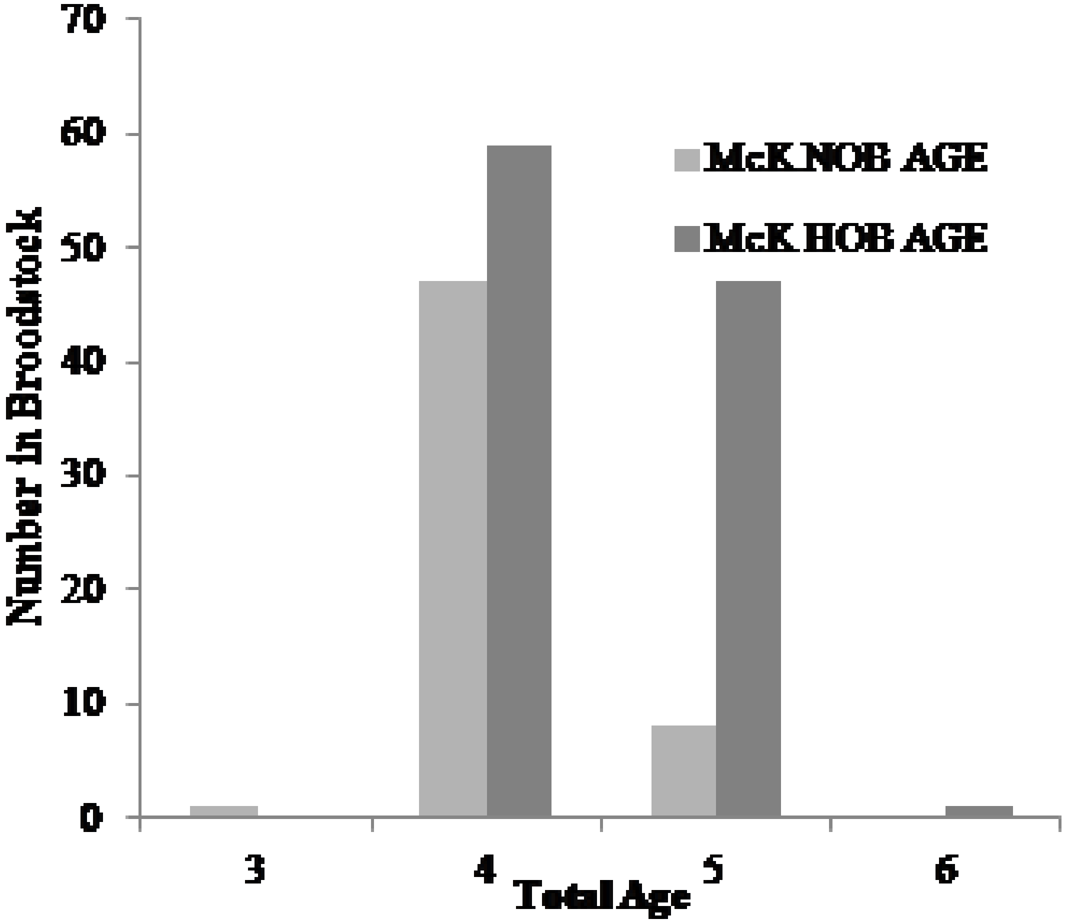

Figure 35. Age structure of NOB and HOB Chinook salmon broodstock at McKenzie Hatchery, 2012.

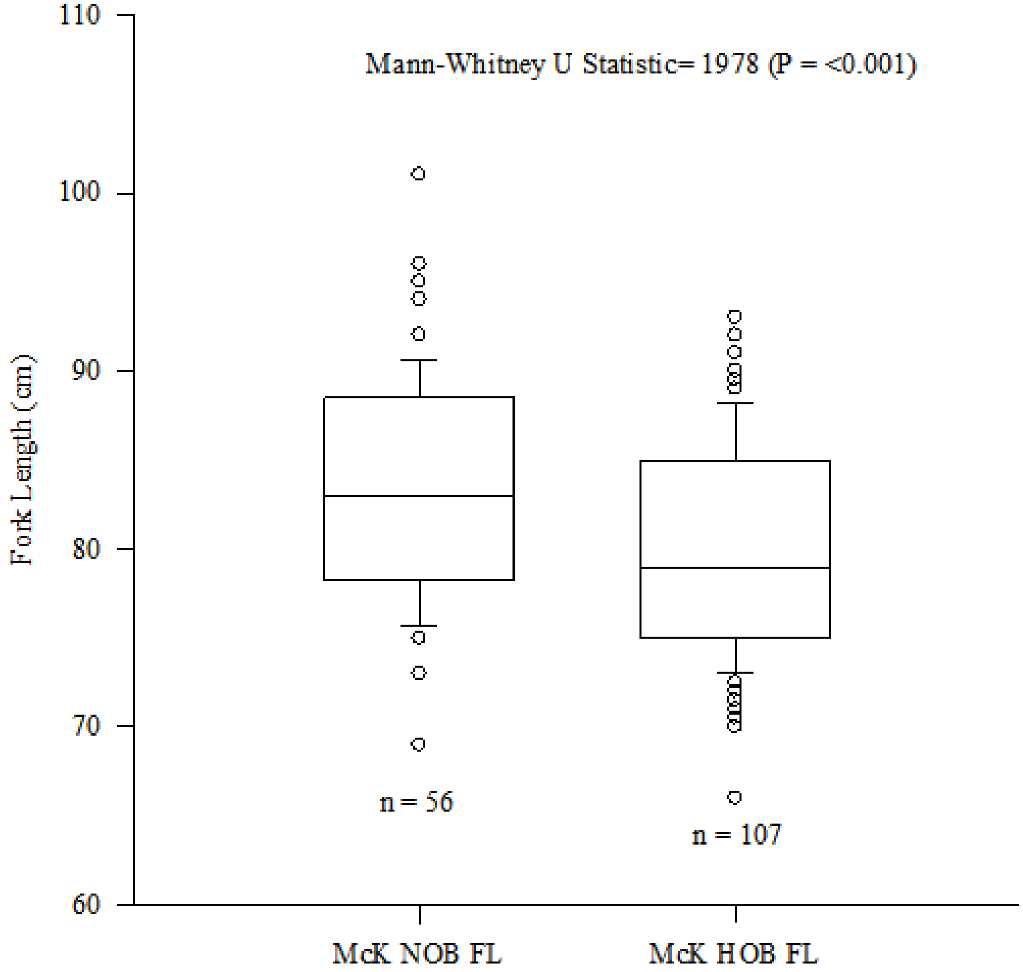

Figure 36. Fork length of McKenzie Hatchery NOB and HOB broodstock, 2012.

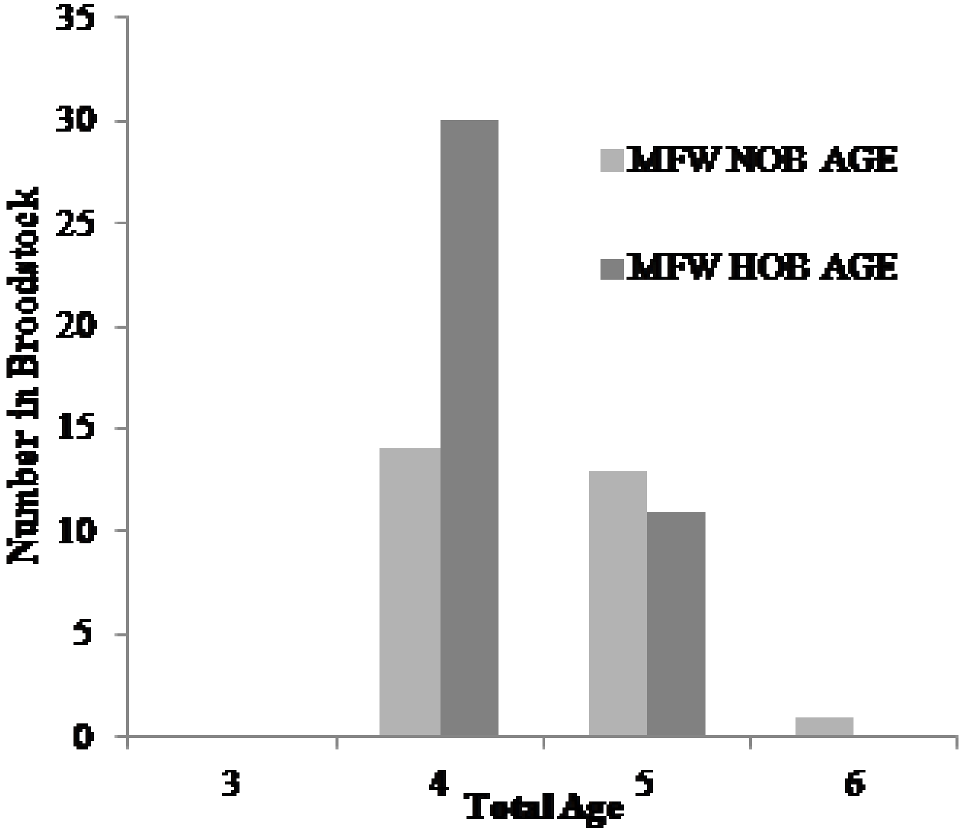

Figure 37. Age structure of NOB and HOB Chinook salmon broodstock at Willamette Hatchery, 2012.

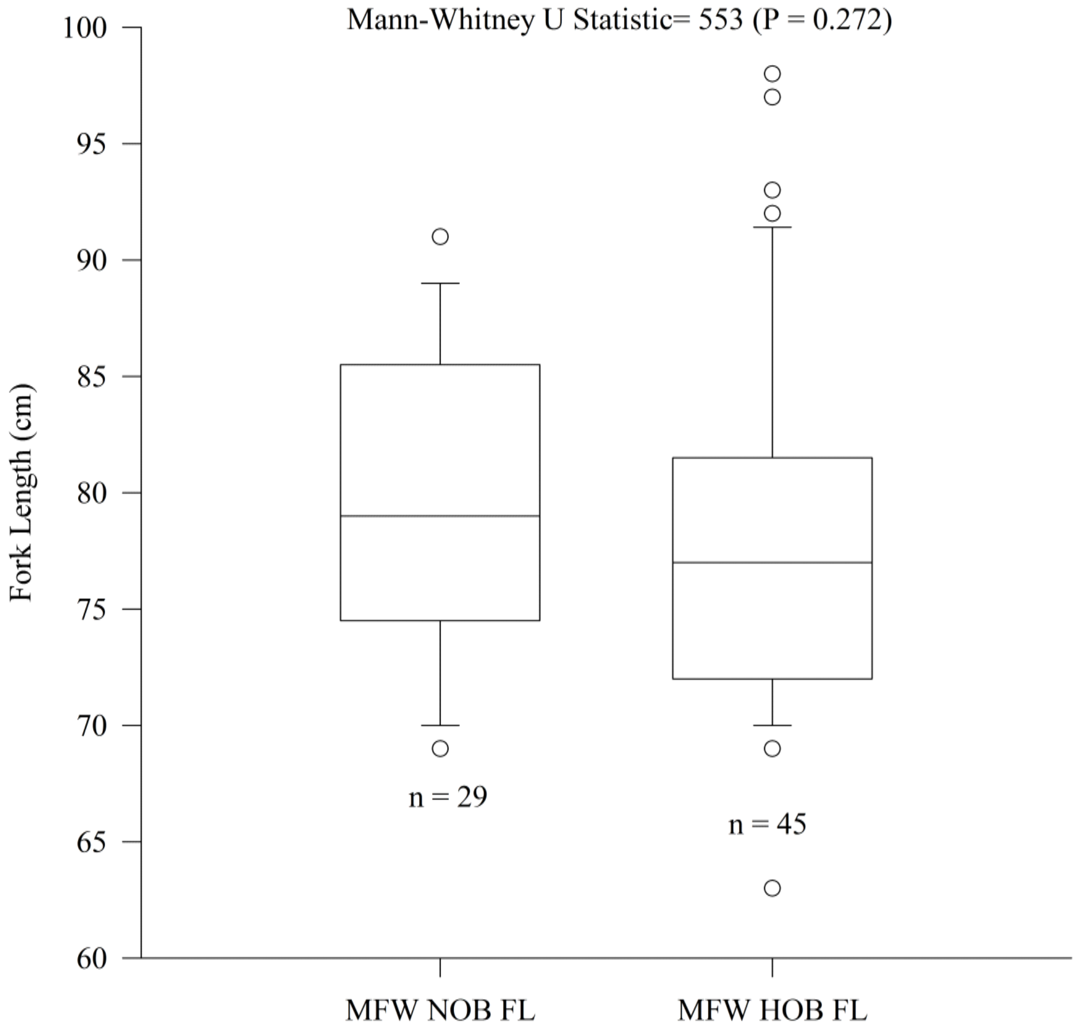

Figure 38. Size comparison of Willamette Hatchery NOB and HOB broodstock, 2012.

Section 4: Discussion

We were successful conducting relatively comprehensive Chinook salmon spawner and prespawn mortality surveys in 2012. Spawner surveys were conducted over the entire spawning season 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.

We were successful at outplanting large numbers of adult Chinook salmon into otherwise depauperate habitat in the South Santiam, McKenzie and Middle Fork Willamette rivers but not in the North Santiam River in 2012. Because the Minto Fish Collection Facility currently under construction is scheduled for completion before Chinook salmon return in 2013, we are confident of success in outplanting more fish from that facility in the future.

Redd densities, which serve as a useful index for spatial distribution and relative spawner abundance, did not differ significantly from recent historical redd densities, except in the North Santiam River above Bennett Dam where higher densities were noted than in recent years. It seems likely that the increase in redd densities in the North Santiam River might be related to the operation on the Upper Bennett trap and inability to operate the Minto trap (under construction). In past years, adult Chinook salmon were removed in large numbers at Minto and released above Detroit Reservoir. In 2012 relatively few hatchery-origin fish were removed for outplanting. The hatchery-origin fish that would otherwise have been removed from the reaches between Bennett Dam and Minto might have contributed to the increased redd densities relative to previous years.

We used the peak redd count expansion method to directly estimate spawner abundance and while the results should be used with caution, there is evidence to support their utility. The peak count expansion estimate for total number of natural-origin spawners in the McKenzie River above Leaburg Dam was 1,606 fish (all mainstem wild spawners plus tributaries including the South Fork McKenzie River). A partially independent estimate of McKenzie River spawner abundance above Leaburg Dam in 2012 (K. Schroeder ODFW, Pers. Comm.) used a combination of counts of unclipped fish passing Leaburg Dam, historical estimates of fall-back over the dam, otolith data from spawner surveys, and prespawning mortality estimates. That estimate for natural-origin Chinook salmon that spawned above Leaburg Dam in 2012 was 2,190 fish, a relatively comparable estimate. No estimates of precision are available for either method. We reiterate that when combined with information from carcasses found on the spawning grounds, redd surveys provide the most useful information about where subsequent juvenile production may be expected to occur, where spawning activity is occurring, and at what general levels (e.g. low, medium, high).

The close alignment between estimates of spawner abundance above Leaburg Dam based on redd counts and estimates based on dam counts is only apparent for 2005 through 2012. For unknown reasons, the estimates in 2002-2004 based on redd count expansion were only about 40% of those derived from the dam counts.

Over the long term (2002 – 2012, generally), North Santiam River redd count expansions parsed into estimates of natural- and hatchery origin spawners suggests that annual hatchery spawner abundance is highly variable and wild spawner abundance may be gradually increasing (with a concomitant decrease in pHOS). An important caveat for abundance estimates in the North Santiam is that there are no data for abundance between Minto Dam and Big Cliff Dam because that reach cannot be surveyed with our current protocols. Some method of surveying that reach should be developed. A similar but less marked slight increasing trend in wild fish spawner abundance in the South Santiam might also be apparent. In the South Santiam for the period when spawner abundance estimates are available for reaches above and below Foster Dam (2007 – 2012), wild fish abundance appeared to be generally increasing. In the McKenzie subbasin the natural-origin spawner abundance estimates derived from redd count expansions suggests that run size of wild fish is not increasing. We think that in the McKenzie spawner abundance may increase when downstream passage issues at Cougar Dam are resolved but other limiting factors (pHOS, rearing habitat) are also involved. Wild spawner abundance in the Middle Fork Willamette River was and has been uniformly low despite very large numbers of spawners outplanted above dams.

We think that our carcass recovery efforts during prespawn mortality and spawner surveys provide useful information on where the well-being of the potential spawners may be seriously compromised. Spawner holding conditions were relatively benign throughout the subbasins in

2012 but we detected specific instances of both high and low PSM that suggest some opportunities for future research and monitoring efforts.

In the North Santiam River we noted high PSM below Upper Bennett Dam and, while the evidence is not conclusive, we think that the difficulties in operation of that trapping facility in 2012 might have contributed to the observed levels of PSM. If upstream migration of some of the adult fish were delayed to the point that the spawners were forced to hold in conditions of lower water quality and, in addition, some injuries were sustained by fish attempting to circumvent the ladder/trap, then PSM rates might have increased for fish holding beneath the dam. In addition, there was a small but significant increase in 2012 in the number of redds that were created below Bennett Dam, compared to 2005-2010.

In the North Santiam River above Detroit Reservoir small numbers of adult fish were outplanted but even with limited sample sizes it is clear that few spawners volunteered to the Breitenbush River and PSM rates in the North Santiam near the Marion Forks Hatchery where most spawners congregated were low. In future years after the Minto Fish Collection Facility is in operation it will be important to derive methods to increase distribution of spawners which, if successful, must include consideration of protocols for monitoring PSM rates in the currently unused spawning habitat. For example, hatchery-origin fish could be collected and held at the Minto Fish Collection Facility until approximately mid-September and then outplanted near desired locations at a time close to the peak spawning date. Floy or PIT tags could be used to track spawning location and success of individual fish. Also, while spawner densities in Horn Creek on the Marion Forks Hatchery grounds were not particularly high in 2012, in prior years when large numbers of hatchery fish were outplanted very heavy redd superimposition was noted. Excluding some fish from Horn Creek with a weir may force spawners to distribute into other suitable habitat.

In the South Santiam River PSM rates were greater above Foster Dam compared to below the dam and, because habitat quality for spawner holding above the dam is thought to be superior to that below the dam, the higher PSM rates might be associated with the stress of capture, crowding, anesthesia (via CO_2), loading, transport, and release of outplanted fish. Efforts to estimate the association between timing or location of outplants and probability of successful spawning were hampered by low sample sizes (recovery of floy-tagged female fish). We noted a weak (non-significant) tendency for fish outplanted late to spawn successfully at a higher rate than fish outplanted early. That outcome is supported by other ongoing research (Naughton et al. 2013) and deserves further consideration. A new Fish Collection Facility below Foster Dam is scheduled for completion in 2014 and it may be worth considering use of delayed outplants to increase successful spawning, especially in years where in-river conditions are predicted to be poor or marginal (Schreck et al. 2013).

In the McKenzie River PSM rates were relatively low in 2012 but they were significantly elevated below Leaburg Dam compared to rates above Leaburg. Radiotelemetry work in 2012 (Jepson et al. 2013) showed that of all the unclipped fish tagged at Willamette Falls that entered the McKenzie subbasin about 25% remained below Leaburg Dam throughout the spawning season. Our otolith data indicate that about 25% of the unclipped fish sampled below Leaburg Dam in 2012 were actually unclipped hatchery fish. Therefore, it does not seem likely that the passage facilities there delay large numbers of naturally-produced fish that subsequently die before spawning. In all other reaches above Leaburg Dam in 2012 PSM rates were negligible or non-detectable, including above Cougar Dam on the South Fork McKenzie River where focused reintroduction efforts are underway (Zymonas et al. 2013; Banks et al. 2013).

In the Middle Fork Willamette Basin systematic PSM and spawner surveys were conducted above Hills Creek Dam for the first time in 2012. We think that the spatial distribution of spawners and low estimates of PSM indicate that the reaches above Hills Creek Reservoir have the potential to produce substantial numbers of salmon once passage issues are resolved.

One of the more pressing Conservation and Recovery goals in the Upper Willamette subbasins is to achieve subbbasin-wide pHOS goals of 10% or less (30% or less in the South Santiam). Clearly, that goal is ambitious. In one instance where only unclipped fish are passed into the spawning reaches above a dam (Foster Dam on the South Santiam River) the pHOS goal was still exceeded because of the number of unclipped hatchery fish returning. In the other instance where only unclipped fish are passed upstream (Fall Creek) pHOS is low but Fall Creek Dam is currently not associated with any hatchery releases. In general, when fish collection facilities are in close proximity to large aggregations of hatchery-origin fish we do not think that the issue can be resolved by increasing the clipping rate of hatchery fish because the automated tagging and clipping trailers already perform with very high efficiency. 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 $\simeq$ 0) 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 program may ultimately succeed when downstream passage issues are resolved.

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 that differed in run timing or age distribution from naturally-produced fish in the North Santiam, South Santiam, or McKenzie hatcheries. Broodstock collection timing 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 are well mixed with respect to run timing before broodstock collection is complete and it is unlikely that the Dexter trapping operation actively selects for early run timing. Hatchery-origin fish did tend to be smaller (by approximately 1 – 3 cm) than natural-origin fish, an observation supported by Johnson and Friesen (2013), who showed a gradual decline in size of Willamette Hatchery-origin spring Chinook salmon. They suggested the possibility of incorporating some larger fish in hatcheries to counteract the tendency for over-representation of smaller fish in broodstock that would, under natural conditions, be selected against. Actual peak spawning of hatchery broodstock in 2012 did generally occur shortly before our estimated average peak spawning date on the spawning grounds, but natural spawning in 2012 also appeared to be earlier than the average. We think that the difference between 2012 broodstock spawn timing and the mean natural spawn timing is at least partially because all 2012 spawning (broodstock and natural) occurred early in the observed range. 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 2012, as in earlier years, we estimated that very 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 (in press), suggest that inter-basin straying of hatchery fish in the Willamette is a minor issue. One possible exception is the tendency for increased stray rates of fish of South Santiam stock reared at the Willamette Hatchery and released directly into the Molalla River. We think that further work is warranted to see if those particular practices contribute to undesired levels of inter-subbasin gene flow.

We expect that in 2013 we will conduct surveys and perform monitoring at hatcheries and traps for Chinook salmon very similar in scope to that of the work described in this document. We anticipate increasing the scope of work towards monitoring winter- and summer-run steelhead, dependent upon availability of funding.

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Appendix 1: Summary of Tasks

Summary of anadromous fish monitoring and hatchery sampling tasks addressed in this report. RPA=reasonable and prudent alternative (NMFS 2008).

SPRING CHINOOK SALMON

Task 1.1: Determine abundance, distribution, & percent hatchery-origin fish on spawning grounds [RPA 9.5.1(2)]

Conduct surveys downstream of federal dams in the North Santiam, South Santiam, McKenzie, MF Willamette basins

1. Conduct spawning surveys to count redds

2. Assess variability in redd counts among crews with re-surveys

3. Conduct spawning surveys to collect carcasses for differentiating hatchery fish from wild fish (fin clips & otoliths)

4. Estimate pre-spawning mortality

5. Assess straying of hatchery fish between basins using coded-wire tags recovered from carcasses

Task 1.2: Monitor clipped & unclipped fish passing Leaburg and Upper Bennett dams [RPA 9.5.1(2)]

Collect information on run size & composition of run (using data from Task 1.1), removal of hatchery fish

1. Operate video recording equipment and count clipped and unclipped fish passing Leaburg Dam

2. Operate adult fish trap in the Leaburg Dam fishway when feasible to remove clipped fish [RPA 6.1.4, interim measure]

3. Operate video recording equipment and count clipped and unclipped fish passing upper Bennett Dam

4. Investigate feasibility of video monitoring at Lower Bennett and Lebanon dams

Task 2.1: Collection, spawn timing, and H/W composition for broodstock management [RPA 9.5.1(1) & 6.2.2]

Hatchery monitoring of returns and broodstocks

1. Record data on return date, numbers of clipped & unclipped fish, disposition (collect biological data on outplants and spawned fish)

2. Collect otoliths on unclipped fish used for broodstock to determine proportion of wild fish

3. Operate Leaburg fishway trap to collect unclipped fish to supplement broodstock [see Task 1.2(2)]

4. Develop monitoring of fin-clipped and unclipped fish at Bennett dams for index of broodstock management (under Task 1.2)

Task 2.2: Determine survival of outplanted fish and abundance of spawners [RPA 9.5.1(3) & 6.2.3; Proposed Action 2.10.1]

Conduct surveys upstream of federal dams in the North Santiam, South Santiam, McKenzie, MF Willamette basins

1. Record numbers, clip information, date, release locations for outplanted Chinook salmon

2. Collect tissue samples from outplanted Chinook salmon to determine spawning success and parentage analysis of returning adults

3. Conduct spawning surveys to count redds as measure of abundance, survival, and distribution of outplants

4. Conduct spawning surveys to collect carcasses for proportion of hatchery and wild fish in some outplant areas

5. Estimate pre-spawning mortality for outplanted Chinook salmon

6. Assist in collection of information needed for condition study in Middle Fork Willamette River and Fall Cr.

STEELHEAD

Task 3.1: Determine the extent of summer steelhead reproduction in the wild [RPA 9.5.2(1) and 6.1.9].

1. Develop a study plan for genetics study and initiate field collections

2. Work with geneticists (Services, OSU) to develop study plan to determine parentage and introgression

3. Review plan and design with ODFW managers, and with independent review group

4. Initiate field collections of tissue samples in North and South Santiam using traps, electrofishing, seines

5. Collect tissue samples on unclipped steelhead smolts in Willamette at Sullivan Plant and using seines or electrofishing

6. Collect tissue samples on winter-run and summer-run steelhead adults if needed to increase reference samples

7. Collect tissue samples from adult resident and hatchery rainbow trout - potential parentage sources

Task 3.2: Evaluate release strategies for summer steelhead to increase migration and reduce impacts on wild fish [RPA 6.1.6]. a

1. Develop study plans to implement volitional releases and monitor outmigration, and initiate field work

2. Develop plans to implement volitional emigration from release facilities and evaluate factors influencing volitional emigration

3. Develop plans to monitor outmigration of summer steelhead releases past Willamette Falls

4. Develop plans to monitor presence, distribution, and size of residual hatchery steelhead in tributaries and main stem.

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				

Subbasin	River Section	Survey Reach (downstream to upstream extent)	Carcass Surveys	Redd Surveys	Peak Redd Count	Redd Density	pHOS	PSM	Escape-ment
South Santiam									X
	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				
McKenzie	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				
		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				

Subbasin	River Section	Survey Reach (downstream to upstream extent)	Carcass Surveys	Redd Surveys	Peak Redd Count	Redd Density	pHOS	PSM	Escape-ment
		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				
		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	Jasper to				X	X	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
Willamette	Dexter Dam	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				
		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**	

Subbasin	River	Description	Start River Mile	End River Mile	Total Distance	Comment
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**	
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**	

Subbasin	River	Description	Start River Mile	End River Mile	Total Distance	Comment
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**	
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: Juvenile Chinook Salmon and Steelhead Liberation in 2012

Appendix Table 4-1. Numbers and pounds of UWR hatchery spring Chinook salmon (ChS) and summer steelhead (StS) released in the UWR basin in 2012. Data are from HMIS and parsed by rearing or release facility and stock.

Hatchery	Release Date	Release Locations	BY	Species	Stock Name (Code)	Release Number	#/Lb.	Lbs.	Release/ Acclimation	Listed	Marks
Marion Forks	3/12/12	N. Santiam	2010	Spring Chinook	N. Santiam (21)	446,000	11	40,545		Y	100K AD,OT,CWT; 346K AD,OT
Marion Forks	4/15/12	N. Santiam	2010	Spring Chinook	N. Santiam (21)	224,000	11	20,364		Y	50K AD, OT, CWT; 174KK AD, OT
Marion Forks	7/30/12	Detroit Res.	2011	Spring Chinook	N. Santiam (21)	100,000	100	1,000		Y	100% AD, CWT, OT
McKenzie	2/15/12	McKenzie	2010	Spring Chinook	McKenzie (23)	400,000	12	33,333		Y	100% AD, OT, CWT
McKenzie	3/12/12	McKenzie	2010	Spring Chinook	McKenzie (23)	252,000	9.5	11,000		Y	100% AD, OT, CWT
McKenzie	3/12/12	Coast fork	2010	Spring Chinook	McKenzie (23)	213,000	9.5	11,000		Y	100% AD, OT, CWT
McKenzie	6/15/12	Mohawk	2011	Spring Chinook	McKenzie (23)	75,000	100	750		Y	100% AD, OT, CWT
McKenzie	11/15/12	McKenzie	2011	Spring Chinook	McKenzie (23)	350,000	11	31,818		Y	100K AD, CWT, OT; 250K AD, OT, Blank wire
South Santiam	2/15/12	S. Santiam	2010	Spring Chinook	S. Santiam (24)	300,000	9	33,333		Y	30K AD, CWT, OT; 270K AD. OT
South Santiam	3/9/12	S. Santiam	2010	Spring Chinook	S. Santiam (24)	421,000	9	46,778		Y	30K AD, CWT, OT; 391K AD. OT
South Santiam	4/1/12	S. Santiam	2011	Spring Chinook	S. Santiam (24)	184,500	4.5	41,000		Y	100% AD

Hatchery	Release Date	Release Locations	BY	Species	Stock Name (Code)	Release Number	#/Lb.	Lbs.	Release/ Acclimation	Listed	Marks
South Santiam	10/31/12	S. Santiam	2011	Spring Chinook	S. Santiam (24)	300,000	8	37,500		Y	50K AD, CWT. OT; 250K AD, OT
Willamette	2/1/12	M. Fk. Willamette	2010	Spring Chinook	Willamette (22)	670,000	12	55,833	Dexter Ponds	Y	30K AD, CWT. OT; 640K AD, OT
Willamette	2/29/12	Molalla	2010	Spring Chinook	S. Santiam (24)	100,000	9	11,111		Y	30K AD, CWT, OT; 70K AD, OT
Willamette	3/4/12	M. Fk. Willamette	2010	Spring Chinook	Willamette (22)	390,000	15	26,000	Dexter Ponds	Y	100K AD, CWT, OT; 290K AD, OT
Willamette	3/4/12	M. Fk. Willamette	2010	Spring Chinook	Willamette (22)	234,000	9	26,000	Dexter Ponds	Y	50K AD, CWT. OT; 184K AD, OT
Willamette	4/14/12	M. Fk. Willamette	2010	Spring Chinook	Willamette (22)	234,000	9	26,000	Dexter Ponds	Y	30K AD, CWT, OT; 204K AD, OT
Willamette	10/31/12	M. Fk. Willamette	2011	Spring Chinook	Willamette (22)	300,000	8	37,500	Dexter Ponds	Y	100K AD, CWT, OT; 200K AD, OT
Leaburg	4/7/12	McKenzie	2011	Summer Steelhead	S. Santiam (24)	108,000	4.5	24,000		N	100% AD
Roaring River	3/15/12	N. Santiam	2011	Summer Steelhead	S. Santiam (24)	55,000	4.5	12,222	Minto Pond	N	100% AD
Roaring River	4/15/12	Willamette	2011	Summer Steelhead	S. Santiam (24)	66,000	4.5	14,667		N	100% AD
Willamette	4/1/12	N. Santiam	2010	Summer Steelhead	S. Santiam (24)	66,000	4.5	14,667	Minto Pond	N	100% AD
Willamette	4/4/12	M. Fk. Willamette	2010	Summer Steelhead	S. Santiam (24)	91,000	4.5	20,222	Dexter Ponds	N	100% AD
Willamette	4/10/12	Willamette	2010	Summer Steelhead	S. Santiam (24)	30,000	4.5	6,667		N	100% AD