FEATURE

Salmon and Steelhead in the White Salmon River after the Removal of Condit Dam—Planning Efforts and Recolonization Results

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Condit Dam, at river kilometer 5.3 on the White Salmon River, Washington, was breached in 2011 and completely removed in 2012. This action opened habitat to migratory fish for the first time in 100 years. The White Salmon Working Group was formed to create plans for fish salvage in preparation for fish recolonization and to prescribe the actions necessary to restore anadromous salmonid populations in the White Salmon River after Condit Dam removal. Studies conducted by work group members and others served to inform management decisions. Management options for individual species were considered, including natural recolonization, introduction of a neighboring stock, hatchery supplementation, and monitoring natural recolonization for some time period to assess the need for hatchery supplementation. Monitoring to date indicates that multiple species and stocks of anadromous salmonids are finding and spawning in the now accessible and recovering habitat.

El salmón y la trucha arcoíris en el Río White Salmon tras la remoción de la presa Condit – esfuerzos de planeación y resultados de la recolonización

La presa Condit, situada en el kilómetro 5.3 del Río White Salmon, en el estado de Washington, fue cerrada en el año 2011 y removida por completo en el 2012. Esta acción liberó hábitats para los peces migratorios por primera vez en 100 años. El grupo de trabajo de White Salmon fue creado para diseñar planes con el objetivo de rescatar a los peces como primer paso para una recolonización, así como también para prescribir las acciones necesarias en pro de la restauración de las poblaciones de salmónidos anádromos en el Río White Salmon después de la desaparición de la presa Condit. Los estudios llevados a cabo por los miembros del grupo de trabajo y por otros investigadores, sirvieron para generar decisiones de manejo informadas. Se tomaron en cuenta las opciones de manejo para las especies en lo individual, incluyendo la recolonización natural, la introducción de stocks vecinos, suplementos de crianza y el monitoreo de la recolonización natural en un cierto lapso para evaluar la necesidad de suplemento de individuos provenientes de la crianza. Hasta el momento, el monitoreo indica que varias especies y stocks de salmónidos anádromos están desovando en los hábitats que ahora ya están accesibles y en recuperación.

Le saumon et la truite arc-en-ciel dans la rivière White Salmon après la destruction du barrage de Condit – résultats des travaux de planification et de la recolonisation

Après la brèche apparue en 2011, le barrage de Condit, situé à 5,3 km sur la rivière White Salmon, dans l'État de Washington, fut complètement détruit en 2012. Cette intervention permit d'ouvrir l'habitat aux poissons migrateurs pour la première fois depuis 100 ans. Le groupe de travail White Salmon fut formé pour élaborer des plans pour le sauvetage des poissons afin de les préparer à la recolonisation et pour prescrire les mesures nécessaires pour rétablir les populations de salmonidés anadromes dans la rivière White Salmon après la destruction du barrage de Condit. Les études menées par les membres du groupe de travail et d'autres ont servi à éclairer les décisions de gestion. Ces dernières, élaborées pour les espèces individuelles, furent prises en compte, y compris la recolonisation naturelle, la mise en place d'un stock voisin, d'écloseries, et le suivi de la recolonisation naturelle pendant une certaine période de temps pour évaluer la nécessité de créer d'autres écloseries. À ce jour, le suivi indique que plusieurs espèces et stocks de salmonidés anadromes peuplent et fraient dans cet habitat désormais accessible et en reconstruction.

INTRODUCTION

As dams built in the last century in the United States and worldwide have aged and filled with sediment, become uneconomical, or become unsafe, the rate of dam removals is increasing (O'Connor et al. 2015). Nearly half of the 85,000 known dams in the United States no longer serve their intended purposes, and over 1,000 have been removed, mostly in the last 20 years (Lovett 2014). The physical response after dam removal can be rapid, with blocked sediment eroding quickly (Major et al. 2012) and river channels stabilizing in months or years, not decades (O'Connor et al. 2015). Many of the dams being removed also altered or completely blocked fish migration. Once a barrier is removed, the biological response to restored sediment transport and river connectivity can also be quite rapid (East et al. 2015; O'Connor et al. 2015). Chinook Salmon *Oncorhynchus tshawytscha* immediately colonized newly accessible habitat above Landsburg Dam on the Cedar River, Washington (Anderson et al. 2014a; Burton et al. 2013). Milner et al. (2011) found that colonization of Pink Salmon *O. gorbuscha* and Dolly Varden *O. malma* occurred within 10 years in a stream formed after glacial recession and Coho Salmon *O. kisutch* were in abundance shortly thereafter. The recolonization rate of anadromous fish is likely influenced by habitat suitability, accessibility, proximity, productivity, life history, and condition of the donor stock (Pess et al. 2014).

In 2012, Condit Dam was removed, restoring access for migratory fish to upstream reaches of the White Salmon River (a tributary to the Columbia River at river kilometer [rkm] 270 in southwestern Washington State) for the first time in 100 years (Figures 1 and 2). Before the construction of Condit Dam at rkm 5.3 in 1913, the White Salmon River was likely productive for anadromous and fluvial fish, including Chinook Salmon, Coho Salmon, Rainbow Trout *O. mykiss* (and the anadromous form, steelhead), Cutthroat Trout *O. clarkii*, and Bull Trout *Salvelinus confluentus* (Northwest Power and Conservation Council [NPCC] 2004). As PacifiCorp, the dam owner and operator, planned for the removal of Condit Dam, a need for coordination was identified among fish biologists and agencies working in the area of the White Salmon River. The White Salmon Working Group (WSWG) was formed to plan and implement actions for the restoration of fish species using the best scientific information available. In this article, we describe the dam removal and efforts to monitor and reestablish migratory fish to their historic range in the White Salmon River.

PROJECT DESCRIPTION

Condit Dam was constructed in 1912–1913 for Northwestern Electric Company as its first generating facility (Federal Energy Regulatory Commission [FERC] 1996). The 38-m-high structure was operated as a run-of-the-river project and had no fish passage structures. Several attempts at fish passage structures during and soon after construction were either damaged in flooding or were unsuccessful and fish passage was abandoned. In 1947, Pacific Power and Light Company (PP&L) acquired Northwest-

Figure 1. Condit Dam prior to removal, August 2011. Photo credit: Steve Stampfli and Andy Maser.

Figure 2. Condit Dam after removal, December 2012. Photo credit: Steve Stampfli and Andy Maser.

Figure 3. Condit Dam immediately after the explosive blast that breached the dam on October 26, 2011. Photo credit: Andy Maser.

ern Electric Company and Condit Dam officially became property of PP&L (a subsidiary of PacifiCorp). FERC issued PP&L an operating license for the Condit hydroelectric project in 1968; this FERC license expired in December 1993 (FERC 2002).

In 1991, PacifiCorp filed an application with FERC for renewal of the operating license for Condit Dam. In October 1996, FERC issued a final environmental impact statement for Condit Dam requiring the installation of fish passage facilities (FERC 1996), which PacifiCorp determined would render the project uneconomic for its electric customers.

At that point, PacifiCorp initiated settlement discussions with the stakeholders to try to arrive at a more cost-effective solution for its customers. The stakeholders supported two alternatives: (1) installation of fish passage facilities or (2) removal of the dam. In 1999, most of the licensing stakeholders signed a settlement agreement. The agreement provided for the continued operation under current license conditions of the Condit Hydroelectric Project for 7 years (until October 2006), after which time the dam would be removed. Upon completion of permitting, FERC issued a surrender order, and the removal of the Condit Hydroelectric Project began in June 2011. Condit Dam was breached on October 26, 2011, and removal activities continued through the following year until the deconstruction was completed on September 14, 2012.

Dam breaching involved excavating a 3.6-m high by 5.5-m wide tunnel near the base of the dam by drilling and using explosives. Drilling began at the downstream face of the dam, creating a 26-m-long tunnel through the concrete until 3 m remained. Explosives were used to remove the final 3 m of concrete (Figure 3). The drain tunnel was capable of passing a flow of 283 m^3/s. After the final blast, the 2.9-km-long reservoir (1.6 million m^3 of water) drained in less than 2 h and released 10% of the 1.8 million m^3 of impounded sediment (Figures 4 and 5). This was the largest volume of sediment ever released in the United States by breaching a dam with explosives (Hatten et al. 2015).Video of the breach and time-lapse footage of the draining of the reservoir can be viewed at: video.nationalgeographic.com/video/news/us-condit-dam-breach-vin. Within eight weeks, about 60% of the reservoir sediment had exited through the tunnel (Wilcox et al. 2014). Once the reservoir was drained, all remaining concrete from the dam was removed down to bedrock. At the time of its deconstruction, Condit Dam was the tallest dam intentionally removed in the United States.

RIVER DESCRIPTION

The White Salmon River basin covers about 1,000 km^2 and originates in glaciers on the southwest flank of 3,751-m-high Mount Adams. The river flows south through a basalt gorge for much of its 72-km length to where it joins the Columbia River (Haring 2003). Bonneville Dam, on the Columbia River, is the only dam between the White Salmon River and the ocean. The White Salmon River, between rkm 8 and rkm 20.4, is part of the National Wild and Scenic Rivers system (U.S. Forest Service 1991), and between its confluence with the Columbia River and rkm 5.3, it is included in the Columbia River Gorge National Scenic Area (Columbia River Gorge Commission 1991). The topography is highly varied, including mountainous terrain, deeply incised canyons, and low-gradient valley floors. The White Salmon River drops 1,524 m between its headwaters and the town of Trout Lake at rkm 40 and drops another 549

Figure 4. Northwestern Lake, the reservoir behind Condit Dam, August 2011. Photo credit: Steve Stampfli.

Figure 5. The White Salmon River at the same location as Figure 4 flowing freely in March 2014 after dam removal and replanting. Photo credit: Steve Stampfli.

Figure 6. The White Salmon River at its confluence with the Columbia River was over 9 m deep in August 2011 (left). After dam breaching, the impounded sediment flushed downstream, filled the lower White Salmon River with sand and spawning gravel, and created a beach and delta in the Columbia River on the downstream side of the Washington State Highway 14 Bridge in August 2013 (right). GIS mapping courtesy of Jill Hardiman.

m between Trout Lake and its confluence with the Columbia River (Haring 2003). Upstream of the former Northwestern Lake (the reservoir formed by Condit Dam), river gradients generally range between 2% and 11% (Haring 2003). The reaches downstream of Condit Dam average approximately 1% in gradient. Prior to the release of sediment behind the dam, the gradient of the lowermost 1.6 km of the White Salmon River was influenced by the backwater effect of the Columbia River's Bonneville Pool (impounded by Bonneville Dam), and the water in the lowermost 0.8 km was more than 9 m deep (Figure 6; Hatten et al. 2015). The outflow of silt, sand, and gravel from dam breaching aggraded the lower river by about 1.5 m (Wilcox et al. 2014). The sediment filled pools throughout the lower river created gravel bars and a small delta at the Columbia River confluence (Figure 6). In 2014, the lowermost 0.5 km of the White Salmon River was still influenced by Bonneville Pool but was only 2 m deep (Hatten et al. 2015). As of 2015, the river had not had a large flood event since dam removal, and the sediment upstream and downstream of the project area is expected to change.

In general, the mainstem White Salmon River water is cold throughout the year, and river flow is maintained by springs and seeps coming from high-altitude snowmelt throughout the summer. It has minimal diversions and minor agricultural runoff (NPCC 2004). The river is located in a climatic transition zone on the eastern edge of the Cascade Mountains, resulting in wet winters and dry summers. The average annual precipitation is about 124 cm, with 85% of this amount occurring from October through March (Haring 2003). Peak flows in the mainstem are usually from snowmelt runoff, increasing from an average daily flow of 19 m^3/s during the fall to 44 m^3/s in the spring (USGS gage 14123500 White Salmon River near Underwood, Washington; Haring 2003). The 100-year flood event is estimated to be 385 m^3/s (FERC 1996). There are several waterfalls that naturally limit the potential fish distribution in the mainstem and accessible tributaries. The likely end of anadromous fish distribution in the mainstem White Salmon River is at Big Brother Falls (a 7.3-m waterfall at rkm 26), and several other waterfalls downstream may be complete or partial barriers to some species. These waterfalls include BZ Falls (a 4.3- to 5.2-m waterfall at rkm 20) and Husum Falls (2.4- to 3.0-m waterfall at rkm 12.2). Tributary habitat is limited, and all tributaries from rkm 0 to 6.4 and upstream of rkm 12 are inaccessible to salmonids because of high waterfalls (Haring 2003; Allen 2012). There are four main tributaries likely accessible to anadromous fish; however, two of these also have waterfalls 2.4–5 km upstream of their mouths that are seasonal or complete barriers, depending on the fish species. These tributaries are Rattlesnake Creek (entering the White Salmon at rkm 11.9), Spring Creek (rkm 10.6), Buck Creek (rkm 8.0), and Mill Creek (rkm 6.4).

FISH DISTRIBUTIONS

Condit Dam restricted anadromous fish to less suitable spawning and rearing habitat downstream of the dam and blocked up to 50 km of potential habitat for steelhead, 7 km of habitat for fall Chinook Salmon, 15 km of habitat for spring Chinook Salmon, and 27 km of habitat for Coho Salmon (Table 1; NPCC 2004; Washington Department of Ecology 2007). Prior to the dam breaching, White Salmon River spring Chinook Salmon, Coho Salmon, and steelhead were considered extirpated, and the fall Chinook Salmon were considered at very high risk of extinction (National Marine Fisheries Service [NMFS] 2013). As shown by Allen and Connolly (2005) and Allen et al (2006, 2012), the White Salmon River and its tributaries upstream of where Condit Dam was located have high potential to support reintroduced or naturally colonizing populations of anadromous Salmon and steelhead. Based on modeling efforts, the expected response to reconnecting the upper White Salmon River to the Columbia River was an increase in natural production of several anadromous fish species (Table 2; NPCC 2004; Allen and Connolly 2005). Though this increase appeared to be a reasonable assumption, questions remained prior to the dam removal as to which species and stocks would be most expected to succeed by natural recolonization and which stocks were available to incorporate into hatchery-based reintroduction, depending on the management decisions implemented. Before hatchery reintroductions were considered, managers needed to know which species and stocks were already present, their

Table 1. Potential available habitat (in kilometers) that is likely accessible to spawning Chinook Salmon, Coho Salmon, and steelhead (NPCC 2004; NMFS 2013; Washington Department of Ecology 2007) in the White Salmon River, Washington. Chinook Salmon habitat is not identified in tributaries due to low water periods during adult migration and holding, predominantly in the mid to late summer.

New stream habitat	Fall Chinook Salmon	Spring Chinook Salmon	Coho Salmon	Steelhead
Mainstem White Salmon River (between rkm 5 and 26)	6.9	14.6	14.6	20.7
Tributary habitat (rkm of confluence)				
Rattlesnake Creek (rkm 12.2)	0	0	2.4	17.0
Indian Creek (tributary of Rattlesnake at rkm 0.8)	0	0	2.2	2.2
Spring Creek (rkm 10.6)	0	0	1.1	1.1
Buck Creek (rkm 8.0)	0	0	5.1	5.1
Mill Creek (rkm 6.4)	0	0	1.3	3.1
Total newly accessible habitat (km)	6.9	14.6	26.7	49.5

Table 2. Modeled historical abundance (NPCC 2004) compared with recent escapement estimates and origin of fall Chinook Salmon and steelhead in 2012 and 2013. Chinook Salmon 95% confidence intervals are provided as well as the percentage of fish spawning upstream of the former dam site in 2012 and 2013 (run years 2012–2013 and 2013–2014 for steelhead). The percentage of spawning upstream of the dam site is determined by the proportion of observed redds for a given year and not based on escapement estimates. Steelhead redd counts were only conducted in tributaries upstream of the former dam site. NA = estimate not available.

Species	Modeled pre-dam adult abundance	Escapement (95% confidence interval)		% Hatchery origin (95% confidence interval)		% Spawning upstream of the former dam site	
		2012	2013	2012	2013	2012	2013
Tule fall Chinook Salmon	745	755 (688–835)	1,232 (1,088–1,409)	7	33 (27–39)	11	1
Upriver bright fall Chinook Salmon	0	1,061 (1,058–1,283)	4,251 (3,755–4,861)	29	64 (60–67)	15	2
Spring Chinook Salmon	871	NA	88 (77–100)	NA	23 (4–58)	NA	43
		Number of redds					
		2013	**2014**	**2013**	**2014**	**2013**	**2014**
Steelhead	1,137	11	12	NA	NA	100	100

genetic relatedness to nearby hatchery stocks, and the abundance of those species in order to recognize needs and opportunities for fisheries restoration in the White Salmon watershed.

Historically, the White Salmon River was integral to salmon hatchery programs in the Columbia River Gorge. Both Spring Creek and Little White Salmon national fish hatcheries, located less than 10 km away on the Columbia River west of the White Salmon River, collected eggs from adult fall Chinook Salmon returning to the lower White Salmon River to initiate fall Chinook Salmon hatchery programs in the early 1900s (Smith and Engle 2011). Hatchery releases of fall Chinook Salmon fry from eggs collected in the White Salmon River started in 1901 and continued through 1918. Hatchery releases occurred in the White Salmon River from 1924 to 1964 for later life stage releases (parr, juvenile, or smolt stage). Collections of adult returns from the White Salmon River for national fish hatcheries production ceased around 1967 and only occurred twice since then, in 1986 and 1987 (Smith and Engle 2011).

Because information was lacking about historical fish distribution in the White Salmon River before Condit Dam, anticipated spawning distributions were based on expert opinion using the swimming/jumping ability and life history characteristics of the anadromous fish species and the stream flow pattern that may influence spawning and rearing distribution. The likely spawning distributions of recolonizing anadromous fish species (steelhead, Coho Salmon, fall and spring Chinook Salmon) are summarized in Table 1. All of the species being considered for management by WSWG, other than Pacific Lamprey *Entosphenus tridentatus*, were included in an evolutionarily significant unit that was listed as threatened under the Endangered Species Act (ESA; NMFS 2013). Fall Chinook Salmon were expected to spawn in the mainstem, up to Husum Falls. Spring Chinook Salmon were expected to spawn in the mainstem, up to BZ falls (rkm 20), farther upstream than fall Chinook Salmon, but the spawning distributions of these salmon runs were considered likely to overlap, resulting in the majority of spawning occurring downstream of Husum Falls. Juvenile spring and fall Chinook Salmon were expected to rear in the mainstem and in the lower portions of Rattlesnake, Spring, and Buck creeks. Most spawning of Coho Salmon was expected to occur in the mainstem, downstream of Husum Falls, and in Rattlesnake, Indian, Spring, Buck, and Mill creeks, with limited spawning up to BZ Falls (Table 1). Because Coho Salmon spawn in the late fall and early winter, they would likely be able to access variable amounts of tributary habitat depending on stream flow conditions. Most steelhead spawning was estimated to occur in the mainstem and tributaries downstream of Husum Falls (Rattlesnake, Indian, Spring, Buck, and Mill creeks). Because steelhead have the greatest swimming speed and jumping ability of the recolonizing anadromous salmonids (Reiser et al. 2006), and because the adults were likely to inhabit the river when high winter flows reduce waterfall heights, they were expected to access more of the White Salmon River and its tributaries than the other species (Table 1). Progressively less steelhead use was expected upstream of BZ Falls up to Big Brother Falls.

WORKING GROUP EFFORTS

With Condit Dam removal approaching, locally involved fisheries and natural resource agencies formed WSWG in 2006. The group largely consisted of fish biologists from the U.S. Fish and Wildlife Service (USFWS), Yakama Nation (YN), Washington Department of Fish and Wildlife (WDFW), NMFS, U.S. Forest Service, PacifiCorp, and USGS. The initial focus of WSWG was implementation of a reasonable and prudent measure in the 2006 NMFS Biological Opinion (NMFS 2006) that involved a salvage effort for ESA-listed fish species. Those discussions evolved into the focus of the group, which was to determine the best actions for restoring fish populations after Condit Dam removal. The management options considered for each species included introduction of a neighboring stock, the use of hatchery supplementation, or natural recolonization with monitoring to assess the need for active management. An important element of this restoration planning was to identify the roles and responsibilities of the WSWG members, because each agency had similar but different missions and expertise. This coordinated approach improved the focus of preremoval studies and the dissemination of information and provided a more critical evaluation of fish restoration actions.

Upriver bright fall Chinook Salmon were the most abundant of the three Chinook Salmon runs present in the White Salmon, whereas Spring Chinook Salmon used more of the spawning habitat upstream of the former Condit Dam site.

Several studies were conducted in the White Salmon River to assess the fish populations and habitat conditions upstream and downstream of the dam prior to removal. This information helped to guide the management options recommended by WSWG. The goals of these studies were to provide information for management decisions and provide a baseline from which to measure change in fish populations after dam removal. Ecosystem diagnosis and treatment modeling (Mobrand et al. 1997) was conducted by USGS and WDFW to estimate the historical, current (with the dam in place), and future (with the dam removed) fish population abundance and productivity (Allen and Connolly 2005). Studies by USGS and YN in Rattlesnake and Buck creeks, the two main tributaries within the potential anadromous zone of the White Salmon River, provided evidence via passive integrated transponder tagging that the Rainbow Trout populations were still producing migratory and potentially anadromous offspring (Allen et al. 2006, 2012). These studies detected three juvenile Rainbow Trout/steelhead in the mainstem Columbia River (fish that had been initially captured and tagged in Rattlesnake and Buck creeks), indicating an attempt at anadromous migration nearly 100 years after Condit Dam had blocked upstream access. Resident and fluvial Rainbow Trout are known to contribute to anadromous populations (Hayes et al. 2012; Weigel et al. 2013; Kendall et al. 2015) and have been shown to speed population recovery after disturbance (Parker et al. 2001). A juvenile fish assessment with a rotary screw trap was conducted by USGS and USFWS for four years, beginning in 2006, to determine species composition and abundance of salmonids in the river downstream of Condit Dam (Allen and Connolly 2011). Genetic samples of Chinook Salmon fry, captured in the screw trap, were analyzed by USFWS and were found to be highly similar to nearby hatchery Tule fall Chinook Salmon stocks and upriver bright fall Chinook Salmon populations that spawn in the lower White Salmon River (Smith and Engle 2011). These projects found that although the nonnative upriver bright fall Chinook Salmon spawned in greater numbers (based on data from WDFW spawning surveys), the native Tule fall Chinook Salmon outmigrated in greater numbers. This suggested that the native stock was more successful in spawning downstream of Condit Dam. In another study, USFWS and WDFW surveyed the White Salmon River for the presence of Bull Trout, which were likely extirpated from upstream of the dam (Theisfeld et al. 2001; Silver et al. 2011). The USFWS surveyed the White Salmon River to estimate the distribution Western Brook *Lampetra richardsonii* and Pacific Lamprey (Jolley et al. 2012). These surveys provided preremoval information to compare with future studies and shaped decisions by WSWG to monitor these populations in a similar manner after removal.

The management options recommended by WSWG for each species were to allow for natural recolonization; except fall Chinook, where adults were translocated from below the dam to above during the fall that the dam was breached, followed by natural colonization thereafter (NMFS 2013). Natural recolonization was recommended for a number of reasons. Implementing fish reintroduction efforts soon after removal was considered risky, because the potential for significant sediment movement was considered high. In addition, several of the species discussed by WSWG were present either upstream or downstream of the dam (Tule fall Chinook Salmon, Coho Salmon, resident steelhead). Therefore, recolonization was considered likely, but uncertainty existed about the timing, abundance, and future distribution of those species. Some species, such as Bull Trout, Pacific Lamprey, and spring Chinook Salmon, were present in nearby basins but in low abundance. Recolonization of those species might take longer and management actions may need to be revisited. Active reintroductions were likely to need additional monitoring and increased resources to complete. In 2016, five years after the removal of Condit Dam, the working group agencies hope to reevaluate the status of each species, compare the abundance of ESA-listed species to recovery plan goals (NMFS 2013), and identify new management options or recolonization goals for consideration, based on the success of natural recolonization. The WSWG recognizes that population-level information and additional monitoring are necessary to get a more complete assessment of the value of decommissioning. This approach to fisheries management by WSWG anticipated repeating assessments at defined intervals to determine the success, failure, or management need for each species, with the goal of recolonization of species and a definable, quantifiable metric for future populations as stated in the recovery plan (NMFS 2013).

Based on the results of working group discussions, a consensus decision was made to translocate adult fall Chinook

Salmon upstream of Condit Dam during the year of dam removal. The purpose was to mitigate for the sediment that was released on the spawning population of Tule fall Chinook Salmon by enabling a portion of the population to spawn naturally upstream of the dam in habitat historically occupied before dam construction. This option was selected over adult collection and hatchery propagation, which was initially required in the NMFS 2006 Biological Opinion for Condit Dam removal (NMFS 2006). In fall 2008 and 2009, two pilot studies were conducted in the White Salmon River related to this decision (Engle and Skalicky 2009; Engle et al. 2010). These studies provided additional fish population information and evaluated the efficacy of the fish capture and transport methods that were used in the lower White Salmon River prior to dam breaching.

In September and October 2011, 679 Tule fall Chinook Salmon (85% of which were natural origin) were translocated from the lower river to sites upstream of Condit Dam in hopes that they would spawn in an area not affected by sediment movement resulting from dam breaching on October 26, 2011 (Engle et al. 2013; Figure 7). A total of 191 salmon redds were observed from the 310 female fall Chinook Salmon that were translocated, but 24% occurred in an area where streambed downcutting resulting from dam removal likely decreased egg survival. Overall, the 2011 translocation effort was considered a success and met the mitigation requirement outlined as a reasonable and prudent measure within the NMFS 2006 Biological Opinion (NMFS 2006) for brood year impacts to ESA-listed Tule fall Chinook Salmon caused by Condit Dam removal.

With the removal of the original coffer dam immediately upstream of Condit Dam in May 2012, the last remaining artificial passage barrier in the former reservoir reach had been eliminated. In fall 2012, Tule fall Chinook Salmon and upriver bright fall Chinook Salmon redds were recorded during individual spawning ground surveys within the basin (Figure 7, Table 2). Redds of both Chinook Salmon stocks were documented upstream and downstream of the former Condit Dam site. Because most hatchery-origin Chinook Salmon could be identified by a clipped adipose fin, the presence of an adipose fin on most of the post-spawn carcasses suggests that most of the spawners were likely natural origin (Table 2; Engle et al. 2013).

In fall 2013, WDFW expanded its viable salmonid population monitoring program (McElhany et al. 2000; Crawford and Rumsey 2011) for Chinook Salmon populations to include the White Salmon River. Spawning ground surveys were conducted weekly over the likely spawning area distribution and duration. The proportion of hatchery-origin spawners was estimated based on presence of an adipose fin clip and/or a coded wire tag from sampled carcasses. Upriver bright fall Chinook Salmon were the most abundant of the three Chinook Salmon runs present in the White Salmon, whereas Spring Chinook Salmon used more of the spawning habitat upstream of the former Condit Dam site (Figure 8, Table 2). During these surveys, other anadromous species were observed spawning in the lower White Salmon in 2013, including Coho,

Figure 7. Darren Gallion, U.S. Fish and Wildlife Service, passing a Tule fall Chinook into a holding tank for transport upstream of Condit Dam prior to dam breaching. Photo credit: Rod Engle.

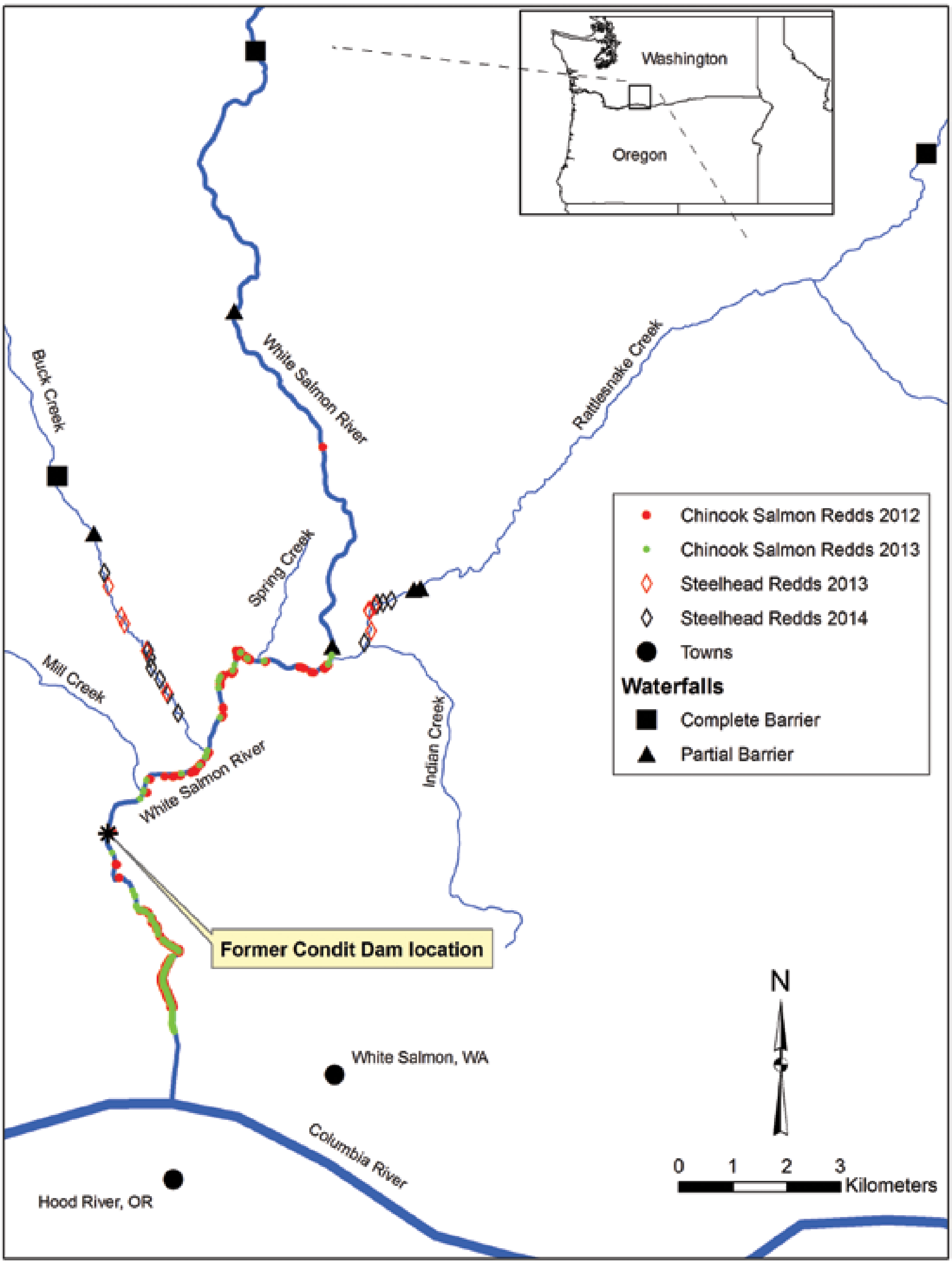

Figure 8. Map of steelhead and Chinook Salmon (Tule and upriver bright fall Chinook Salmon stocks combined) redds in the White Salmon River from September 2012 through May 2014. Included are the former Condit Dam location, natural passage barriers, and location within Washington.

Pink, and Sockeye *O. nerka* Salmon. Preliminary results from 2014 spawning surveys indicate that about 215 spring Chinook Salmon spawned in the White Salmon River, which is more than two times as many as in 2013 (Table 2). The preliminary fall Chinook Salmon escapement estimate in 2014 was also greater, with about 50% more fish than 2013 (J. T. Wilson, WDFW, unpublished data).

A few additional assessments have occurred since removal. Fall Chinook Salmon redds were mapped in coordination with a two-year bathymetry survey of the effects of dam removal on Tule fall Chinook Salmon spawning habitat conducted by USGS (Hatten et al. 2015). The USFWS surveyed for juvenile lamprey presence in the lower river postremoval. They found *Lampetra* and unidentified lamprey species in the lower river and Pacific Lamprey at the newly formed White Salmon River delta (Jolley et al. 2013). The WDFW has reopened a sport fishery for salmon and steelhead from Big Brother Falls (rkm 26) to the mouth. In 2013, WDFW conducted creel surveys, as well as spring and fall Chinook Salmon spawning surveys, from the mouth to BZ Falls (rkm 20). As of 2014, the spring and fall Chinook Salmon have

Figure 9. One of the first steelhead in 100 years documented jumping at the 5-m-high BZ Falls (rkm 20) on the White Salmon River. Photo was taken July 16, 2012, nine months after Condit Dam breaching, while the dam was still being dismantled. Photo credit: Jeanette Burkhardt.

generally recolonized to the reaches as anticipated.

In spring 2013 and 2014, YN staff conducted steelhead spawning surveys in anadromous-accessible tributaries (Rattlesnake, Indian, and Buck creeks in 2013; Rattlesnake, Indian, Buck, Mill, and Spring creeks in 2014). The mainstem has not been surveyed due to poor visibility and high flow during the spawning season. Relatively few redds were observed in both years (Figure 8, Table 2), along with one live adult steelhead in each year and two carcasses in 2013, which were too decomposed for genetic analysis. The origin of these steelhead spawners (e.g., out-of-basin strays, in-basin returns of previously resident *O. mykiss* populations) was unknown. In 2012, steelhead were observed jumping at BZ Falls (Figure 9), and there have been anecdotal reports of successful angling for steelhead up to BZ Falls. Steelhead have recolonized into expected tributaries and mainstem reaches, but the extent and source of the recolonizing fish is unknown. Additional monitoring is needed to understand the pace and extent of the recolonization of steelhead as well as other species.

CONCLUSIONS

Dam removals in the Pacific Northwest have numerous permitting requirements and planning needs. We suggest coordination through the formation of specific technical working groups similar to WSWG for preremoval planning, management during removal, and postremoval monitoring. In retrospect, the development of management options by WSWG for each fish species followed a similar decision framework as that outlined by Anderson et al. (2014b). The management options ultimately coalesced on postremoval monitoring and reassessment of fish populations and management options in five-year intervals. A similar process could be followed by fisheries managers or other technical groups formed for planning the removal of dams where migratory fish are involved. Recent dam removals in the Pacific Northwest have shown rapid sediment movement (Major et al. 2012; East et al. 2015; Warrick et al. 2015), as did the White Salmon River (Wilcox et al. 2014). We recommend that fisheries professionals working on dam removals work closely with geomorphologists to better understand sediment transport after dam removals and the implications to fish habitat, particularly if employing translocation or active reintroduction to upstream areas that may be affected by sediment instability. Coordination at this level may have led to WSWG forming exclusion zones or altering translocation release sites in the upper White Salmon River, where bedload movement destroyed a portion of redds constructed by translocated Tule fall Chinook Salmon (Engle et al. 2013).

Many questions remain about the pace, extent, and source of anadromous recolonization of the White Salmon River, but it is clear that the White Salmon River has once again become home for anadromous salmonids and other migrating fish species. The USGS has drafted a postremoval monitoring and evaluation plan with input from WSWG. In the short term, WSWG is striving to monitor the recolonization of Pacific Northwest salmon and steelhead along with other important aquatic species in the White Salmon River. In the long term, WSWG hopes to conduct studies and appropriate levels of monitoring to adaptively manage the newly accessible habitat.

DISCLAIMER

The findings and conclusions in this article are those of the author and do not necessarily represent the views of the U. S. Fish and Wildlife Service.

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Additional links with video and content related to Condit Dam removal and fish and habitat recovery:
whitesalmontimelapse.wordpress.com/
www.fws.gov/wafwo/condit.html
www.pacificorp.com/about/newsroom/mr/cdmr.html