Addressing limiting factors and critical uncertainties in the reintroduction of chum salmon to Oregon tributaries of the Columbia River

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Abstract
Historically, chum salmon *Oncorhynchus keta* represented a significant portion of the annual returns of salmon and steelhead to the lower Columbia River; it is thought that 10-15 million salmon and steelhead returned annually (Gresh et al. 2000), of which chum may have comprised 7 – 10% of the return (NPPC 1986). Beginning in the early 1800s, settlement along the lower Columbia River (LCR) and tributaries resulted in changes to land use and harvest of chum salmon (Figure 1) that ultimately led to the extirpation of 90% of chum salmon populations in the LCR. By the 1950s, returns to the LCR numbered in the thousands, and in 1999, chum salmon were listed as 'threatened' under the Endangered Species Act (USFWS 1999). Following listing, the Oregon Department of Fish and Wildlife (ODFW) developed the Chum Salmon Recovery Strategy (ODFW 2010), which outlined the overall approach towards restoring chum salmon populations. In preparing that recovery strategy, it was determined that (1) very little historic data existed on distribution and abundance, making it difficult to set recovery goals, (2) it was unclear which specific factors currently limited survival and reproduction, and (3) there were several critical uncertainties regarding the specific techniques required to re-establish viable chum salmon populations.

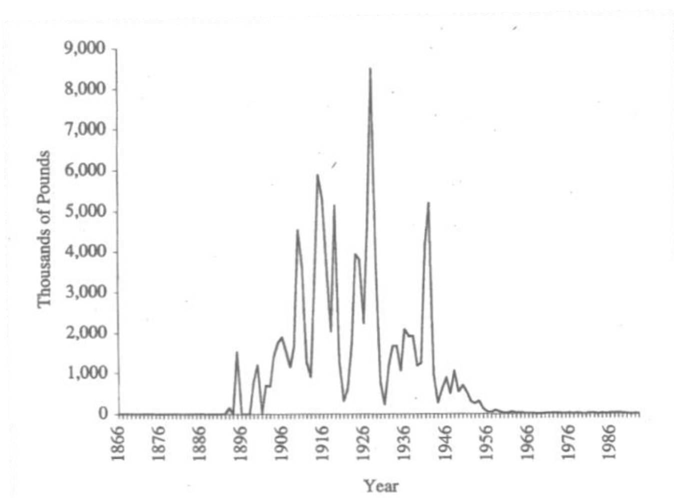

Figure 1. Commercial harvest (in thousands of pounds) of chum salmon *Oncorhynchus keta* in the Columbia River, 1866-1966. Figure from Johnson et al. 1997.

Introduction

The ODFW Chum Salmon Reintroduction Project was initiated in 2012 to address identified data gaps and initiate the recovery process. Project efforts were organized into six general steps: (1) identify and address limiting factors, (2) restore habitat to promote natural recolonization, (3) supplement populations that have an abundance below a critical threshold, (4) reintroduce chum salmon into habitats that historically supported spawning but where they are currently extirpated, (5) construct spawning channels and create conservation broodstocks to support supplementation and reintroduction work, and (6) monitor recovery in an adaptive management framework. Each reintroduction technique is associated with a particular location in the ESU such that returns in one population may be used to build a broodstock or recolonize spawning channels or restored habitat elsewhere in the population (Figure 2).

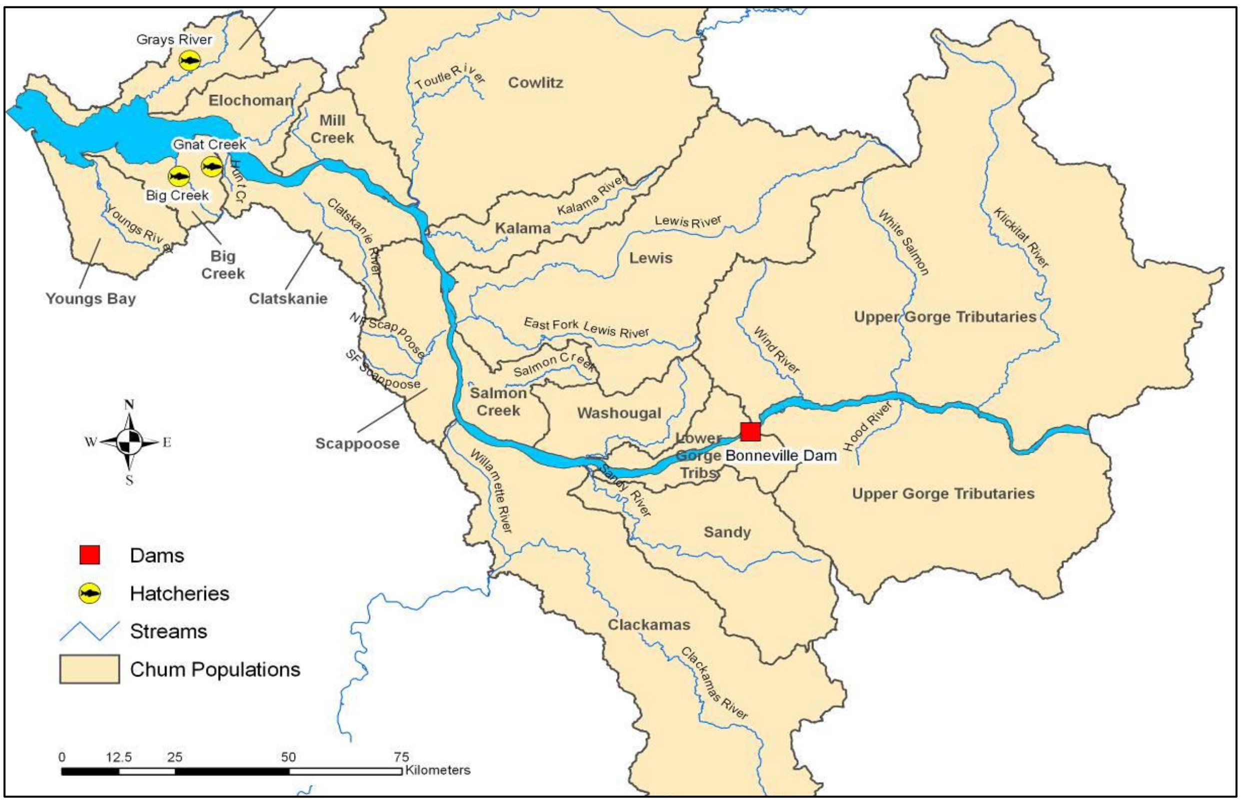

Figure 2. Chum salmon *Oncorhynchus keta* recovery populations within the lower Columbia River ESU.

The first important step on the reintroduction project was the successful creation of a conservation broodstock. For five years (2010-2014,) approximately 100,000 eggs were collected from predominantly wild chum salmon in the Grays River (WA) and transferred to Big Creek Hatchery (OR), where they were reared and released at the fed- fry stage. These fry were all marked with coded wire tags (CWT) and otolith thermal marks and are the only chum salmon fry in the Columbia Basin with CWT. In fall 2014, eggs were also collected from returning broodstock adults at Big Creek Hatchery to increase the total fry release to 200,000. Beginning in 2015, the broodstock will be maintained using only chum salmon that return to Big Creek Hatchery.

Broodstock fry releases, adult returns, and egg collection at Big Creek Hatchery provided an opportunity to evaluate limiting factors related to fry survival and to address critical uncertainties related to reintroduction strategies. As such, studies were initiated in 2013 to: (1) identify hatchery fry movement in the estuary, and (2) develop and test life-stage specific reintroduction techniques. Experimental reintroductions were continued and expanded in 2014.

Methods and summary

Objective 1: hatchery fry movement

Methods

Migration patterns of hatchery-released chum salmon fry were determined using CWT detections during beach seining. Approximately 108,500 chum salmon fry were tagged and released from Big Creek Hatchery on April 15 and 16, 2013. Beach seines were used to sample juvenile salmonids April 16-18 at eight stations in Cathlamet Bay and also in the estuary at Point Adams Beach (Figure 3). Captured chum salmon were scanned for CWTs, measured, and released. Chum salmon migration distances were calculated as the total distance a fry could travel from the hatchery release point to the recapture point, following the most direct path. Migration rates were calculated for each individual as the total km / day using the hour of release as the start time for the calculation. This represented a minimum migration rate because fry could have taken a more circuitous route that was not detected in our beach seining.

Summary

In three days of seining, a total of 614 chum salmon fry were encountered at 9 sample stations (Figure 3). Approximately 15% of captured chum salmon fry had a CWT (n = 92). Migration rates and routes varied among hatchery fry. On the first day of seining, CWT fry were captured at Karlson Island and Minaker Island in Cathlamet Bay; both sites were 1.8 km from the hatchery release site at the mouth of Big Creek. By the second day of seining, individuals were detected again at Karlson and Minaker islands, and at Russian Island (4.4 km from Big Creek), near Lois Island (9.3 km from Big Creek), and at Point Adams Beach (34.5 km from Big Creek). Detections at Point Adams Beach corresponded with a minimum migration rate of 17.3 km/ day, assuming chum salmon fry migrated along direct routes between Big Creek and Point Adams Beach.

Collectively, these results indicate that hatchery chum salmon fry migrated rapidly through the estuary, primarily using shallow water habitat adjacent to vegetated islands. These habitats were also used by wild chum salmon fry; a genetic analysis of these fry indicated they originated from populations throughout the lower Columbia River basin (Small et al. 2013). However, considering that hatchery fry are released at 55-70 mm total length (TL) and wild fry leave natal streams at 35-40 mm TL, it is likely that migration rates of hatchery fry may be more rapid than those of wild fry. Despite that difference, their co-occurrence suggests that shallow-water habitat around island complexes may be important to this species during their brief estuary residence.

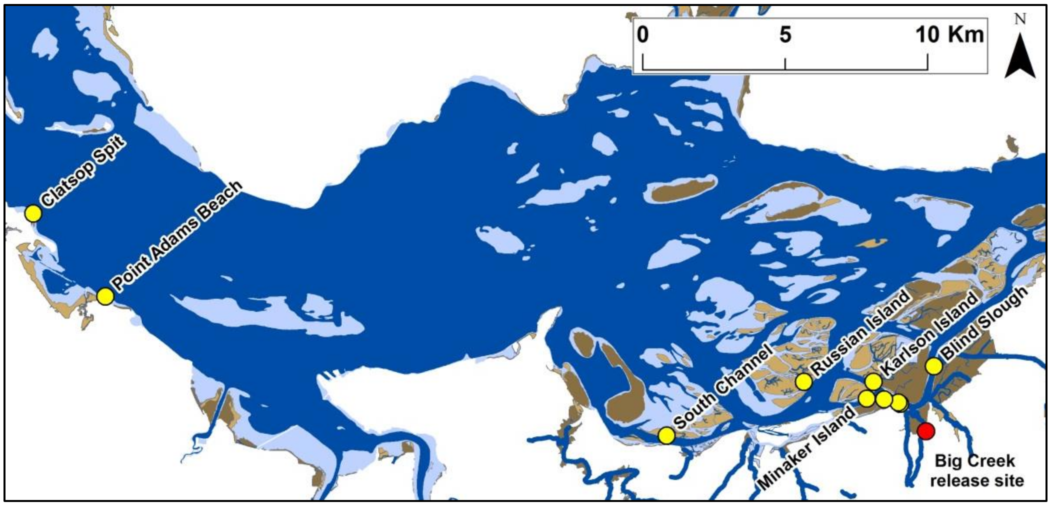

Figure 3. Beach-seine locations in the Columbia River estuary (yellow dots) and release location for hatchery chum salmon fry (red dot), 2013.

Objective 2: experimental reintroductions

<u>Methods</u>

To address critical uncertainties in reintroduction, we successfully completed two experimental reintroductions in the Clatskanie River population (Figure 2). In 2013, adult chum salmon broodstock returns were collected at Big Creek Hatchery and released into Graham Creek and Stewart Creek. These two creeks were selected as reintroduction sites following basin wide habitat surveys (Alfonse and Homel, in prep.) because of their similar size, land use, and availability of spawning substrates. Adult traps were installed just above tide water to prevent released chum salmon from leaving each creek. Spawn surveys were completed three times/ week to determine whether fish spawned and to estimate egg deposition. For each year, egg deposition was estimated using the average fecundity observed at the Grays River Hatchery during spawning. In February, juvenile traps were installed to estimate juvenile production and egg-to-fry survival.

Two life stages were experimentally reintroduced in 2014. First, adult chum salmon were released into Stewart Creek using the same method as the prior year. Unlike 2013 releases, adult releases in 2014 occurred after egg collection goals had been met at the hatchery; this delayed collection resulted in a sex ratio skewed towards females. Second, eyed-eggs were outplanted in remote site incubators (RSIs) located on Perkins Creek, another tributary in the Clatskanie River population. These eggs came from broodstock returns that were spawned and reared to the eyed-egg stage at Big Creek Hatchery. Egg-to-fry survival was calculated at the RSIs by summing the total number of dead eggs and dead or dying alevins that remained in the egg barrels once the surviving fry had volitionally outmigrated. This number was subtracted from the total number of eggs originally collected at the hatchery.

<u>Summary</u>

Experimental reintroduction of adult chum salmon was differentially successful between Graham and Stewart Creek. In Graham Creek, one chum salmon left during a flood event (when the trap was not fishing) and returned to Big Creek Hatchery. Because there was little cover or deep pools available near spawning gravels, most chum salmon remained (and eventually spawned) in poor habitat inside the culverts under Highway 30; this resulted in little fry production (Table 1). In Stewart Creek, numerous pools existed where chum salmon were observed holding, and spawning occurred throughout the accessible extent of the stream. Similar to Graham Creek, one fish left during a flood event and returned to Big Creek. An estimated 4,336 fry outmigrated from Stewart Creek in 2013 and 10,285 outmigrated in 2014. Although the number of adults released into the creek differed between 2013 and 2014, egg-to-fry survival rates were similar (Table 1). The experimental reintroductions in Graham Creek and Stewart Creek demonstrated that releasing adults to spawn naturally does result in successful production of fry. However, the relative success at a site depends on the quality and complexity of the spawning habitat.

Results from on-site rearing of eyed-eggs in Perkins Creek were promising. Prior to outplanting, there was a 10.5% egg loss at the hatchery (largely due to the poor condition of many of the females during spawning). Post outplanting, there was only a 6% egg loss in the RSIs (Table 1), and an estimated 40,366 fry outmigrated into Perkins Creek. As such, outplanting eyed-eggs in RSIs appears to be a viable method to release large numbers of acclimated fry into a system.

There are benefits and drawbacks to each reintroduction method. The first technique allows natural processes, such as mate selection, to occur, but fewer offspring are produced. The second requires bringing adults into the hatchery to spawn, but the resulting production is significantly higher and not limited by habitat quality. At this time, considering the low overall abundance of chum salmon within the ESU, early reintroduction efforts will focus on increasing abundance through high-production methods (e.g., RSIs) and then transitioning to releasing adults once habitat restoration has occurred.

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Table 1. Summary of adult and eyed-egg experimental reintroductions, 2013-2014, in the Clatskanie River population, Oregon. For eyed-egg releases, egg-to-fry survival is calculated using the total number of eggs collected at Big Creek Hatchery to be consistent with values reported for adult releases.

	2013		2014	
	Graham Creek	Stewart Creek	Stewart Creek	Perkins Creek
Adults released	12 M, 10 F	11 M, 10 F	6 M, 25 F	NA
Eyed-eggs released	NA	NA	NA	47,958 eggs collected 42,911 eyed-eggs released
F spawned-out carcasses	3	6.5	14	NA
Estimated egg deposition	7500	16,250	36, 988	NA
Fry estimate	15 captured/ 0 recaptured (no estimate)	4,336 (SE = 424)	10,285 (SE = 591)	40,336
Egg-to-fry survival	NA	26.7%	27.8%	84.1%

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