2015 Snake River Kelt Management Plan (KMP)

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Executive Summary

The 2015 Kelt Management Plan describes actions occurring in calendar year 2015 and recent research results supporting three major strategies to meet the goals of increased steelhead spawner abundance, defined in the 2008 Federal Columbia River Power System (FCRPS) Biological Opinion (RPA 33 and 42). The three major strategies to meet these goals are 1) reconditioning or aquaculture based rehabilitation programs for post-spawn female steelhead, 2) transportation of kelts through the hydrosystem via barge or truck, and 3) hydrosystem actions to improve in-river migration.

The Snake River Basin Steelhead Kelt Reconditioning Facility Master Plan was sent to the Independent Science Review Panel (ISRP) for review in 2016. In full implementation, kelt reconditioning at the production scale hatchery facility is projected to substantially contribute to meeting the goal of a 6% increase in abundance of wild B-run steelhead spawners. Recent reconditioning results investigating maturation status and diet during reconditioning show that bioenergetic status of maiden spawners strongly influences the frequency of consecutive year and skip spawning among kelts. Research will continue at the Prosser hatchery facility on a high lipid diet which has increased initial growth rates of collected kelts. Results of Genetic Stock Identification (GSI) and demographics analysis are reported, showing the sex ratio, length distribution, and 1- and 2- ocean frequencies of kelts originating from different Snake River tributaries. Conventional indicators of B-run status (length >78cm, 2 ocean history) showed that each tributary displayed mixed-stock distribution of A- and B-run steelhead, with the highest frequency of female B-run spawners returning to the Clearwater River.

Extensive renovations to Lower Granite Dam are planned for 2016, supporting improved downstream passage, enhanced ladder conditions in late summer when a thermal gradient has impeded upstream passage, and better capacity to collect adult migrants at the juvenile bypass facility (JBS). An analysis of the survival outcomes after fallback of overwintering steelhead outside of the season of spill targeted at juvenile migrants at McNary Dam showed that the increased frequency of fallback when spill is provided at the temporary spillway weir (TSW) in winter may mitigate the relative survival benefit. Operation of the TSW at McNary Dam outside of the spill for fish passage season to provide downstream passage may benefit downstream populations that overshoot their natal tributaries such as John Day and Umatilla stocks but is unlikely to be beneficial for upstream stocks such as Snake River or B-run steelhead unless operation of the TSW decreases the potential turbine fallback by at least 25%. The timing of passage of acoustic- and radio-tagged kelts showed that a substantial majority pass McNary Dam after the current start of spill on April 3.

The 2008 FCRPS Biological Opinion (BiOp) identified the capability among steelhead for iteroparity (repeat spawning) as an important trait for increasing steelhead population abundance and stability. The actions identified in the FCRPS BiOp focus on a combination of hatchery (reconditioning) and hydrosystem operations at projects on the Lower Snake and Columbia Rivers to benefit Snake River B-run Steelhead (RPA 33), and hatchery operations to benefit upper and middle Columbia River Stocks (RPA 42).

RPA Action 42 requires Action Agency funding of steelhead kelt reconditioning programs for middle and upper Columbia River steelhead populations. RPA 42 requires: 1) Funding a program to recondition natural origin kelts for the Entiat, Methow and Okanogan subbasins (Upper Columbia) including capital construction, operation, and monitoring and evaluation costs; and 2). Funding a program to recondition natural origin kelts in the Yakima subbasin (Mid-Columbia) including capital construction, implementation, and monitor and evaluation costs. Progress towards meeting the objectives of RPA 42 is detailed in the annual reports for CRITFC's Kelt Reconditioning project (BPA project 2007-401-00 http://www.cbfish.org/Project.mvc/Display/2007-401-00). Unlike RPA 33, RPA 42 does not specify a numerical target for an increased number of returning steelhead spawners; it only mandates funding for hatchery based reconditioning programs that conserve and build genetic resources for the recovery of listed steelhead populations in the Upper and Middle Columbia Distinct Populations Segments (DPS).

RPA Action 33 requires the U.S. Army Corps of Engineers (Corps) and the Bonneville Power Administration (BPA) to "prepare a Snake River Kelt Management Plan in coordination with NOAA Fisheries and the Regional Forum. BPA and the Corps will implement the plan to improve the productivity of interior basin B-run steelhead populations as identified in Sections 8.5." RPA 33 requires a Plan that will focus on the wild component of the B-run steelhead and should include:

1. Measures to increase the in-river survival of migrating kelts,
2. Potential for collection and transport (either with or without short-term reconditioning) of kelts to areas below Bonneville Dam,
3. Potential for long-term reconditioning as a tool to increase the number of viable females on the spawning grounds, and,
4. Research as necessary to accomplish the plan elements.

Coordinated expansion of infrastructure and aquaculture facilities in the Snake and Columbia Rivers, and lessons learned during early stages of the program have been beneficial for fulfilling both kelt RPAs. Research conducted in the middle Columbia River under RPA 42 pertaining to experimental development of techniques for reconditioning, monitoring of survival rates through the lower Columbia dams, and monitoring of kelt return rates has been helpful for successful implementation of the Snake River reconditioning program, planned under RPA 33.

B-run summer steelhead have been identified as a special management concern with conservation priority for the Snake River. The B-run are typically composed of larger bodied adults with a two-year ocean life history, although firm distinguishing traits from A-run adults returning to Snake River tributaries are hard to identify. Some fraction of one-year ocean or A-run adults typically exceed the traditional B-run fork length criteria of 78cm, although a clear inflection node occurs at ~65cm in the length distribution of the entire Snake River steelhead distribution. B-run adults may originate from A-run parents in a pedigree, and vice versa. While it is generally believed that B-run steelhead predominantly occur in the South Fork Clearwater River, and South Fork and Middle Fork Salmon River, and Secesh and Lochsa rivers, an analysis of scale samples and length indicates that a sizable fraction of returning adults to many other tributaries of the Snake River should be classified as B-run based on the 2-ocean and size criteria. Each of 10 monitored subpopulations had some returning individuals classified in the B-run group.

The 2-ocean life history pattern is associated with cold, high elevation habitat which results in late emergence, slower early growth rates, and juvenile outmigration at the second year. The critical period hypothesis suggests that hormonal signals for transition into the smolt stage and for adult maturation are regulated by energy reserves during a developmental time window (Thorpe 2007). It is yet unclear to what extent annual variation in temperatures and flows may influence prevalence of the one and two year steelhead freshwater lifestage, or duration of the ocean stage. In addition, recent research by the kelt reconditioning project has consistently found that some fraction of kelts do not remature in the first year ("skip spawners"). Plasma estradiol (E2) levels of female kelts in July are associated with energetic status, and are predictive of individual rematuration later in the first year.

The frequency of kelting is higher among A-run than among B-run individuals. There appears to be a reduction in the B-run steelhead composition between the maiden and kelt stage, but the B-run composition of repeat spawners is similar to the initial outmigrating kelt composition. Underlying biological and behavioral factors contributing to such discrepancies are not well understood but likely warrant further investigation of potential causes. With more data including escapement comparisons, it may be possible to refine the confidence in estimated rates of iteroparity among Reporting Groups (RGs). Age appears to be less of a factor in rates of iteroparity than size. Both the A- and B-run life history was observed to be present among all RGs.

Three BiOp strategies to improve steelhead productivity

Kelt Reconditioning Strategy

Kelt reconditioning is used as a means of increasing post-spawning survival and repeat spawning. This strategy includes two variations on reconditioning which are distinguished between lengths of time (short vs. long) that the post-spawned fish are held to aid their recovery. However, the reconditioning approach primarily being utilized is long-term reconditioning, which consists of holding post-spawned kelts for 6-10 months.

Physiology studies have provided us with a much better understanding of energetic and physiological status of kelts, improved our understanding of alternative life histories in post-spawning fish, and improved survival and health of reconditioned fish. Blood hormone assays are useful to classify consecutive and skip spawner steelhead. Future work needs to focus on optimizing strategies for skip spawner contributions. Artificially reconditioned kelt steelhead appear to repeat home with high fidelity. Data indicates that natural repeat spawners in the Snake River exhibited a 15% stray rate.

Collection and Transportation Strategy

Transportation has not occurred in recent years after experiments conducted 2002-2011 in the Yakima River Basin were completed, comparing outcomes after treatment and control groups of in-river downstream migration, transportation below Bonneville (BON) immediately following collection, short term conditioning with transportation below BON, and long-term reconditioning. Availability of kelts collected in Snake River tributaries and at Lower Granite Dam (LGR) adult trap is a joint limiting factor for the reconditioning and transportation strategies.

Enhanced In-river migration Strategy

This strategy includes operational or structural modifications to hydro facilities that create conditions which could enhance survival rates of kelts passing a hydro facility. These modifications may physically guide or passively attract kelts towards either a collection-passage system or spillways. Perhaps the most important category of structural modification has been installation of surface passage weirs and sluiceways, which was completed for the eight FCRPS dams between LGR and BON in 2009. Subsequent monitoring has broadly indicated that kelts and adult steelhead are effectively finding these routes and experiencing high downstream survival rates through the route.

Objectives of the 2015 KMP

The Kelt Management Plan for 2015 is intended to evaluate progress of the three major strategies towards meeting the goals laid out in the 2008 FCRPS BiOp, and to provide an annual status update including recent research results and near-term planning for key infrastructure. Starting with the original framework introduced in the 2009-2010 plan, subsequent annual plans have progressed using approaches of adaptive management (BPA project 2007-401-00 http://www.cbfish.org/Project.mvc/Display/2007-401-00)

Current status and research results

In 2015, 24 rematured kelts were released from the reconditioning facility at Dworshak dam (Table 1).

Table 1. Annual releases of Snake River origin reconditioned steelhead.

Release by Year							
	2011	**2012**	**2013**	**2014**	**2015**		
	2	10	69	36	24		

Strategy 1: Long term reconditioning

The Kelt Steelhead Reconditioning and Reproductive Success Evaluation Project (BPA project 2007-401-00 http://www.cbfish.org/Project.mvc/Display/2007-401-00) is a research, monitoring, and evaluation (RM&E) category project funded through the Columbia Basin Fish Accords. The project studies and evaluates two broad topics with respect to post-spawn (kelt) steelhead, first it assesses reconditioning processes and strategies, and second, it measures reproductive success of artificially reconditioned kelt steelhead. The project specifically addresses FCRPS BiOp Reasonable and Prudent Alternative Actions 33 and 42 (NMFS 2008). RPA Action 33 requires the Action Agencies to develop and implement a Snake River steelhead kelt management plan designed to provide at least a 6% improvement in B-run population productivity. Toward that goal, a variety of approaches are being tested and implemented including passage improvements and reconditioning kelt steelhead. RPA Action 42 focuses on the reconditioning component and seeks to preserve and rebuild genetic resources through safety-net (kelt reconditioning) and mitigation actions to reduce short-term extinction risk and promote recovery.

Large numbers of kelt steelhead are available for collection at many sites across the Columbia River Basin. These sites generally are associated with juvenile bypass systems or weirs. For example, from 2000-2015 we captured a total of 13,653 downstream migrating kelts at Chandler Juvenile Monitoring Facility, on average about 26% of each annual wild steelhead return. In 2015, steelhead kelts were quite abundant across the basin. We collected 1,098, 22, 83, and 35 at Chandler Juvenile Monitoring Facility on the Yakima River, Lower Granite Dam, Fish Creek Weir, South Fork Clearwater River, respectively. All collections were Group B-run steelhead except for collections in the Yakima River. Additional fish were available at Lower Granite Dam but our reconditioning capacity was already met. Later in the year, we installed two additional 20’ circular tanks at Nez Perce Tribal Hatchery to increase capacity.

Long-term reconditioning survival averaged 40% at the Prosser Fish Hatchery (PFH) over the last 16 years (Hatch et al. 2013b). The reconditioning survival rate has been more variable for the past 4 years at Dworshak National Fish Hatchery (DNFH) with an average of 28% for the hatchery fish, 32% for the fish captured at LGR, 27% for fish from the South Fork Clearwater, and 34% for the Fish Creek kelts. Low survival at DNFH resulted from water quality issues in the early years and also obtaining/training staff that have experience with fish culturing skills and training them in reconditioning techniques. This site has had continuous improvement every year since its inception.

Since we are operating the Snake River Program at a research scale, as approved by the ISRP in the 2008 review, the capacity of our facility is too small to meet the RPA 33 goal of increasing the LGR ladder count of B-run steelhead by 6%. However, we have demonstrated the feasibility of reaching the 6% goal (Table 1). In 2013, we released 69 reconditioned B-run steelhead (approximately 40% of RPA 33's goal). In 2015, we released 24 reconditioned B-run steelhead below Lower Granite Dam in association with RPA 33, an additional 21 fish were determined to be skip spawners and retained for release in 2016.

Geographic Comparison of Reconditioning Programs

Survival and maturation data from Prosser, Winthrop, and Dworshak are shown in Figure 1. Since our main interest is in identifying trends due to common environmental conditions, we have not included data from years where results were compromised by problems with fish holding facilities or disease. The Dworshak project was compromised by water quality issues in 2011 and 2012 (chlorine in the water supply and kelts placed on effluent water, respectively), and the Winthrop project was compromised by fish not receiving effective copepod treatment during their first year of operation in 2012. Results at DNFH in 2014 may have been compromised by issues with formalin treatment and fish care.

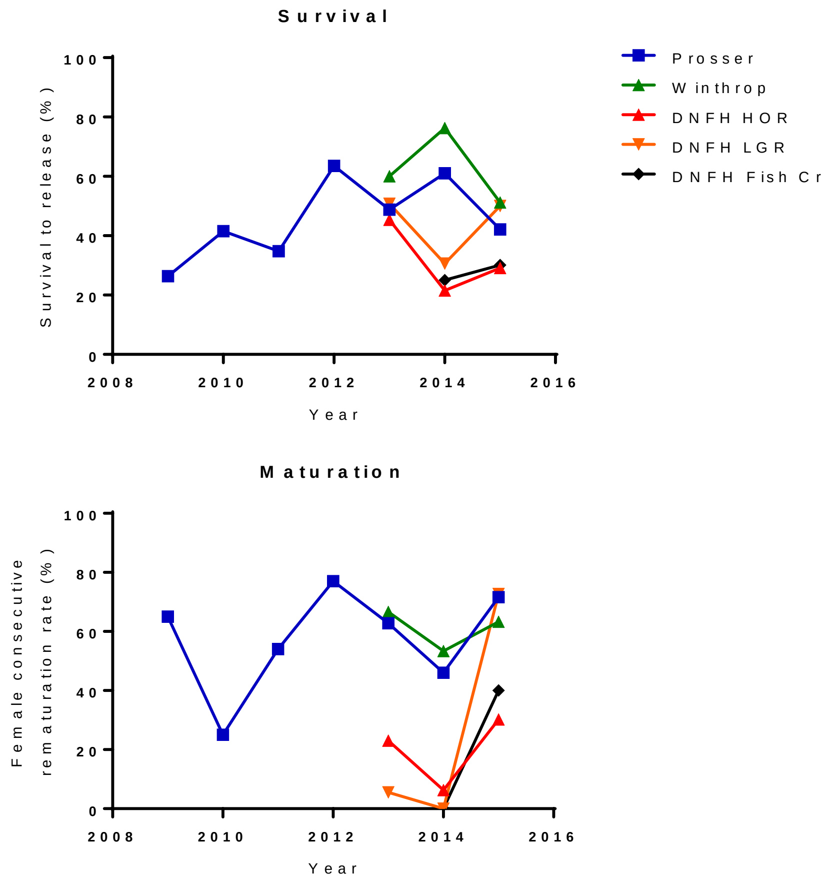

Figure 1. Survival and female consecutive maturation rates in Columbia River Basin (CRB) kelt reconditioning projects. Fish reconditioned at the Dworshak project include air spawned hatchery origin kelts from the DNFH stock (DHFH HOR), kelts collected at Lower Granit Dam (DNFH LGR), and kelts collected at Fish Creek (DNFH Fish Cr) on the Locha River in 2014 and 2015.

Survivals in the Prosser and Winthrop projects from 2012 onward have consistently been in the 50 – 80% range, and survivals of kelts collected at Lower Granite Dam have been similar at Dworshak in 2 of 3 years. In 2012, the Prosser project began treating all kelts with emamectin benzoate by intraperitoneal injection for copepod infestation. Previous treatment had been with ivermectin by gavage. We attribute the increased survival to the change to a less toxic treatment. Results suggest that survivals above 50% are attainable in CRB kelt reconditioning.

With the exception of 2010, consecutive rematuration rates in the Prosser and Winthrop projects have consistently been near 60%. Maturation rates at Dworshak have been lower. However, in 2012, 4 of 5 (80%) of surviving hatchery origin kelts at Dworshak were rematuring when lethally sampled in the fall, and in 2015, a 73% maturation rate was attained with kelts collected at Lower Granite Dam and reconditioned at Dworshak. Thus, high rematuration rates appear to be possible for Snake River fish. Overall, results suggest that rematuration rates averaging near 60% can be expected in the CRB kelt reconditioning projects.

Interestingly, both survival and rematuration rates in the Prosser and Winthrop projects appear to be varying together over the three comparable years, suggesting that common environmental conditions prior to capture may influence fish performance in captive reconditioning. Additional years of data are required before conclusions can be drawn on this topic.

Genetic Stock Identification and Snake River Kelts

The demographic benefit of an iteroparous life history is realized when kelts migrate to the ocean and successfully complete one or more subsequent spawning migrations. Kelts are found throughout the Snake River Basin, but their spatial distribution or occurrence among watersheds is highly variable. Rates of iteroparity or repeat spawning in the Snake River are highest among populations characterized by smaller, 1-ocean age individuals (A-run). Conversely, repeat spawning is less frequent among B-run steelhead which are characterized as larger, 2-ocean age individuals (Narum et al. 2008). We used multilocus genotype data at single nucleotide polymorphism (SNP) loci to conduct an analysis of genetic stock composition among kelt steelhead sampled at Lower Granite Dam (LGD) between 2009 and 2013. The objective of this study was primarily to estimate stock proportions in a mixed stock sample, providing a better understanding of the origins of post-spawn steelhead among the major subbasins (e.g., Clearwater River, Salmon River, Grande Ronde) and major population groups (MPG's) within the Snake River Basin. Results will provide managers with valuable information about the behaviors and population demographics exhibited by genetically assigned kelt stocks.

The majority of kelt steelhead emigrating from tributaries of the Snake River pass downstream of Lower Granite Dam through a removable spillway weir (Colotelo et al. 2014) when in operation. A large bypass system directs approximately 4-6% of the total annual kelt emigration into a juvenile fish facility (JFF). All kelts entering the JFF were sampled from 2009 to 2014, and sampling occurred over the entire emigration period from late March to late June (Hatch et al. 2015). This included a total of 5,712 natural-origin kelts and 2,642 hatchery-origin kelts (Table 2 and Table 3). Caudal fin or opercule punched tissue samples were stored dry on whatman paper (LaHood et al. 2008). Biological data recorded during kelt sampling included: tag detection and presence of physical marks (i.e. indicating hatchery origin), sample date, fork length (FL), gender and condition rating of "poor", "fair" or "good". The rating protocol (see Buelow 2011; Hatch et al. 2015) was predetermined with specific criteria, and uniformly scrutinized, based largely on the presence and severity of fungus and injury, along with other aspects of physical appearance.

Table 2. Age and length statistics for hatchery-origin kelts (2011-2014). Known stock origins were determined via PBT, and ocean age was calculated based on parental brood year. The corresponding GSI reporting groups (RG) are shown for each hatchery stock. Age proportions are shown as % total, and fork length (FL) is the mean size at age. These values were used to infer age of natural-origin kelts.

		PBT assignment			1-ocean		2-ocean	
PBT stock	RG	(n)	%	mean FL	%total	FL	%total	FL
Female kelts								
CGRW	GRROND	203	0.11	59.6	69%	56.3	31%	67.3
WALL	GRROND	75	0.04	59.3	67%	56.5	33%	65.0
LSCR	IMNAHA	75	0.04	57.9	79%	55.6	21%	66.2
LYON	LSNAKE	5	0.00	56.4	**100%**	56.4	na	na
TUCW	LSNAKE	9	0.00	61.8	67%	56.8	33%	71.7
EFSW	UPSALM	78	0.04	61.1	65%	57.0	35%	68.5
OXBO	UPSALM	177	0.09	61.8	53%	57.1	47%	67.2
PAHH	UPSALM	567	0.30	57.6	84%	56.1	16%	65.5
SAWT	UPSALM	550	0.29	57.6	81%	55.7	19%	65.6
	subtotal/mean	*1739*	0.91	*58.5*	*76%*	*56.1*	*24%*	*66.3*
DWOR	SFCLWR	167	0.09	75.3	8%	61.5	91%	76.5
Male kelts								
CGRW	GRROND	55	0.08	57.9	98%	57.7	2%	65.0
WALL	GRROND	14	0.02	57.3	93%	57.1	7%	60.0
LSCR	IMNAHA	21	0.03	57.3	**100%**	57.3	na	na
LYON	LSNAKE	13	0.02	57.4	**100%**	57.4	na	na
TUCW	LSNAKE	2	0.00	62.5	50%	61.0	50%	64.0
EFSW	UPSALM	97	0.13	57.6	98%	57.6	2%	61.0
OXBO	UPSALM	53	0.07	57.8	94%	57.2	6%	68.7
PAHH	UPSALM	204	0.28	56.1	99%	55.9	1%	64.0
SAWT	UPSALM	208	0.28	56.5	99%	56.3	1%	68.0
	subtotal/mean	*667*	0.91	*56.8*	*98%*	*56.6*	*2%*	*65.2*
DWOR	SFCLWR	66	0.09	64.6	92%	63.3	8%	80.9

Table 3. GSI results for natural-origin kelts (2009-2014) Origins were determined on the basis of highest ranked individual assignment likelihood scores (p).

RG	region	GSI assignment proportions						
		2009	2010	2011	2012	2013	2014	total
natural-origin kelts (n)		*262*	*1,362*	*1,111*	*1,121*	*437*	*1,419*	*5,712*
LOCLWR	A	6%	5%	8%	11%	8%	8%	8%
LOSALM	A	11%	7%	7%	7%	9%	7%	7%
GRROND	A	19%	15%	20%	24%	20%	22%	20%
IMNAHA	A	11%	13%	16%	13%	16%	15%	14%
LSNAKE	A	7%	9%	10%	12%	11%	14%	11%
UPSALM	A	19%	34%	18%	16%	21%	19%	22%
total/overall		**74%**	**83%**	**78%**	**82%**	**84%**	**85%**	**82%**
MFSALM	B	15%	10%	11%	8%	8%	6%	9%
SFSALM	B	5%	3%	4%	3%	3%	2%	3%
UPCLWR	B	3%	3%	3%	2%	3%	3%	3%
SFCLWR	B	3%	2%	4%	5%	2%	3%	3%
total/overall		**26%**	**17%**	**22%**	**18%**	**16%**	**15%**	**18%**

The expected level of assignment resolution resulting from reference baseline testing varied depending on RG-of-origin and run type region (Table 4). The accuracy of assignment to RG was weak to moderate within the putative A-run region, with proportions of correct assignments ranging from 43% in LSNAKE to 72% in IMNAHA (mean 59%). Corresponding likelihood scores ranged from *p*=66.9 to *p*=84.0 (mean *p*=76.4). For reporting groups in the putative B-run region the accuracy associated with RG assignments was relatively strong. Correct assignment proportions ranging from 86% in MFSALM to 93% in SFCLWR (mean 89%), and corresponding likelihood scores ranged from *p*=94.5 to *p*=96.7 (mean *p*=95.4). Assignment accuracy at the regional level (RGs combined by putative run-type region) was markedly improved among “A-run” RGs (mean correct assignment – 96%; mean score *p*=96.6), and moderately improved among “B-run” RGs. These results indicate a high level of confidence in assigning regional origins of “unknown” individuals (Winans et al. 2004; Ackerman et al. 2011; Ensing et al. 2013; Hess et al. 2014).

Table 4. Reference baseline assignment accuracy/resolution and kelt GSI assignment confidence. The proportion of correct self-assignments among baseline individuals (% self) and corresponding assignment likelihood scores (mean p) are shown for assignments at the level of RG-of-origin and traditional run type region.

RG	region	baseline (self)		baseline (mean *p*)		kelts (mean *p*)	
		RG	run	RG	run	RG	region
LOCLWR	A	58.0%	92.0%	80.4	95.6	64.0	94.0
LOSALM	A	55.0%	89.0%	81.9	94.0	63.0	92.0
GRROND	A	56.0%	98.0%	69.6	97.5	64.0	98.0
IMNAHA	A	72.0%	98.0%	84.0	96.6	75.0	97.0
LSNAKE	A	43.0%	97.0%	66.9	97.0	59.0	98.0
UPSALM	A	67.0%	97.0%	77.4	97.3	75.0	98.0
	total/mean	*59.0%*	*96.0%*	*76.4*	*96.6*	*67.0*	*96.0*
MFSALM	B	86.0%	87.0%	94.5	95.6	87.0	88.0
SFSALM	B	92.0%	94.0%	94.9	96.0	84.0	87.0
UPCLWR	B	91.0%	97.0%	96.7	98.3	92.0	96.0
SFCLWR	B	93.0%	98.0%	95.2	97.0	87.0	91.0
	total/mean	*89.0%*	*93.0%*	*95.4*	*96.7*	*87.0*	*90.0*

We observed moderate temporal variation in estimated GSI stock proportions for natural-origin kelts sampled between 2009 and 2014. We observed moderate temporal variation in estimated GSI stock proportions for natural-origin kelts sampled between 2009 and 2014. Variation was highest in UPSALM among six RGs in the A-run region (18%) and in MFSALM (9%) among four RGs in the B-run region (Table 3). Overall GSI proportions were dominated by kelts from RGs in the putative A-run region (82%), particularly from UPSALM (22%) and GRROND (20%). The average proportion of kelts assigned to RGs in the B-run region was small, ranging from a total 15% to 26% of annual mixture samples. Modest statistical confidence was observed for RG assignments within the A-run region. Likelihood scores ranging from p=0.59 in LSNAKE to p=0.75 in both IMNAHA and UPSALM (mean p=0.67; Table 4). By comparison, RG assignments within the B-run region were highly confident. Likelihood scores ranging from p=0.84 in SFSALM to p=0.92 in UPCLWR (mean p=0.87). On a more coarse scale, kelts assigned to the "correct" run-type region with a high degree of accuracy. Corresponding likelihood scores ranged from p=0.92 to p=0.98 (mean p=0.96) for the A-run region, and from p=0.87 to p=0.96 (mean p=0.90) for the B-run region. This represents a significant improvement in mean likelihood score (up 29%) between assignment to RG vs. assignment to putative run-type region or the A-run type.

Kelt demographics

The ratio of females to males among natural-origin kelts ranged from 66% to 80% among RGs in the A-run region, and from 70% to 85% among RGs in the B-run region (Table 2). Female kelts were rated in significantly better overall condition (% "good") than males among RGs in the A-run region (P<0.001; Table 4), with the exception of LOSALM (lower Salmon). There was no difference in condition rating between males and females among RGs in the B-run region, or between A-run and B-run regions (e.g., 58% vs. 56% for females). Kelt emigration timing was variable, and females emigrated significantly earlier than males (range 5-11 days) among all 10 reporting groups. Kelts originating from SFCLWR (South Fork Clearwater) were the first to be encountered at LGR during the emigration period (mean ordinal day 119) while the remaining three RGs in the B-run region exhibited the most delayed emigrations. The emigration times for kelts from RGs in the B-run region (mean day 140.3) were significantly later than kelts from RGs in the A-run region (mean day 131.0; Table 4), which includes some of the longest emigration distances to LGR.

Kelt Modeling

In 2014 we began formal parameterization of the model using known steelhead spawning abundances, smolt migration abundances, survival rates of kelt release groups, portions of captured kelts going into each release group, and the kelt capture rate itself. We obtained spawning abundance data from upstream-migrating (prespawn) steelhead at Prosser. Smolt abundances were taken from Frederiksen et al. (2012). Kelt success rates of each release group were obtained from summaries of tagged captures and returns. Estimates of survivals were 39.75%, 3.6%, 15%, and 2.6% respectively for long-term reconditioned fish, in-river releases, fed transported fish, and unfed transported fish. Success rates were calculated as the average success rate over all years that a cohort of kelts was available for each category. We parameterized the model such that the predicted success rate of each kelt category was the same each year. We used the average of the proportions of kelts falling into each category as evaluated from the total collections and returns.

Initializing the model requires initial spawning abundances, which were available from 1985-2013. Smolt abundance data were also available for the same period. For the model to be able to predict future generations of fish, it must be able to predict smolts from spawners, adults in the ocean from smolts, and returning spawners from ocean adults. We obtained estimates of the Ricker smolt production parameters by fitting the smolt abundances predicted by the Ricker function to the observed smolt abundances. A Ricker function was fit to the model using a process error model with a log-normal negative log-likelihood minimization. We used migration year total smolts two years after the spawning year as the estimated smolts from a spawning group. Since the majority of emigrating juveniles are two years old, this value would be most robust to temporal variation. The model fit estimates a Ricker productivity parameter of 3.94, and a capacity parameter of 11,278 (using the Ricker formula in the model description). We see that smolts per spawner have been approximately 15-20 smolts per spawner on average, requiring a ratio of approximately 5-7% Smolt to Adult Returns (SAR) for population stability. Because we did not have age structure data of returning adults, we assumed that all returning adults spent two years in the ocean. We fixed the maturation rate of first year ocean fish to zero so that all fish would remain an additional year in the ocean, and we fixed the second year maturation rate to 1.0 so that all fish would return after the second year in the ocean. The model thus predicted only four year old returns. Additional assumptions in the life cycle parameterization included: 1) infinite ocean capacity; 2) kelt capture rates of 40%; 3) repeat kelt rate of 25%; 4) 6% in-river release portion of kelts; 5) 5% transport unfed portion of captured kelts; 6) 15% transport fed portion of kelts; 7) and 73% long term recondition portion of kelts. Additionally, we used the Ricker productivity and capacity parameters estimated from fitting the Ricker smolt production function.

The parameterization described above produced a prediction of future spawning abundances, smolt abundances, and adult returns based on the parameters derived from acoustic tagged kelt capture and release analysis, the rates of tagging and release groups, and the Ricker stock recruitment analysis. We further refined the model by fitting the predicted spawners to the observed spawners. We fit the model with a log-normal likelihood function, where the predicted spawners were compared to the estimated spawners. We minimized the negative log likelihood by searching for the values of first and second year ocean survival that minimized the likelihood. Since the kelt capture rates, the portions in release and recondition groups, and the survivals of those groups were all fixed to the values described, the only remaining parameters to estimate were ocean survivals, which were estimated to be 10% survival in the first year and 49% survival in the second year in the ocean. Note that since all fish returned as two-salt fish, only the product of the two is relevant, which is about 5%. Recalling that 5% is approximately the SAR required for the population to be stable at about 20 smolts per spawner production levels, the estimate seems correct.

Having been statistically fit to empirical data, the model can be used as a population prediction tool. By predicting population trends with initial spawning abundances and known parameters (fixed and estimated), we can postulate the relative effect of altering a parameter of interest. An example of this is the kelt capture rate. The assumption in the model as parameterized, was that 40% of kelts were captured, and the uncaptured kelts survived as in-river fish of good, fair and poor conditions. If the assumption that capturing more kelts would ultimately result in more spawners, and if that would lead to an increase in the overall population size, then the obvious question is to what degree would additional kelt collection increase spawning escapement. To answer this question, we used the predicted returning kelts and returning spawners over a fifteen year period, and calculated the average portion of spawners that were returning kelts (Figure 2). We also wanted to determine how the collection of a greater number of kelts might alter overall escapement (Figure 3).

Two results were apparent from this modelling effort:

1. Increasing the capture rate of kelts increases the number of kelts that ultimately re-spawn.
2. There is no decline in the rate of production from increasing kelt capture rates.

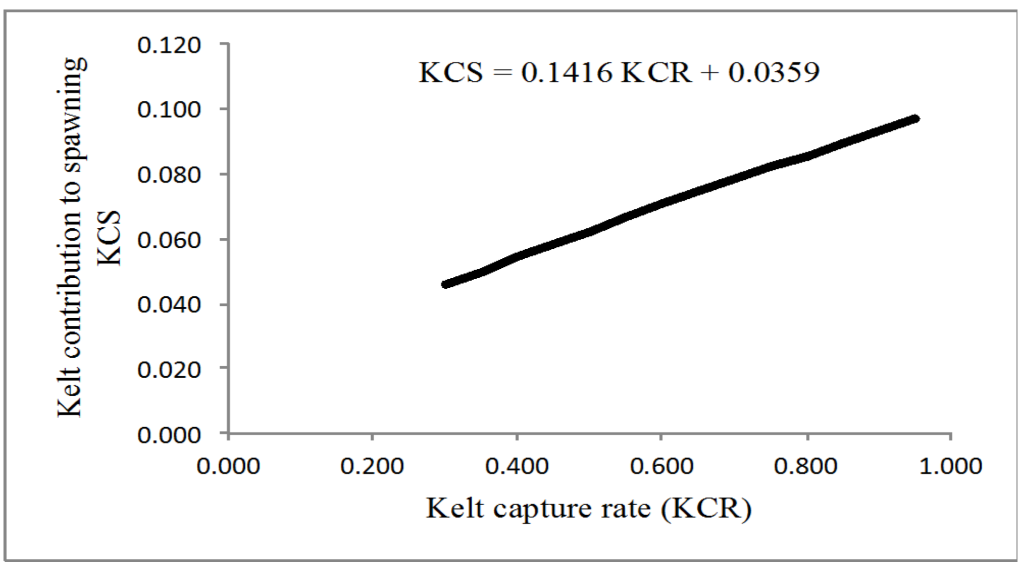

Figure 2. Relative contribution of kelts to escapement.

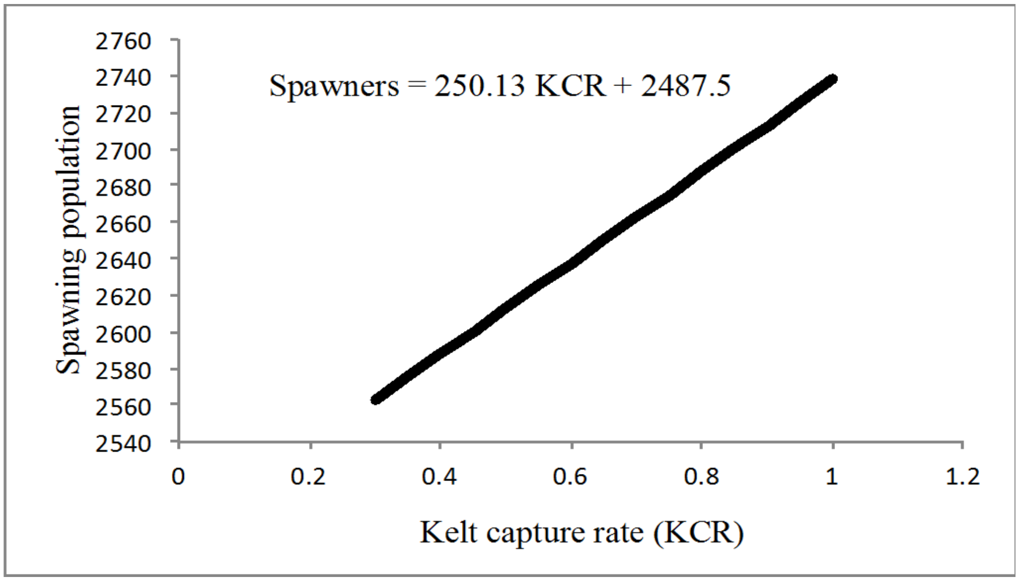

Figure 3. Predicted increase in spawning escapement with increase in kelt capture rate.

Reproductive Success Studies

We evaluated reproductive success at a variety of scales including in a controlled spawning channel and in the Yakima River using parentage analysis. Additionally, we conducted studies on maturation status of reconditioned kelts by measuring plasma estrodial (E2), we compared reproductive performance of maiden and repeat spawnings of steelhead, we evaluated the effect of different diets on lipids and maturation success, and we compared reconditioned kelts and maiden fish in terms of length, weight, and condition, lipid stores, season variation in vitilogen levels and maturation.

Cle Elum Spawning Channel Feasibility Study

Reconditioned kelt steelhead were successful in spawning in the Cle Elum artificial channel. As a feasibility study the 2015 effort was successful, however, there are several ways we can improve the channel prior to implementing a full study.

First, fish stress during transport and holding will need to be improved. High mortalities were seen during and shortly after stocking the fish. To address this we will sedate fish utilizing a low level of anesthetic. Also, additional cover was added to the channel to provide holding and resting areas for fish which should reduce stress and encourage spawning.

Second, deposition of fine sediments within the channel will be addressed by increasing flows when fish are spawning so that sediment should not settle out as readily into the channel. Sampling of the hydrology and substrate should be continued to determine how effective kelt channel improvements will be and also the differences in observed sedimentation (pers. comm. with Chad Stockton, WDFW at Cle Elum Hatchery) that occur at the Cle Elum hatchery from year-to-year. Samples will be collected just prior to kelt release/watering the channel sometime in early/mid-February (weather permitting), a mid-season sampling in the elbow section (June), and another following final expected redd emergence in August/September to monitor the amount of total fine sediment buildup. This also could help explain any differences in juvenile representation seen in the genetic sampling.

Third, trap efficiency and slippage between the sections will be addressed by improving design of the trap boxes and to use an additional trap box at the outflow to insure that we are collecting all juveniles.

Fourth, collection of every tenth juvenile sample should continue at both the trap and electrofishing stages. Re-sampling at the tank stage will only be used as a backup as it may contain mortality based biases.

Finally, all lengths of offspring will continue to be collected. It may be impossible to differentiate between variable sizes of target progeny and non-target juveniles that enter through the hatchery intake.

Yakima River Reproductive Success

The reproductive success of long-term reconditioned kelts needs to be explored to assess the net benefit of the kelt reconditioning program. Specific questions regarding the success of artificially reconditioning kelt steelhead include:

1. Do reconditioned kelts produce viable offspring that contribute to recruitment?

2. How does artificially reconditioned kelt reproductive success compare with natural repeat spawner success?

3. How does artificially reconditioned kelt reproductive success compare with first time spawner success?

In this study we utilize DNA markers and pedigree analysis to address these questions for kelt steelhead in tributaries of the Yakima River Basin.

The 2014 spawning event was the second consecutive year that we successfully assigned multiple progeny to reconditioned kelts. A total of 42 juveniles are attributed to a spawning event following successful reconditioning of a kelt. We have currently assigned 310 progeny to at least one anadromous parent. This reflects the methodology of focusing sampling efforts on age-0 fish in areas that spawning was expected to have occurred. Additional years will add to this number, and we plan to increase the number of potential offspring sampled and genotyped.

Future sampling will continue to focus on age-0 fish in areas that spawning was expected to have occurred. Locations that fail to provide adequate sample numbers or have few assignments to anadromous adults across multiple years will be dropped. The only site that has currently been dropped for this reason is Willy Dick Creek in the Toppenish drainage which was excluded from sampling in 2015.

The presence of progeny shows that reconditioned kelts are able to successfully spawn in the wild. While relative reproductive success of female reconditioned kelts was lower than that of pre-spawn, any spawning by a reconditioned kelt is additive to the population and should be considered a success. Due to the higher RRS of fish from the post-spawn collections, lifetime reproductive success of female reconditioned kelts was calculated to be 2.06 times that of the pre-spawn maidens. This is similar to findings by Seamons and Quinn (2010) who theorized and found that lifetime reproductive success of repeat spawners should scale with the number of breeding spawners.

Reconditioned kelt steelhead have demonstrated that they are capable of spawning in the wild. With additional sampling in future years we hope to have more accurate numbers and modeling potential.

Current data shows that reconditioned kelt steelhead contribute to the productivity of the natural population on a scale similar to that of natural kelts, helping to preserve this important life history.

Maturation Status of Reconditioned Kelt Steelhead

An understanding of the reproductive status of female kelt steelhead during reconditioning and at release is required to maximize the success of Columbia River Basin kelt reconditioning projects. Natural steelhead production is limited by the number of female spawners. In order to contribute to ESA-listed steelhead populations, female kelts must not only survive reconditioning but also remature and produce viable eggs. Questions regarding reproductive performance of reconditioned fish underlie issues raised regarding kelt reconditioning projects during ISRP review (ISRP 2011). We believe these issues can be best addressed by research aimed at an improved understanding the life history and physiology of post-spawning steelhead.

Iteroparous female salmonids have two major post-spawning life history trajectories (Chaput and Jones 2006; Keefer et al. 2008; Rideout et al. 2005; Rideout and Tomkiewicz 2011). After a spawning event, some fish are able to restore energy lost during migration and spawning, redevelop a mature ovary, and spawn the next year. These fish are termed consecutive spawners. Other fish do not initiate redevelopment of the ovary for the next spawning season, but instead skip a year. These fish are termed skip spawners. We hypothesize that these life history trajectories are the result of the effect of energy balance on maturation decisions made during seasonally defined critical periods. The influential critical period model of the first reproductive maturation (puberty) in salmonids posits that maturation is initiated during a decision window approximately one year prior to spawning (Campbell, et al. 2006b; Satterthwaite, et al. 2009; Shearer and Swanson 2000; Thorpe 2007). This decision is made based on energy reserves. If maturation is initiated during this critical period, it may be arrested at a second critical period before the onset of exogenous vitellogenesis, if energy reserves are not sufficient (Yamamoto, et al. 2011). We hypothesize that a similar decision mechanism regulates rematuration in post-spawning steelhead. Consistent with this idea, we found that energy restriction affected reproductive development within 10 weeks after spawning in female rainbow trout (Caldwell, et al. 2013; Caldwell, et al. 2014). In post-spawning fish, energy driven decisions take place in the context of the extreme energy deficit incurred by migration and spawning (Penney and Moffitt 2014a, 2014b, 2015). Threshold energy levels for maturation or rematuration are determined by the genetic makeup of the fish and subject to selection (Carlson and Seamons 2008; Hutchings 2011).

It is now well established that some female steelhead kelts remature after a summer of reconditioning, whereas other fish do not, and that plasma E2 level from mid-August onward indicates maturation status. Evidence in both steelhead kelts and post-spawning rainbow trout suggests that the initial decision to remature is made early, before mid-July for kelts and during the 10 weeks after spawning in rainbow trout (Bromage, et al. 1992; Caldwell et al. 2013; Caldwell et al. 2014; Hatch, et al. 2013a). Plasma E2 levels in rematuring and non-rematuring kelts for 2015 at Prosser and Dworshak were similar to previous years. A shift upward in the high mode is probably due to the later sampling date. At DNFH, many Fish Creek females had plasma E2 levels in the 700-900 pg/ml range. Since the spawn timing of Fish Creek fish is very late, it is possible that these fish, which were classified as non-rematuring, were actually early rematuring fish. These fish are being held for further reconditioning, so maturation status will become clear as the season advances. Plasma E2 levels were shifted upward in both the low and high modes in Winthrop kelts. The reasons for this are not known, but may relate to the genetic stock or physiological condition of the fish. Winthrop kelts had some of the highest muscle lipid levels and condition factors ever observed in any Columbia Basin kelt project (M. Abrahamse, personal communication). The similarity in E2 levels between reconditioned Winthrop kelts and maiden steelhead at Wells dam suggests that reproductive development is on track in the rematuring kelts. All Winthrop kelts were released this fall as the facility is being prepared for year round fish holding.

Female consecutive maturation rates were high at all projects this season. It is possible that this relates to pre-capture environmental conditions common to the three projects. The high consecutive maturation rates found in Snake River kelts was particularly notable. Previously, Snake River steelhead, and steelhead from the Skeena and Nass systems in British Columbia, which have a life history similar to Snake River B-run steelhead, have been found to repeat spawn predominantly as skip spawners Keefer et al. 2008; Moore, et al. 2014). This has been hypothesized to be due to the longer migration and later spawn timing of these fish. The present results show that high consecutive rematuration rates are possible for Snake River steelhead in captive reconditioning. Captive kelts do not undergo the long return migration during warming river temperatures that natural repeat spawning Snake River steelhead must undergo. Obtaining kelts soon after spawning, and proper husbandry and feeding protocols to reverse the energy deficit incurred by migration and spawning are likely reasons for the improved results with Snake River kelts this season.

Non-rematuring fish held for a second year rematured at very high rates (90% or higher) in 2015 at both Prosser and DNFH. This adds to a growing body of data showing that non-rematuring females will remature as skip spawners if held for a second year. Skip spawning is a natural life history in Columbia Basin steelhead. Increased size, fecundity, and energy reserves in skip spawners would be expected to result in greater relative reproductive success versus maidens or consecutive repeat spawners. The presence of skip spawners increases life history diversity, which would be expected to increase population stability in steelhead populations (Moore et al. 2014; Schindler, et al. 2010). Moreover, whether and how much culture conditions can influence the proportion of consecutive and skip spawning kelts in captive reconditioning is not well understood. These considerations suggest that Columbia Basin kelt reconditioning programs should find ways to accommodate the skip spawner life history.

During maturation in male salmonids, the testes produce large amounts of testosterone. Testosterone is converted to 11-KT by enzyme systems in the Leydig cells of the testes. Plasma 11-KT levels were bimodally distributed in male steelhead kelts sampled in the fall at Prosser, indicating that rematuring and non-rematuring individuals are present. This result is not surprising: during necropsy of mortalities at Prosser, male fish with no evidence of maturation in the testis have been found. Because the energy required for reproductive maturation is lower in males than in females, one might hypothesize that consecutive maturation rates for males would be higher than those for females. On the other hand, males remain in spawning tributaries longer than females and expend more energy (Quinn and Myers 2004), which could lead to a lower consecutive rematuration rate. The present finding of similar male and female consecutive rematuration rates does not strongly favor either hypothesis.

Testosterone can also be converted to E2 by aromatase activity, which is found in a number of tissues including brain and fat. Elevated E2 levels in some rematuring males are likely due to conversion of circulating testosterone to estradiol by tissue aromatase activity. A few male kelts had plasma E2 levels in the range of rematuring females. However, all of these males were rematuring based on 11-KT level. Only one female kelt had an elevated 11-KT level. This fish also had a rematuring 11-KT level. Prosser kelts were classified as male or female based on appearance for the analysis reported here. It is possible that some fish may have been incorrectly classified. The female with elevated 11-KT may actually be a male. Additional ongoing work will enable us to identify the sex of each fish using genetic markers. Combined with plasma E2 and 11-KT levels, this will enable us to classify all fish as rematuring or non-rematuring males or females.

Reproductive Performance of Maiden and Repeat Spawnings of Steelhead

In their recent review of the Upper Columbia Kelt Reconditioning Program, the ISRP recommended that: "Methods to assess the fat levels, maturation timing, fecundity, egg size, and gamete viability of the project's reconditioned kelts need to be developed and implemented…" (ISRP Memorandum 2014-9, Qualification 3). To address ISRPs recommendation, we are conducting an experiment to assess reproductive performance in hatchery origin kelts at DNFH.

It is difficult to directly to assess egg quality and fecundity in wild fish, because wild fish spawn naturally before collection, and reconditioned wild fish are released to spawn naturally. The DNFH hatchery origin kelt model provides a unique opportunity to directly assess egg quality and fecundity in a large number of maiden spawners. If these fish can be successfully reconditioned, egg quality and fecundity in the first spawning can be directly compared to the second spawning. Production of high quality eggs is necessary for reconditioned kelts to contribute to listed Snake River steelhead populations. If issues with egg quality are identified, they will need to be addressed in order for the project to succeed. On the other hand, fecundity increases with body size in salmonids (Quinn 2005), suggesting that reconditioned kelts should have higher fecundity than maiden fish. The production of eggs that can be fertilized and develop successfully is a necessary but not sufficient condition for reproductive success of reconditioned kelts in the wild. However, if egg quality and spawning success are equal, then the relative fecundity of reconditioned kelts can provide an estimate of the productivity of reconditioned kelts versus maiden steelhead. Thus, assessment of egg quality and fecundity in reconditioned kelts is a step toward our goal of measuring the relative reproductive success of reconditioned kelts.

Survival and maturation rates of hatchery origin kelts improved in 2015 versus 2014. The reasons for this likely include better fish condition at intake and more consistent fish care. Maturation percentage in years without issues with fish condition at intake or fish care have been in the 20-30% range, which may reflect what is possible for the genetic background and migration conditions of the DNFH hatchery stock under our current culture conditions. Survival was lower than our maximum survival rate of 45% obtained in 2013. This may be due to head injuries in a proportion of fish. These injuries were determined to be due to fish getting their heads caught between the sides of the tanks and PVC sheaths along the tank walls installed to hold oxygen probes. No new injuries were observed after the oxygen probe sheaths were removed partway through the season.

Maturation rates of kelts held for a second year of reconditioning have been consistently high, indicating that fish most that do not remature as consecutive spawners after one summer of reconditioning are actually skip spawners which will remature the following season. However, survival of kelts over the second year has not been as good as anticipated, ranging from 50% to 20%. Survival over the second year is measured over a time period twice as long as survival to the late summer to fall sampling, which accounts for part of the difference. We believe that survival rates for skip spawners can be improved with improved holding facilities.

Plasma E2 levels have consistently shown complete separation between rematuring and non-rematuring DNFH hatchery kelts by August to September, similar to our results in wild kelts at Prosser (Branstetter et al. 2011; Hatch et al. 2013a; Hatch et al. 2012). Plasma E2 levels in rematuring kelts were in the 6,000-20,000 pg/ml range, similar to Prosser kelts and considerably higher than maximal levels in maturing rainbow trout. Plasma E2 levels increase to a peak approximately four months before spawning in rainbow trout (Prat, et al. 1996; Tyler and Sumpter 1996; Tyler, et al. 1990), so levels in kelts sampled in August to September are likely less than maximal. The high E2 levels in rematuring kelts suggest a high level of reproductive investment in these fish.

Egg weight, GSI, and fecundity increased with length in both maidens and kelts, as expected (Quinn 2005; Quinn et al. 2011). The steeper slope of the regression lines in kelts versus maidens indicates a greater increase in reproductive investment per unit increase in length in kelts than in maidens. We hypothesize that this is due to better nutritional condition in kelts resulting in less adjustment to reproductive effort by atresia. Consistent with this hypothesis, GSI was not reduced in kelts versus maidens, even though kelts had much higher condition factors and lipid stores at spawning than maidens (data not shown), resulting in a greater somatic weight. This suggests that reproductive investment in steelhead may be determined by mass at spawning, rather than length.

Kelts were generally superior to maidens in measures of reproductive performance, suggesting that kelts released to spawn naturally should be more productive than maidens. The increase in fecundity of kelts suggests that they should produce approximately 1.4 fold the number of offspring of maidens, and the increase in egg size suggests that kelt offspring will begin life with a size advantage that should result in increased survival versus maidens. The greater fecundity of Atlantic salmon repeat spawners results in a disproportionate contribution to population productivity (Halttunen 2011; Moore et al. 1995; Niemela et al. 2006a). Skip spawning reconditioned kelts were expected to have even higher fecundity than consecutive spawning fish, however, this was not found in the comparison of spawning categories conducted here. However, as this study progresses, the analysis will be further refined by directly quantifying changes in fecundity and egg size in the maiden and kelt spawnings of the same fish, which should help clarify things. Fertilization success in consecutive repeat spawning reconditioned kelts was not significantly different from maiden spawners. However, fertilization success was significantly reduced in skip spawners versus maidens. A number of skip spawners were observed to have infections in the body cavity at their second spawning, which may account for the reduced fertilization success. Further study is required to determine the reasons for reduced fertilization success in skip spawners and correct the problem. However, since skip spawning is a normal life history in steelhead, it is not anticipated that this problem is inherent in the biology of the fish.

The ovulation timing of consecutive and skip spawning reconditioned kelts was 1-3 weeks earlier than their maiden ovulation. How closely this corresponds with the shift in spawn timing in kelts released to spawn naturally is not known. One would expect that females would be able to adjust ovulation timing to some degree based on environmental conditions and the presence or absence of ripe males. Consistent with the present results, Atlantic salmon repeat spawners have been found to ascend rivers earlier than maiden spawners (Niemela, et al. 2006b). Results suggest that spawn timing was not substantially altered by artificial reconditioning. Given the broad spawn timing of steelhead, we would not expect an advance of 1-3 weeks would cause synchronization issues with finding mates or fry emergence timing.

Kelts did not increase in length over the first six months of reconditioning, but did increase during the second six months. This was the case for both consecutive and skip spawners, suggesting that the fish first replenish muscle and lipid tissue lost due to the demands of migration and spawning (Penney and Moffitt 2014a, b, 2015), and then initiate skeletal growth. Weight growth rate was elevated in consecutive versus skip spawners from intake to August. This is before ovarian growth would be expected to substantially contribute to increases in weight. Similar to these results, elevated growth rates and increased late summer to fall muscle lipid levels have been consistently found in rematuring Prosser kelts. The consistent and strong association of growth rate and maturation suggests that 1) increased growth rate stimulates maturation, and/or 2) maturation stimulates growth. Evidence exists for both of these possibilities. Growth rate has been found to greatly impact divergent maturation within populations of other salmonids, such as Chinook (Shearer, et al. 2006), and body growth has been found to influence oocyte development rate during the critical period for initiation of maturation in

Coho (Campbell, et al. 2006a; and 2006b). On the other hand, the earlier stages of the maturation process stimulate feed intake and growth in Atlantic salmon (Kadri, et al. 1996; Stead, et al. 1999), which may be due to growth stimulatory effects of reproductive steroids and other gonadal factors (Bhatta, et al. 2012).

Muscle lipid levels showed a clear pattern of increase up to six months prior to spawning followed by decrease during the final six months in both consecutive and skip spawners. The decrease in muscle lipid stores in rematuring fish during the final six months is likely due to mobilization to support ovarian development. During exogenous vitellogenesis, which occurs during the final six months of ovarian development, stored lipids are mobilized and transported to the ovary, where they are incorporated into the eggs (Lubzens, et al. 2010; Tyler and Sumpter 1996). Significantly greater muscle lipid levels in consecutive spawners versus skip spawners after the first six months of reconditioning may be due to appetite stimulation during early maturation. One year after their maiden spawning, skip spawning kelts had increased lipid levels to much higher than kelts at intake in the spring, which may account for the much higher rematuration percentage of fish held for a second year.

Effect of Different Diets on Lipids and Maturation Success

Studies conducted from 2009-2011 at the reconditioning project at Prosser showed that muscle lipid levels in the fish at release are strongly related to whether fish show characteristics associated with successful spawning after release (Branstetter, et al. 2010, 2011). Female fish with high muscle lipid levels at release were more likely to be consecutive spawners undergoing active ovarian development at the time of release, whereas females with lower muscle lipid levels at release were more likely to be skip spawners, fish with undeveloped ovaries that would spend an additional year in the ocean prior to maturation in the natural environment (Keefer et al. 2008). Both female and male fish with high muscle lipid levels at release were more likely to be detected migrating upriver after release, and reconditioned kelts that were recaptured during downriver migration the spring after release were fish that had very high muscle lipid levels at release. These findings suggest that treatments which increase muscle lipid levels in the fish at release time will increase the proportion of kelts that migrate and spawn successfully in the river after release.

There is a strong relationship between dietary lipid levels and carcass lipid levels in salmonids (Halver and Hardy 2002). Thus, supplementing our diet with additional sources of readily available lipids may be effective at increasing muscle lipid levels in reconditioned kelts. The feeding motivation of kelts is low at intake into reconditioning. Previously Cyclopeeze (Argent) was utilized (Hatch et al 2013a and Hatch et al. 2014) by topcoating feed along with fish oil. This technique showed great promise but supplies of this resource became scarce and unreliable to obtain (Hatch et al. 2013a). We contacted Dr. Rick Barrows of the U.S. Department of Agriculture Aquaculture Research group to assist us in producing a better feed that we could tailor to the needs of steelhead kelts. He suggested that we utilize a similar product, artemia cysts or brine shrimp, and that improved diet conditions could be incorporated more effectively into the pellet by producing a semi-moist pellet that incorporated the feed into the pellet. This would have the effect of fish more readily consuming the additive and not producing as much waste from the topcoating being removed when placed into the water column.

The results of the preliminary diet trial were encouraging. Fish fed the semi-moist Barrows diet increased in weight at about 1.5 fold the rate of fish on the Standard diet, and had substantially higher condition factors and plasma E2 levels in the fall. This suggests that energy reserves and investment in ovarian growth were greater in the Barrows diet fish. Data are insufficient at this point to statistically evaluate the effect of diet on maturation rate, however, a trend toward a higher maturation rate in the

Barrows diet was found. All of these results point to a potential benefit of the semi-moist diet. This result should be confirmed with further trials.

After reconditioning in the ocean, steelhead may spawn either in the same year, known as consecutive spawning, or in the following year, known as alternate- or skip-spawning. Consecutive repeat spawning and alternate (skip) repeat spawning are diverse life histories found within populations of successfully repeat spawning (iteroparous) post-spawn fish (kelts), which have been detected in the wild in Alaska (Nielsen, et al. 2011), and on the Snake River (Keefer et al. 2008), and in the captive kelt reconditioning project on the Yakima River (Branstetter, et al. 2011; Hatch et al. 2013b; Hatch, et al. 2012), and Upper Columbia (Abrahamse and Murdoch 2013). The causes and consequences of alternate reproductive life histories in post-spawning in steelhead have been little studied, although relevant information is available in Atlantic salmon. Atlantic salmon repeat spawning kelts add life history variation to populations and function as population stabilizers (Halttunen 2011). In naturally repeat spawning Atlantic salmon, egg size was decreased in consecutive spawning kelts versus skip spawning kelts, possibly due to reduced energetic reserves for ovarian development (Reid and Chaput 2012). The availability of prey in the estuary was associated with differing migration patterns and return proportions of consecutive and skip spawners (Chaput and Benoit 2012), suggesting that post-spawning life history is plastic and depends on feeding conditions in the ocean. This is supported by studies in steelhead showing that maturation is associated with growth in the marine environment (Quinn, et al. 2011).

In this experiment, we aim to compare the reproductive performance of DNFH hatchery-origin female steelhead at their maiden spawning with that of kelts which survive and remature at their second spawning. Since we anticipate that repeat spawners may follow either a consecutive or skip spawning trajectory, we will compare reproductive parameters in these two types versus maiden spawners. This experiment is ongoing, and results may change as more data is collected and additional analysis is completed.

Homing and Straying of Reconditioned Kelts

In spawning migrations of fishes, three types of homing are recognized (McCleave 1967): 1) natal homing: the return of adults to spawn in the same location in which they were hatched, termed "reproductive, parent stream, or natal homing" by Lindsey et al. (1959); 2) repeat homing: the return of adults to spawn in subsequent breeding seasons at the location of initial spawning; and 3) in-season homing: the return of adults within the same breeding season to the location of initial choice after displacement. With respect to reconditioned kelt steelhead, some data exists regarding natal homing, and much more data demonstrates repeat homing.

The following sources provide conclusive data confirming repeat homing of reconditioned kelt steelhead (Table 5). First, in the Yakima River, steelhead tagged (radio or PIT) prior to their first spawning event and detected in tributary streams exhibiting behavior consistent with spawning were later collected as kelts at the CJFH and reconditioned. Detection of these fish in the same tributaries during repeat spawning events provides conclusive data confirming repeat homing. In the Yakima River all 27 fish that we detected as maiden and kelts returned to spawn in the same tributary, thus exhibiting no straying. Second, PIT detections of reconditioned kelt steelhead at in-stream arrays in Satus and Toppenish creeks in the Yakima River basin accompanied by GSI of the same kelts to Satus or Toppenish creeks provides additional conclusive data on repeat and natal homing. The third conclusive data source is from Omak Creek (Okanogan River tributary), where kelt steelhead were collected at a weir migrating out of the stream and following reconditioning were released near the mouth of the Okanogan River, and later detected at the Omak Creek weir on their repeat spawning run. Our last conclusive data source for repeat homing is from the upper Yakima River, where all adult fish crossing Roza Dam are sampled and PIT tagged. Fish initially tagged at Roza Dam that participate in the reconditioning program and are detected at Roza Dam on a repeat spawning run provide conclusive data on repeat homing.

Table 5. Observed and inferred homing from artificially reconditioned kelt steelhead in Omak Creek and the Yakima River from 2001 to 2015. Column A consists of fish with tag detections (PIT or radio) in spawning tributaries as maiden and repeat spawners. Column B are fish with tag detections in tributaries as repeat spawners and consistent GSI conformation of reporting group (pending). Column D are fish with PRO detections as repeat spawners. Column E are post-repeat spawn fish collected at CJFF a second time.

	Conclusive Evidence for Homing				Consistent with Homing		
Location	A. Maiden/ Repeat Spawner Tag Detection	B. Repeat Spawner Tag Detection + GSI confirmation	C. Conclusive Homing total A+B		D. Repeat spawner PIT Detection at PRO	E. Post Spawn Repeat Spawner Recaptured at CJFF	F. Consistent with homing, some fish are in both D and E
Yakima R.	27	200	227		561	103	629
Omak Cr.	11	-	11		-	-	-
Total	38	200	238		561	103	629

In addition to the conclusive data on repeat homing, we have collected data that is consistent with homing. These data are at a broader scale, and thus not as conclusive (Table 5). First, reconditioned kelt steelhead released downstream of Prosser are detected crossing Prosser. The fish were all collected in Yakima River as kelts and their initial upstream movement after reconditioning is consistent with repeat homing. Second, a number of steelhead collected as pre-spawners in the South Fork Clearwater were air-spawned, reconditioned, radio-tagged, and released. Subsequent detections of these fish in the SFCR are consistent with repeat homing. Third, some steelhead reconditioned and released in the Yakima program have been collected as post-spawners a second time at the Chandler Juvenile Monitoring Facility. These fish spawned upstream of Prosser on their initial and subsequent spawning run thus providing data consistent with repeat homing.

Lastly, we compared the spawning location of natural origin steelhead tagged at LGR against the RG identified by GSI for each tagged individual. Out of a candidate list of over 20,000 PIT-tagged steelhead, we were able to assign 8,711 individuals to a spawning location by assessing the dates they entered and emigrated from a given tributary, the timing of that period relative to the period of spawning, and subsequent detections. Of those individuals 2,096 had accompanying GSI assignments exceeding 80% probability. Scale analysis identified 20 of these individuals as repeat spawners based on the presence of a spawning check with the remaining 1,945 individuals classified as first-time spawners. Three of the 20 repeat spawners (15%) spawned in a location that was not in agreement with their accompanying GSI assignment, whereas 330 of the 1,945 of the first-time spawners (17%) spawned in a location that was not in agreement with their GSI assignment. Based on this analysis, natural origin repeat spawners do not stray at a higher rate than natural-origin first-time spawners.

Evaluating Steelhead Kelt Management Scenarios to Increase Iteroparous Spawners in the Columbia River Basin

We evaluate kelt steelhead management options and we compare three geographically different long term reconditioning programs. It is thought that downstream passage through the hydrosystem limits repeat spawner steelhead in the Columbia River (Wertheimer and Evans 2005; Wertheimer 2007). In recent years, there may be some evidence that emigrating kelt survival has improved as a result of smolt management actions (e.g. removable spillway weirs, mandated spill). Colotelo et al. (2014) reported that 27.3% of kelts tagged at or upstream of Lower Granite Dam (river kilometer 695) survived to Martin Bluff (river kilometer 126) passing 8 hydroelectric dams along the way. Collecting and transporting kelt steelhead around hydroelectric projects could improve emigration survival and result in increased repeat spawner abundance. Our goal is to compare the benefits of long term reconditioning to alternate kelt management treatments like transporting kelts downstream of the hydropower system. Our team recently published a manuscript comparing kelt management options (Trammell et al. 2016).

Long-term reconditioning demonstrated significantly higher return rates of repeat spawners (11-18%) than other treatments (1-3%) (Table 6). This result was supported in spite of variation in river, ocean, and fish condition between years that was incorporated into the error term in our analysis. The data extrapolation required in our analysis does not account for variation in environmental or fish conditions between years. However, this method does provide a best and worst case interpolation of data for earlier years in the long-term reconditioned group, thereby strengthening our ability to draw conclusions among the four treatments. For more in-depth analysis see Trammell et al. (2016).

Table 6. Sample size (N), mean, and grouping output for Tukey post-hoc test from ANOVA of PIT tag detections at Prosser Dam.

Treatment	N	Mean	Grouping
Long-term min	10	11.5	A
Long-term max	10	17.6	A
Short-term	7	3.2	B
Transport	7	0.9	B
Control	7	2.7	B

Strategy 2: Transportation

No steelhead kelts were barged to the estuary in 2015. Nearly all kelts collected at Snake River tributary weirs and at the Lower Granite Dam adult trap were made available to the reconditioning program at DNFH.

In 2015, kelt passing Lower Granite Dam experienced conditions similar to those experienced in recent previous years. This includes passing downriver primarily through spillway, turbine, or juvenile bypass system (JBS) routes. For kelt passing through the JBS, upon passing the Extended Length Submersible Bar Screens (ESBS's) and entering the gatewell environment, kelt passed through one of the existing 10" orifices or single prototype 14" orifice, into the juvenile collection channel, pressurized underground bypass pipe, and into the separator at the Juvenile Fish Facility (JFF). Upon entering the separator at the JFF, fish were either returned to the Snake River via the adult return flume or bypassed to the kelt holding tanks were they were processed by the Nez Perce Tribe for transport to Dworshak Dam for reconditioning or returned to the Snake River.

Strategy 3: Enhanced in-river migration

Analysis of Operating One Top Spillway Weir (TSW) at McNary Dam for Overwintering Adult Steelhead and Steelhead Kelts

Upstream or Overwintering Movements of Adult steelhead

Summer-run steelhead (*Oncorynchus mykiss*) typically migrate up the Columbia River from May – October, overwinter in the mainstem Columbia or tributaries, then spawn in tributaries the following spring. Active migration typically slows significantly in November, followed by a winter period characterized by relative inactivity although at least one ladder is operational at McNary Dam year round. Active migration typically resumes in the late winter or early spring, as river temperatures increase (Keefer et al. 2008). During active migration periods steelhead may pass upstream of the natal origin (overshooting), and require subsequent downstream movement to reach natal areas for spawning. In some instances, overshooting steelhead may require falling back over dams in an attempt to return to their natal river (Keefer and Caudill 2012). A fallback is a Pre-spawn adult that has not yet reached its natal spawning tributary. A downstream migrant can be either pre or post spawn. Downstream passage for summer steelhead after overshoot at dams is typically via turbines because it occurs outside the operation period of the juvenile bypass and voluntary spill for juvenile fish passage from November through early April (Ham et al. 2012 a, b).

Downstream Movements of Adult steelhead

After spawning in Snake River tributaries in early spring (Feb – April), steelhead kelts appear at mainstem dams in significant numbers as downstream migrants from late March through early June. It is important to distinguish the behavior and timing of kelts during migration from winter fallback and overshoot, which may have different patterns and management implications at each dam project.

Downstream movements through turbine, bypass, and spillway routes can potentially result in no harm, or can cause either a direct (immediate mortality) or indirect (injuries) source of mortality for adult steelhead. Overwintering summer steelhead that did not survive migrating through the FCRPS to a spawning area were nearly 3 times more likely to have fallen back through a dam than overwintering summer steelhead that survived to spawn in natal areas (60% vs.21%; Keefer and Peery 2007, Keefer et al. 2008). Minimum winter fallback rates at McNary Dam from 2005 through 2015 based on reascension of PIT-tagged fish have averaged 8.7% overall and ranged from 6.9% to 12.5% (Columbia River Dart data). Direct survival was significantly higher for the adult steelhead passing downstream through the TSW (97.7%) versus the turbines (90.7%) at McNary Dam (Normandeau Assoc. 2014). Wagner and Hilson (1993) estimated mortality rates for adult steelhead passing back through the McNary JBS from September 15 to December 15 at < 0.3% however, injury rates were relatively high at 58.8%. Bruising was the most common injury and likely caused during passage from the gatewell into the collection channel when passing through the 12 inch orifices.

Operation of the McNary Dam TSW and fallback rates were evaluated during the winter of 2014-2015 using hydroacoustics (Ham et al. 2015). Project discharge during this test (November 11 to December 14) averaged 135 kcfs overall and averaged 132 kcfs (range 105 to 156 kcfs) under the no spill treatment. Project discharge during the spill treatment averaged 138 kcfs (range 107 to 161 kcfs). Project fallback numbers increased with increased flows. In addition, operation of the TSW increased fallback numbers overall and fewer fish falling back via turbines however, fallback rates could not be calculated since the numbers in the forebay during the evaluation is unknown. During this test the fish guidance screens were operational; however, fish guidance was not evaluated.

An adult steelhead radio telemetry study conducted by the University of Idaho during the 2014-2015 TSW winter test found 4 of 17 (23.5%) radio tagged steelhead fell back during the no spill condition and 7 of 17 (41.2%) radio tagged steelhead fell back during the spill condition(Keefer et al. 2016). Sample sizes were small and insufficient to measure statistical differences in fallback rates.

In general there is a lack of data on impacts or benefits of operating the TSW at McNary Dam during the winter (1 evaluation from November to December) for adult steelhead including a lack of season wide information, no test results for operating the TSW with the guidance screens not deployed, and no information for river flow conditions less than 105 kcfs or higher than 161 kcfs. In addition, it is unknown if the increase in downstream passage during spill is volitional, non-volitional and which stocks are passing downstream at McNary Dam. Adult steelhead response to operation of the TSW and fallback rates would likely be different during other times of the year, when the screens are not deployed, or under different flow conditions.

Upstream Movements of Adult steelhead

McNary turbine steelhead passage mortality was estimated between 9.3% in a steelhead direct injury study using balloon tags (Normandeau Assoc. 2014) and 20.0% in an active tag study using Snake River kelts (Colotelo et al. 2013). McNary TSW steelhead passage mortality was estimated between 2.3% (Normandeau Assoc. 2014) and 2.8% (Colotelo et al. 2013). Fallback rates when the TSW was not operated were 24% and with the TSW operated 41% (Keefer et al. 2015). Using a combination of these data a TSW operation benefit can be estimated for a range of TSW passage efficiencies (Table 7).

Assumptions

- McNary fallback rate during no spill is 24% and all fish pass through the turbines (i.e., screens not deployed) (Keefer et al. 2015).
- McNary fallback rate during TSW operation is 41% and all fish pass either through the turbines or the TSW (i.e., screens not deployed) (Keefer et al. 2015).
- McNary turbine passage mortality is 9.3% and TSW passage mortality is 2.3% using estimates from Normandeau Assoc. 2014. Using estimates for kelts (Colotelo et al. 2013) turbine passage mortality is 20% and TSW passage mortality is 2.8%.
- Fallback rates represent the interannual average.
- Analysis did not include cumulative effects of multiple fallback events.

Analysis

1. Calculated the overall fallback mortality rate when the TSW was not operated between 2.23% and 4.80%. (Calculation 24%*9.3% = 2.23% and 24%*20% = 4.80%).

2. Calculated the overall fallback mortality rate when the TSW was operated for various levels of TSW passage efficiency on the potential turbine passage between 0% and 100% (i.e., at 0% efficiency operation of the TSW only the additional fallbacks passing via the TSW with turbine passage remaining the same as when the TSW was not operated and at 100% efficiency all fish fall back only via the TSW).

3. Applied route specific fallback mortality rates from Normandeau Assoc. 2014 and Colotelo et al. 2013.

4. Estimated the TSW efficiency rate at which operation of the TSW decreases overall fallback mortality below the estimated turbine passage mortality (2.23% and 4.80%; Table 7).

The efficiency rate at which operation of the TSW decreases overall fallback mortality occurs between 13% and 25% of the potential turbine fallbacks passing through the TSW rather than the turbine depending upon which route specific mortality rates (Normandeau Assoc. 2014; Colotelo et al. 2013) are used. Although this is the best data samples sizes were small from most sources and may or may not be representative (Table 8).

Table 7. Efficiency rate at which TSW operation decreases overall fallback mortality by shifting turbine fallbacks to the TSW.

				Overall Fall back mortality	
TSW passage of potential turbine fallbacks	**Turbine fallback rate**	**TSW fallback rate**	**Overall Fallback Rate (Keefer et al. 2015)**	**Using Normandeau Assoc. 2014 mortality rates**	**Using Colotelo et al. 2013 mortality rates**
0%	24%	0%	24%	2.23%	4.80%
0%	24%	17%	41%	2.62%	5.28%
4%	23%	18%	41%	2.55%	5.10%
8%	22%	19%	41%	2.48%	4.93%
13%	21%	20%	41%	2.41%	4.76%
17%	20%	21%	41%	2.34%	4.59%
21%	19%	22%	41%	2.27%	4.42%
25%	18%	23%	41%	2.20%	4.24%
29%	17%	24%	41%	2.13%	4.07%
33%	16%	25%	41%	2.06%	3.90%
38%	15%	26%	41%	1.99%	3.73%
42%	14%	27%	41%	1.92%	3.56%
46%	13%	28%	41%	1.85%	3.38%
50%	12%	29%	41%	1.78%	3.21%
54%	11%	30%	41%	1.71%	3.04%
58%	10%	31%	41%	1.64%	2.87%
63%	9%	32%	41%	1.57%	2.70%
67%	8%	33%	41%	1.50%	2.52%

71%	7%	34%	41%	1.43%	2.35%
75%	6%	35%	41%	1.36%	2.18%
79%	5%	36%	41%	1.29%	2.01%
83%	4%	37%	41%	1.22%	1.84%
88%	3%	38%	41%	1.15%	1.66%
92%	2%	39%	41%	1.08%	1.49%
96%	1%	40%	41%	1.01%	1.32%
100%	0%	41%	41%	0.94%	1.15%

Table 8. Sample sizes used to estimate efficiency rate at which TSW operation decreases potential turbine fallbacks resulting in a decrease in overall fallback mortality.

Data source	Turbine	TSW
Normandeau Assoc. 2014	167	222
Colotelo et al. 2013	5	36
Keefer et al. 2015	4 of 17	7 of 17

Operation of the TSW at McNary Dam outside of the spill for fish passage season (September 1 to April 6) would likely benefit populations with high levels of overshoot behavior such as John Day and Umatilla River stocks by providing a safer downstream passage route. However, for adult prespawn Snake River steelhead (including B-run steelhead) which need to migrate upstream to spawn upriver of McNary Dam, the operation of the TSW at McNary Dam outside of the spill for fish passage season is likely to be detrimental due to increased fallbacks leading to increased delay and mortality unless operation of the TSW decreases the potential turbine fallback by at least 13 to 25%.

John Day and Umatilla River Steelhead

Within the FCRPS, McNary Dam has a relatively high level of steelhead overshoots that are primarily comprised of John Day and Umatilla river stocks. Radiotelemetry studies completed from 1996-2003 suggested that 17.9% to 54.2% of overwintering steelhead that fallback past McNary Dam were likely overshoots (Boggs et al. 2005). Wilson et al. (2010) reported that of 46% (n=114) of the 2008-2009 John Day River origin steelhead adults detected at Bonneville Dam (n=247) overshot the John Day River and passed McNary Dam. A minimum of 43% (n=49) of these 114 John Day River steelhead overshoots fell back downstream over McNary Dam and were detected in the John Day River.

Operation of one TSW at McNary Dam may provide a survival benefit to McNary forebay overwintering steelhead that overshoot natal downstream tributaries. We estimated the magnitude of adult steelhead overshoots at McNary Dam by examining fish ladder PIT-tag detections at Bonneville and McNary dams for adult returns that spawned from 2006 through 2013. The analysis start date was based on the first year that returning adults passed under the court ordered spill which began in 2005. We estimated the potential increase in adult returns to the John Day River by operation of the McNary TSW across various levels of passage efficiency for the TSW.

Several important assumptions are made throughout the analysis; the result is intended to be a conservative estimate of the maximum likely benefit to John Day River stocks. The following is a step-by-step description of our analysis:

Assumptions

- McNary TSW passage survival 0.977 (Normandeau Assoc. 2014).
- No McNary JBS passage due to removal of screens during winter months.
- McNary turbine survival 0.907 (Normandeau Assoc. 2014).
- 100% of overshoots attempt to fallback.
- If an overshoot survives the fallback event they return to the John Day River and successfully spawn.
- Survival from McNary tailrace to return to John Day River = 1.000
- A spawning return is comprised of passage at Bonneville and McNary dams from May 1 through April 30.
- Data included the 2006 through 2013 spawning years.
- Fallback estimates from 2006 to 2013 are typical.
- The analysis did not include the cumulative effects of multiple fallback events.
- Bonneville Escapement Estimate was not adjusted for harvest and based on juvenile outmigration estimate.
- The adult PIT-tag returns sufficiently represent the entire John Day population for 2006 through 2013 spawners.
- Adult PIT-tag detection efficiency = 100%.

Analysis

1. Queried PTAGIS for adult detections at Bonneville Dam of John Day River origin (tagged as juveniles) from May 1, 2005-April 30, 2013 (Table 9).
2. Queried PTAGIS for adult detections at McNary Dam of John Day River origin (tagged as juveniles) from May 1, 2005-April 30, 2013 (Table 9).
3. Assigned spawning year for PIT-tag detections. Spawning year comprised returns from May 1 through April 30.

4. Removed duplicate tag codes (i.e., fallback reascension) and accounted for repeat spawners.

5. Estimated John Day River overshoot rate passing McNary Dam for each spawning year (Table 9).

6. Used Banks et al. (2014) estimate of John Day River returns to Bonneville Dam to estimate potential John Day River adult returns by year (Table 9).

7. Estimated percent fallback loss (direct survival estimates from Normandeau Assoc. et al. 2014) for various levels of McNary TSW passage efficiency (Table 7).

8. Estimated the number of steelhead that would be lost during fallback across a range of TSW passage efficiencies (Table 10)

9. Estimated the maximum potential increase (maximum benefit) in adult steelhead to the John Day River provided by operation of the TSW (Table 10)

Table 9. Numbers of unique PIT-tagged John Day River origin adult steelhead detected each spawning year (May 1-April 30) at Bonneville (BON) and McNary (MCN) dams, calculated overshoot rates at McNary Dam and estimate of John Day River escapement based on BON detections (Banks et al. 2014)

	2006	2007	2008	2009	2010	2011	2012	2013
John Day River Origin BON adult detections	66	119	110	245	418	377	285	150
John Day River Origin MCN adult detections	36	66	68	113	211	148	104	81
MCN Overshoot rate	55%	55%	62%	46%	50%	39%	36%	54%
BON estimate of John Day Escapement*	422	436	778	1,323	1,498	1,568	737	1,325

Table 10. Estimates of John Day River Basin adult steelhead escapement passing Bonneville Dam (BON; Banks et al. 2014) by spawning year, McNary Dam (MCN) fallback losses for various TSW passage efficiency rates, number of steelhead losses at various levels of TSW passage efficiency rates, number of steelhead losses at various levels of TSW passage efficiency, and max benefit of operating the TSW.

		2006	2007	2008	2009	2010	2011	2012	2013
Estimated John Day Escapement at BON		422	436	778	1,323	1,498	1,568	737	1,325
TSW Passage Efficiency	MCN fallback loss	Estimated steelhead project fallback losses for various levels of TSW passage efficiency							
0%	5.07%	21	22	39	67	76	80	37	67
5%	4.88%	21	21	38	65	73	77	36	65
10%	4.69%	20	20	36	62	70	74	35	62
15%	4.50%	19	20	35	60	67	71	33	60
20%	4.31%	18	19	34	57	65	68	32	57
25%	4.12%	17	18	32	54	62	65	30	55
30%	3.93%	17	17	31	52	59	62	29	52
35%	3.74%	16	16	29	49	56	59	28	50
40%	3.55%	15	15	28	47	53	56	26	47
45%	3.35%	14	15	26	44	50	53	25	44
50%	3.16%	13	14	25	42	47	50	23	42
55%	2.97%	13	13	23	39	45	47	22	39
60%	2.78%	12	12	22	37	42	44	21	37
65%	2.59%	11	11	20	34	39	41	19	34
70%	2.40%	10	10	19	32	36	38	18	32
75%	2.21%	9	10	17	29	33	35	16	29
80%	2.02%	9	9	16	27	30	32	15	27
85%	1.83%	8	8	14	24	27	29	13	24
90%	1.64%	7	7	13	22	25	26	12	22

95%	1.45%	6	6	11	19	22	23	11	19
100%	1.25%	5	5	10	17	19	20	9	17
Max Benefit		16	17	30	51	57	60	28	51

On average 50% of the adult steelhead that were PIT-tagged as juveniles in the John Day River Basin overshot McNary Dam as adult returns from 2006-2013 spawning years (range 36% to 62%). Based on the 2014 McNary direct injury evaluation of steelhead passing through turbines fall back losses without spill are estimated to be approximately 5% of the John Day return or 21 to 80 adults per year (average 51 adult steelhead). Depending on the TSW passage efficiency, operating the TSW could provide a maximum benefit to the John River Basin steelhead returns of up to a 4% increase or 16 to 60 adults. This analysis did not include benefit analysis for the kelt passage March-April or benefits to other ESA-listed steelhead ESUs, although fallback of steelhead from all downstream stocks that overshoot McNary Dam would likely benefit from operation of the TSW since direct passage survival for TSW was 7% higher than direct turbine passage survival.

Enhancing Survival Through Hydro Facilities

The Kelt Management Plan (2013) section on Enhanced In-river Migration Strategy describes operational or structural modifications to hydro facilities that create conditions which could enhance survival rates of kelts passing a hydro facility. Under this section the most important category of structural modification has been installation of surface passage weirs and sluiceways, which was completed for the eight FCRPS dams between LGR and BON in 2009. Subsequent monitoring has broadly indicated that kelts and adult steelhead are effectively finding these routes and experiencing high downstream survival rates through these routes. However, return rates of repeat spawners have not increased substantially since efforts to enhanced in-river migration have been implemented, thus suggesting that this strategy alone is not likely to meet the 6% abundance increase goal.

For more than a decade operation of the Lower Granite Dam JBS has begun by March 25 and spring spill for juvenile fish and kelts passage by April 3. At McNary Dam operation of the JBS begins by April 1 and spring spill for juvenile fish and kelts passage begins by April 10 (Table 11).

A consistent theme of past kelt studies is that sampling for kelts typically begins once the JBS is watered up. Adult steelhead are present during initial water up indicating a potential for missing the earliest portion of the kelt outmigration, however, adult steelhead encountered in the JBS earlier than mid-April are typically pre-spawn adults (Keefer et al. 2015).

Table 11. Fish Passage Plan (FPP) and actual dates the JBS and spill for fish passage operations begin at Lower Granite and McNary Dams.

	Lower Granite Dam				McNary Dam			
	FPP JBS	**JBS Actual***	**FPP Spill**	**Actual Spill***	**FPP JBS**	**JBS Actual***	**FPP Spill**	**Actual Spill***
2015	25-Mar	17-Mar	3-Apr	3-Apr	6-Apr	30-Mar	10-Apr	29-Mar
2014	25-Mar	20-Mar	3-Apr	3-Apr	1-Apr	28-Mar	10-Apr	7-Mar
2013	25-Mar	18-Mar	3-Apr	3-Apr	1-Apr	26-Mar	10-Apr	1-Apr
2012	25-Mar	22-Mar	3-Apr	30-Mar	1-Apr	29-Mar	10-Apr	1-Apr
2011	25-Mar	23-Mar	3-Apr	30-Mar	1-Apr	27-Mar	10-Apr	8-Feb
2010	25-Mar	25-Mar	3-Apr	3-Apr	1-Apr	1-Apr	10-Apr	8-Apr
2009	25-Mar	24-Mar	3-Apr	3-Apr	1-Apr	26-Mar	10-Apr	9-Apr
2008	25-Mar	27-Mar	3-Apr	3-Apr	1-Apr	27-Mar	10-Apr	9-Apr
2007	25-Mar	25-Mar	3-Apr	27-Mar	1-Apr	28-Mar	10-Apr	14-Mar
2006	25-Mar	25-Mar	3-Apr	3-Apr	1-Apr	23-Mar	10-Apr	3-Apr
2005	25-Mar	25-Mar	3-Apr	30-Apr	1-Apr	28-Mar	10-Apr	10-Apr
Min		17-Mar		27-Mar		23-Mar		8-Feb
Max		27-Mar		30-Apr		1-Apr		10-Apr
Ave.		22-Mar		4-Apr		27-Mar		26-Mar

*Actual dates came from Columbia River DART and 1st PIT-tag detections for the JBS

Narum et al. (2008) reported the median and 95% CI collection dates at Lower Granite Dam for the Clearwater River (4/15; 4/11-4/20) and Asotin Creek kelts (4/23; 4/20-5/16) in 2002. Colotelo et al. (2013 and 2014) reported Snake River Dam kelts passage beginning in mid-April (Table 12 and Table 13).

Keefer et al. (2015) radio-tagged adult late run steelhead at Bonneville Dam and followed them upstream through the FCRPS, to the spawning grounds and back down through the FCRPS as kelts. Kelts entered the FCRPS from late March through mid-May, with peak abundance in April at most dams with the earliest fallback events by post-spawn kelts in late March or early April. This emigration timing meant that most kelts migrated downstream through the FCRPS after initiation of the spill for fish passage operation (Figure 4 and Figure 5).

Kelts travel time from Lower Granite Dam to McNary Dam is an average of 7 days (Wertheimer and Evans 2005; Keefer et al. 2015). Snake River kelts would need to complete spawning by mid- March to pass McNary Dam prior to the spill for juvenile fish passage operations. In general, kelts are not passing

McNary Dam prior to the spill for juvenile fish passage operations, thus no modification of the operations at McNary Dam is warranted to facilitate kelts passage.

Table 12. Snake River steelhead kelts downstream passage timing Lower Granite Dam to McNary Dam (Colotelo et al. 2013)*.

	n	1st	10%	25%	50%	75%	90%	Last
LGR	124	21-Apr	26-Apr	30-Apr	10-May	11-Jun	19-Jun	30-Jun
LGS	291	21-Apr	27-Apr	1-May	11-May	30-May	17-Jun	2-Jul
LMN	263	23-Apr	28-Apr	2-May	11-May	29-May	15-Jun	30-Jun
IHR	233	24-Apr	28-Apr	3-May	12-May	30-May	14-Jun	30-Jun
MCN	211	25-Apr	29-Apr	3-May	12-May	30-May	12-Jun	1-Jul

* Early portion of the runs were not tagged due to permitting issues thus missed the 12.0% at LGR, 45.7% at Asotin Creek, 10.1% of Potlatch River, and 7.3% of Joseph Creek of the run.

Table 13. Snake River steelhead kelts downstream passage timing Lower Granite to McNary Dam (Colotelo et al. 2014)*.

	n	1st	10%	25%	50%	75%	90%	Last
LGR	144	14-Apr	17-Apr	23-Apr	28-Apr	21-May	5-Jun	17-Jun
LGS	364	17-Apr	28-Apr	5-May	13-May	24-May	6-Jun	22-Jun
LMN	294	19-Apr	2-May	11-May	15-May	25-May	7-Jun	24-Jun

* High runoff conditions in the Potlatch River and Fish Creek delayed the onset of tagging.

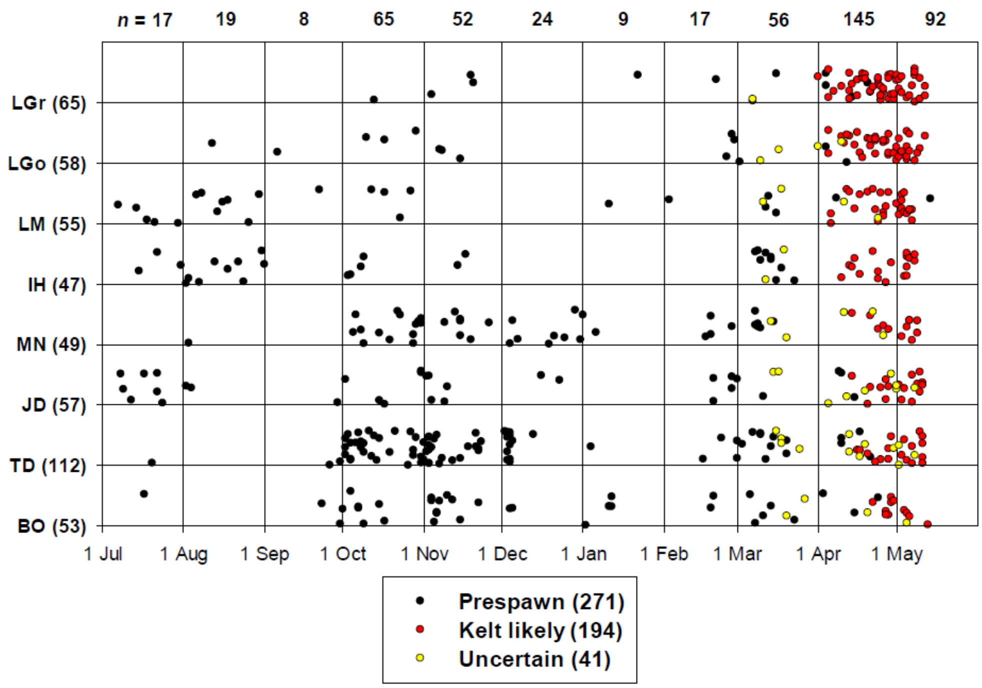

Figure 4. Estimated dates that radio tagged steelhead fell back at dams in 2013-2014. Fallback events are color coded to represent likely steelhead reproductive status at the time of fallback (Keefer et al. 2015).

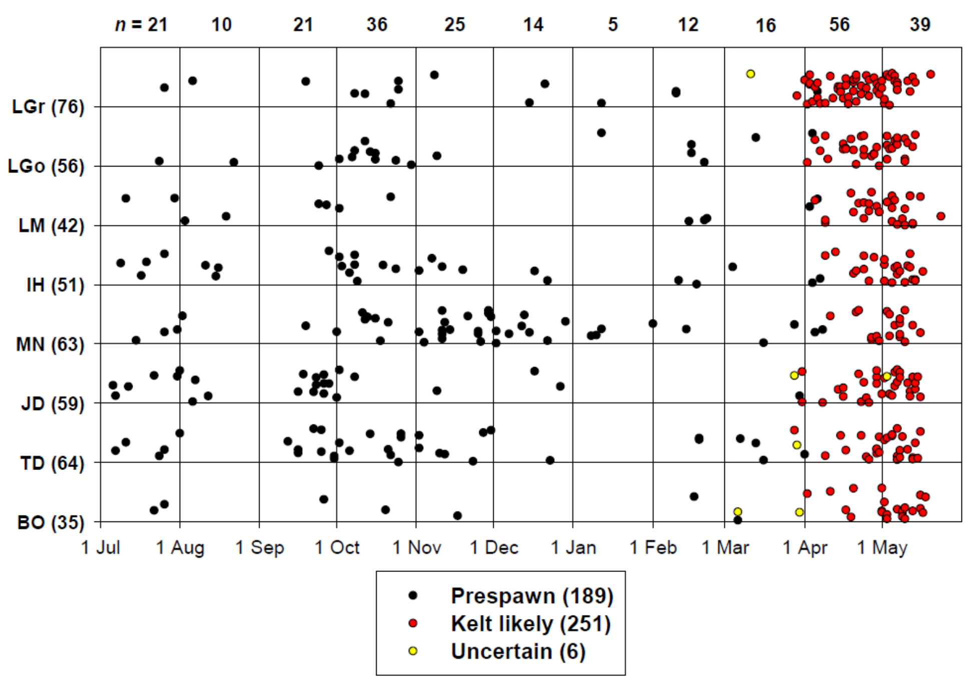

Figure 5. Estimated dates that radio tagged steelhead fell back at dams in 2014-2015. Fallback events are color coded to represent likely steelhead reproductive status at the time of fallback (Keefer et al. 2015).

Skip Spawners

Boggs et al. (2008) found that > 95% of steelhead kelts that were consecutive spawners or skip spawners passed McNary Dam after the initiation spill for fish passage season (April 3).

Recommendation

In general, increased spill increases overall fallback rates at dams. Operation of the TSW at McNary Dam outside of the spill for fish passage season to provide downstream passage may benefit downstream populations that overshoot their natal tributaries such as John Day and Umatilla stocks but is unlikely to be beneficial for upstream stocks such as Snake River or B-run steelhead unless operation of the TSW decreases the potential turbine fallback by at least 25%. Operation of the TSW at McNary Dam outside of the spill for fish passage is unlikely to benefit Snake River kelts (and particularly B-run kelts) because their downstream passage timing at McNary Dam occurs after the initiation spill for fish passage.

Future Planning (2016-2018) for infrastructure and research

Strategy 1: Long term reconditioning

The kelt reconditioning master plan will be submitted for Independent Scientific Review Panel (ISRP) review. This plan has seven sections including: 1. The Northwest Power and Conservation Council (NPCC) Three-Step review process; 2. Summary of Columbia River basin kelt reconditioning initiatives; 3. Motivation for the incorporation of kelts in Columbia River Basin fisheries management programs; 4. Summary of hydrosystem modification and observed improvements in kelt survival; 5. Alternatives considered to improve Snake River kelt survival; 6. Proposed Snake River kelt reconditioning program; and, 7. Facility alternatives. Following final ISRP and Council review, the plan will be revised and an engineering firm will be contracted to develop design documents and to construct the project.

Strategies 2 and 3: Transportation and Enhanced in-river migration

Upon completion of JBS Phase 1 construction activities in March 2017, kelt will pass through an upgraded JBS with new 14" orifices, open channel transportation channels and flumes, and improved dewatering structures. For kelt bypassed through the upgraded JBS while the system is in primary bypass mode, kelt will be directed to a new mid-river release location. When the facility is in facility bypass (aka collection mode), kelt will continue to experience similar routing and handling efforts as experienced in the current Juvenile Fish Facility. However, as part of the JBS upgrade, kelt retained in the existing onsite south kelt recovery tank will be able to be transferred directly from the tank to transportation vehicles (i.e. via a water-to-water transfer) through the installation of a new truck loading ramp and modifications to current valve systems.

In 2016, the Corps will evaluate the effectiveness of modifications and operational changes at the Lower Granite ladder to minimize a thermal barrier which may arise in late summer and early fall. A spray bar was installed at the ladder exit in winter 2015/2016 and behavior of adult sockeye, steelhead, and Chinook will be monitored when it is turned off and on will be monitored in summer 2016 with sonar camera. The temperature differential in the ladder will also be monitored, post installation of new pumps.

Adaptive Management Synthesis of current status and future planning

1. Columbia River steelhead populations upstream of Bonneville Dam are listed under ESA and need novel recovery strategies.

2. There is a relatively large abundance of kelt steelhead in the Columbia River Basin even in the upper most areas.

3. In general, repeat spawning steelhead make up a very small proportion of the spawning run.

4. Increasing repeat spawners in steelhead populations can have many positive effects on populations including increasing; genetic diversity, lifetime fecundity, and fitness since genes are distributed across generations.

5. Long-term reconditioning kelt steelhead provides 5 to over 100 times more repeat spawners than leaving the fish in the river.

6. Despite the understanding in recent years that the B-run life history is relatively uncommon outside the middle and south forks of both the Clearwater River and Salmon River, our results suggest otherwise. In fact age 2-ocean fish were prevalent among all 10 reporting groups. This finding has implications for management of steelhead populations in the basin, and provides evidence that regionally based classifications of life history types or their distributions warrants reconsideration.

7. The upper Salmon River region produces a disproportionate number of Snake River kelt steelhead, and is presumably an important factor in spawner abundance for that region. This result is mirrored among hatchery-origin fish.

8. As proposed in the Kelt Reconditioning Master Plan submitted to the NPCC , adding a production level kelt reconditioning facility will support achieving the goal of RPA Action 33, i.e. increasing the abundance of adult b-run steelhead.

9. Reproductive success studies are underway at a variety of scales: hatchery analog, spawning channel, and natural river. Results are showing trends that reconditioned kelts are successfully spawning and reproducing.

10. Reconditioned fish on the "Barrows" diet appeared to perform better than fish on the standard kelt diet. Efforts will continue to work with USDA to improve the diet.

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