2012-2013 Kelt Management Plan

July 9, 2013

Edited by Bonneville Power Administration

Background

As a strategy to increase ESA-listed steelhead in the Columbia Basin through the Federal Columbia River Power System (FCRPS), NOAA Fisheries identified actions to improve the productivity and abundance of steelhead kelts in two Reasonable and Prudent Alternatives Actions (RPAs) in the 2008 FCRPS Biological Opinion (BiOp). These two RPA Actions 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 #33 requires the U.S. Army Corps of Engineers (Corps) and the Bonneville Power Administration (BPA) to “prepare a Snake River Kelt Management Plan (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.

In Chapter 8.5 (FCRPS Biological Opinion, 2008), it is stated that NOAA’s analysis of Prospective Actions (Supplemental Comprehensive Analysis Hydro Modeling Appendix) indicates that a combination of transportation, kelt reconditioning, and in-stream passage improvements (e.g. spill-flow modifications) could increase kelt returns enough to increase the number of returning Snake River B-run steelhead spawners to Lower Granite Dam by about 6% (Supplemental Comprehensive Analysis Steelhead Kelt Appendix- Bellerud *et al*. 2007). Based on Table 1 in Bellerud *et al*. (2007), the Action Agencies interpret this 6% increase to be a 6% increase to the average B-run steelhead run abundance. Assuming a successful long-term recondition program and after adding a likely but unspecified abundance increase from in-river survival improvements, NOAA believes that it is reasonable to expect that an increase of 6% in B-run Snake River steelhead returns to Lower Granite Dam is possible.

Considering the potential gains in B-run spawners and the caveats discussed for each enhancement strategy, NOAA believes that an estimate of increased B-run returns could be somewhere in the 0.4 –9% range depending on the strategies adopted.

In practice, the goal of the program is to improve adult (female) returns of Snake River B-run steelhead to Lower Granite Dam by 6% (180 total increase in adult females above the baseline 3000 adult females estimated in Bellerud *et al*. 2007). A kelt reconditioning program in the Snake Basin may be critical for achieving run improvements, particularly if operational measures alone will not increase the returns of Snake B-run steelhead by an average of 6%.

Objectives of the 2012 Plan

The Kelt Management Plan for 2012 is intended to provide an annual update to the management framework introduced in the 2009 plan, which was revised with pertinent research results and status reports in subsequent annual plans:

http://www.salmonrecovery.gov/Hatchery/KeltReconditioning.aspx

A more detailed background and description on an integrated Snake River and upper and middle Columbia River Kelt Management Plan is provided by the 2010-2011 Kelt Management Plan: http://www.salmonrecovery.gov/Files/Hatchery/2010-2011%20Draft%20Kelt%20Mgmt%20Plan_12_23_10%20.pdf

This document details the current status of near and long-term planning for meeting 2018 BiOp goals, and presents results and evaluation from recent research. Updated lists of infrastructure needs and critical uncertainties and data gaps are provided to help direct future funding priorities for research and plan implementation.

The FCRPS BiOp states that a Kelt Management Plan should be prepared every year, along with annual progress reports citing the status of project implementations and milestones. Progress toward achieving the objectives of the Kelt Management Plan will be detailed in the 2013 and 2016 Comprehensive RPA Evaluation Reports. To reflect ongoing efforts, knowledge, and management priorities, the Kelt Management Plan will adapt and/or may change significantly in scope and format over time in order to maintain effectiveness and relevance in achieving plan objectives

The Snake River Basin Kelt Master Plan was drafted by the Nez Perce Tribe and Columbia River Inter-tribal Fish Commission (CRITFC) to develop facility specifications for kelt reconditioning sites in the Snake River. In 2013, the Master Plan will be vetted with regional managers and then submitted to the 3-step process developed by the Northwest Power and Conservation Council for capital improvement projects.

Synthesized alternatives and future planning

Prospective measures to improve abundance rates for kelt and overwintering B-run steelhead can currently be classified under three major strategies: 1. Reconditioning of kelts at specialized hatchery facilities, 2. Transportation of kelts to the Columbia River estuary, and 3. Operation of the hydropower system to enhance kelt passage during outmigration. Research on kelt reconditioning strategies have previously considered short-term and long-term approaches to aquaculture, as well as different release strategies. Recent research has provided some insight on the effects of passage through powerhouse and spillway routes at dams as well as survival through the system via in-river migration and barge/truck transport. Turbine survival and passage distribution rates are quite variable by hydropower project, but survival was typically substantially higher via traditional spillway, surface spill, and juvenile bypass system routes. Thus dam infrastructure improvements and operational changes to increase likelihood of spillway passage are considered a major strategy for prospective adult passage improvement. A second category of operational strategy involves collection and transportation of either with reconditioning or without reconditioning ("transport unfed"). Recent research has shown poor success rates among transported groups, thus future consideration of this alternative may require innovative or novel approaches which have not been previously considered.

Retrospective and Current status towards meeting objective

In 2012 a credit of 1.4 percent of the 6.0 percent estimated improvement goal to female Snake River B-run steelhead spawning population has been completed with the modified operation at The Dalles Dam for overwintering B-run steelhead, and preliminary kelt reconditioning efforts at Dworshak National Fish Hatchery.

Considerable research has been accomplished since the 2008 BiOp, addressing major questions on the life history of steelhead kelts in the Columbia River system, uncertainties relating to aquaculture techniques for adult steelhead, and operation of hydropower projects to maximize downstream survival for kelts and reservoir survival of overwintering steelhead. These recent gains in knowledge should put the Action Agencies on track to achieve the targeted 6% goal of increased abundance by implementing an improved reconditioning program and identifying strategies for transportation, in-river release and hydropower operations that have demonstrated the greatest success.

<u>Progress and planning towards achieving goal</u>

Alternative 1: Long Term Reconditioning

2008-2012 (Accomplishments and Results by end of CY 2012)

Background - Synthesis of alternatives, results and results relative to other kelt reconditioning programs

Long-term reconditioning steelhead is the process of collecting kelt phase fish during their seaward migration, containing them in a hatchery setting, and rehabilitating the fish by feeding special diets and treating pathogens for 5 to 7 months. Fish are then released back into the collection stream. After release (generally October), the majority of the fish move upstream, complete re-maturation, and spawn in the coming spring. The sex ratio of collections is generally skewed (80% +) toward female fish (Hatch *et al*. 2013). In the suite of kelt management options long-term reconditioning is the most time and resource consuming, and also yields the greatest benefits measured to date.

Since 2008, BPA has funded long-term reconditioning studies through project 2007-401-00, implemented by the Columbia River Inter-Tribal Fish Commission (CRITFC) and its member tribes. Long-term kelt reconditioning was conducted at a variety of locations including the: Yakima River; Clearwater River; Okanogan River; Hood River; and Deschutes River (Figure 1 *site map*). Each of these locations has somewhat different objectives and hypotheses being tested, but each site conducts or conducted long-term reconditioning that can be compared among locations and against "controls" to calculate benefits (Hatch *et al* 2012).

Reconditioning locations

Since 2008, long-term reconditioning studies were conducted at five locations in the Columbia River Basin. These collection locations and their distance from the ocean include: Hood River 180 RM; Shitike Creek (Deschutes subbasin) 303 RM; Yakima River 380 RM; Snake River 433 RM; and, Omak Creek (Okanogan subbasin) 566 RM.

The number of fish collected, handled, released, and held reconditioning vary at each location due to stream size, trap efficiency, and steelhead population size. Fish collection sizes range from as few as a dozen fish at Shitike Creek to thousands of steelhead at Lower Granite Dam. Collection techniques vary among locations with juvenile bypass systems used at Lower Granite Dam and on Yakima River and various weirs used at Hood River, Shitike, and Omak Creek. At all collection locations fish were graded by condition (good, fair, poor) and color (bright, intermediate, dark), and biological measures of length, weight, marks, time, etc were collected. Survival was calculated by dividing the number of fish surviving at the end of the reconditioning process by the number initially held for reconditioning.

We calculated long-term reconditioning benefits by comparing the survival rate of long-term reconditioned kelts from each location divided by three different control groups (Figures 2, 3). The control groups were: 1. Survival rates of in-river release groups to Bonneville Dam. 2. Literature values (Hockersmith *et al*. 1995). 3. The composition of repeat spawners in the run at large sampled at Bonneville Dam. None of these control groups are perfect comparisons, for example survival of the in-river release groups is return rate back to Bonneville Dam not the river of origin so these are biased high due to mortality that likely occurs between Bonneville Dam and the river of interest. However, the in-river groups are paired by year with the treatment groups reducing annual variation. This calculation yields a number that represents the relative positive or negative benefit of the treatment. For example if your long-term survival rate return rate was 4% and the control rate was 2%, the long-term reconditioning would benefit kelts 2x (4/2=2) versus leaving the kelts in the river. Comparisons were made within each year and across years using weighted means to account for different sample sizes among years.

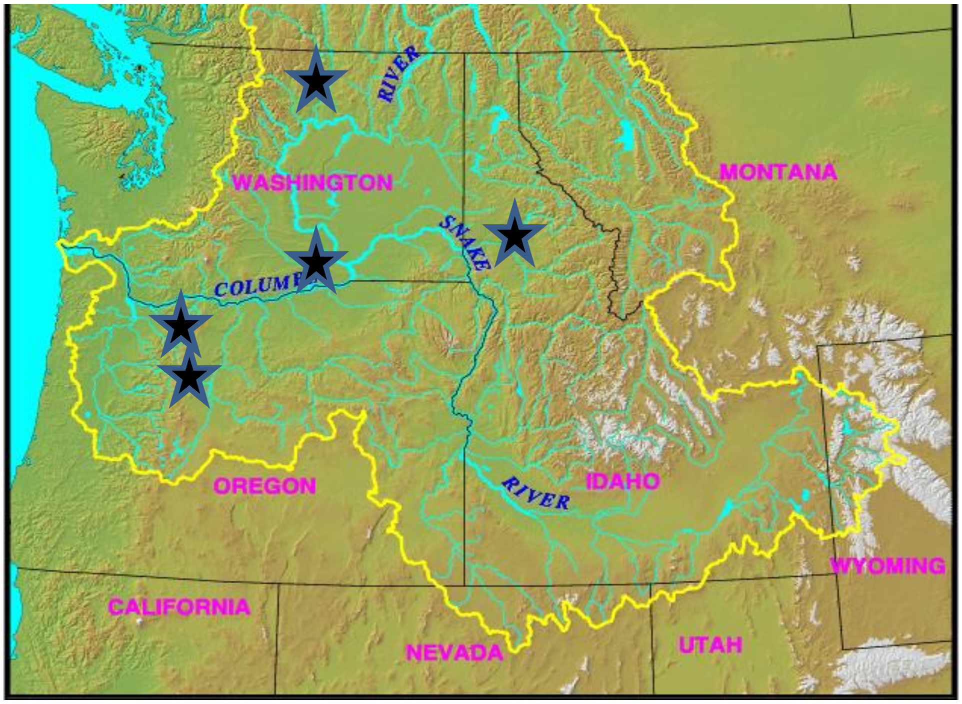

Figure 1 Map of long-term reconditioning sites (stars) including the: Okanogan River, Clearwater River, Yakima River, Deschutes River, and Hood River.

Figure 2. Survival rate of long-term reconditioned kelt steelhead collected at 5 locations from 2008-12. Shitike Creek fish were collected from 2005-08 and Snake River fish from 2010-12.

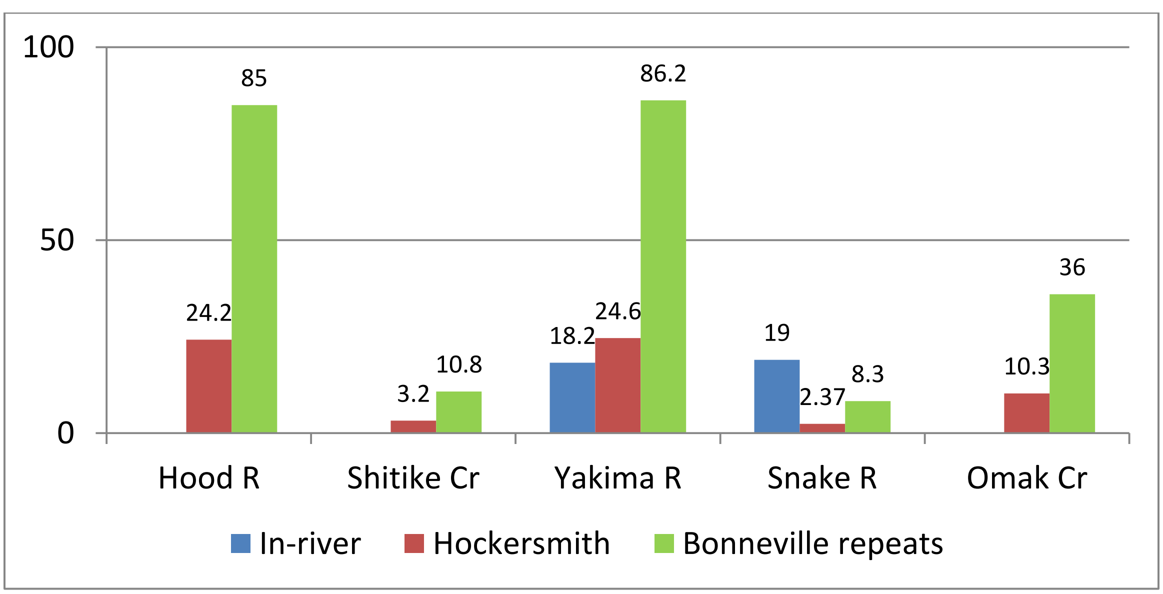

Figure 3 Relative benefits of long-term reconditioned kelt steelhead collected at 5 locations from 2008-12 compared to 3 "controls". Shitike Creek fish were collected from 2005-08 and Snake River fish from 2010-12.

Future Planning (2013-2018)

Research priorities and needs

RPA 33 calls for research and implementation of long-term kelt reconditioning as a measure to increase the number of viable females at spawning areas. Based on Bellerud *et al*. (2007), the Action Agencies interpreted the RPA 33 to call for actions to increase B-run steelhead abundance in the Clearwater River and other Snake River tributaries. Continued investigations life history and physiology of Snake River b-run steelhead and optimization of aquaculture techniques will be helpful for managing kelt reconditioning programs.

- What limits survival in captive kelt reconditioning programs? What are the major causes of mortality? Does survival relate to energy stores at arrival? Can survival of individual fish be predicted? What is involved in the initiation of feeding in kelts? What can be done to reduce mortality at intake and stimulate feeding?

In 2013, Nez Perce Tribe and CRITFC sponsored projects will continue to test additional management scenarios such as short-term reconditioning and in-river release. For example, Null *et al*. (2012) report return rates of 33% for kelts that were air-spawned, held and reconditioned for 3-5 weeks and then released back into the Sacramento River. This management scenario will be tested at Dworshak National Fish Hatchery in 2014.

- Are there differences in iteroparity rate between steelhead populations? What are the population structures and gene flow rates between Snake River A-run, B-run, and resident rainbow trout populations? What are natural repeat spawner rates, does it differ between A-run and B-run groups, and is there a genetic basis for differences?

CRITFC and the Nez Perce Tribe will continue to sponsor a Snake River steelhead genetic stock identification effort in collaboration with BPA and Idaho Department of Fish and Game. In this multiyear effort, steelhead, and rainbow trout sampled at Lower Granite Dam will be used to identify biometric and run-timing indicators for A-run and B-run steelhead, to genetically assign fish to the natal tributary, and to explore life history factors influencing iteroparity rates.

- When is rematuration determined in steelhead kelts, and what factors influence the decision to remature? Can fish be screened for rematuration status at intake? Can rematuration rates be increased by diets or other treatments in captive reconditioning programs? When can maturation status be determined with certainty based on blood hormone levels? What is the best strategy for allowing non-rematuring fish, aka skip spawners, to contribute? Do any non-mature kelts migrate upstream? If so, what are the mechanisms causing migration?

These physiological questions are being addressed in CRITFC's 2013 reconditioning program.

<u>Questions for future research (2015-2018)</u>

- How do fecundity, gamete quality, and juvenile quality compare between spawners from the ocean and reconditioned kelts? If problems are identified, can they be rectified by modifications to diet or other aquaculture conditions? Would captive kelts benefit from saltwater rearing?
- What limits the successful spawning of rematuring reconditioned kelts after release? How do the reproductive development, energy reserves, migration patterns, spawn timing, spawning location, and spawning behavior of reconditioned fish compare to those of spawners from the ocean? Would tributary weir collected kelt destined-for-reconditioning produce a higher rate or fitness of successful repeat spawner compared to Lower Granite Dam separator collected kelt?
- Why is the steelhead stock composition at Lower Granite Dam different on the downstream migration compared to the upstream migration?

Infrastructure needs

- Additional holding tanks at Prosser *(Current development)*
- Additional holding tanks at Dworshak**.** Address water supply issues. *(Current development)*
- Modified facilities at Bonneville Hatchery to facilitate reconditioning. *(Prospective)*
- Complete the Snake River Kelt Master Plan Process to develop a long-term kelt reconditioning facility. Multiple facilities may be required for successful reconditioning of at least 500 repeat spawners.

  Alternatives:
  - In order to adequately compare program and RPA success with Bellerud *et al*. (2007) or subsequent 2014 FCRPS BiOp RPA, a specific kelt separating/diversion, handling, holding, and bypass facility at Little Goose Dam should be constructed into the existing JFF. *(To be scheduled in the 2013/2014 Master Plan)*
  - Build kelt collection facilities at the Little Goose Dam bypass. *(To be scheduled 2015-2018)*
  - Convert juvenile salmon transport barge to kelt reconditioning barge. The Corps operates four large 8000 series barges, two medium 4000 series, and two small 2000 series barges for juvenile salmon transport. The two 2000 series barges are the smallest and oldest of the Corps fish barges (circa 1970s converted military water tankers), but the most likely to be retired and excessed. There are no plans to retire or replace the small barges in the near future, at least until there is some reduction in the capacity of the transport program. *(Prospective)*
  - Expansion at Clearwater River locations. *(Prospective)*
  - Lower Granite Dam. *(To be scheduled post-2015)*
  - Modifications to existing B-run tributary weirs or construction of new weirs to permit collection and short-term holding of kelts. *(To be scheduled post-2014).*

<u>Lower Granite Upgrades</u>

  - Modification to LGR juvenile bypass to reduce head injuries. In spring 2013, erosion to the concrete in the existing JFF upwell box was repaired. Kelt collected off the separator at Lower Granite in 2013 qualitatively appeared to have less trauma in their condition compared to previous years collections.
  - Lower Granite Dam JFF Upgrade Phase 1 (Bypass facility focus) and Phase 2 (Transport facility focus) with kelt facility. Current LGR JFF Phase 1 components under design only include the gatewell to existing JFF low velocity separator fish conveyance system that

replaces the old downwell to pressurized underground pipe to upwell to existing low velocity separator system. All other components of the pre-2013 JFF upgrade designs have been deferred. Options have been proposed, but not prioritized for final design or funding, to date. An option of a new primary bypass outfall pipe has been scheduled for 2014-2015 construction, but the option of an in-line adult/debris separator prior to a new in-line smolt high velocity sort-by-size separator was on the table in 2013, but recently deferred. This KMP places additional high priority on finishing the design and construction of both the adult/debris separator and the in-line smolt high velocity sort-by-size separator by 2015 because of the benefits to survival of kelt attributable to reduced handling for kelt destined for the reconditioning program, as well as those returned to river migration.

Incidence of handling of kelt should be minimized for all post-spawned kelt, whether research sample kelt or non-research passing kelts. At the newly designed JFF at LGR, a prototype gatewell overflow weir and a 14 inch orifice LGR turbine unit 5 during 2013 were constructed and biologically evaluated for smolt passage rate (travel time) and condition. No adults were evaluated in 2013. Successful 2013 evaluation indicates that the 14-inch orifice may be the better routing for smolt passage between the three gatewell-to-collection channel routes, whereas the overflow weir may be better for juvenile lamprey. Testing for fish condition and passage rate for adult steelhead will occur in 2014 when a new overflow weir and 14-inch orifice is added in the turbine unit 6 gatewell. These new gatewell-to-collection channel passage structures could be expected to reduce descaling and other injury rates in smolts, adults that have fallen back, and downriver migrating post-spawned kelt. It may be possible that the head trauma sometimes observed to be about 30% in kelt passing through the existing 10-12 inch orifices and the pressurized down- and up-well could be reduced. Included would be direct bypass to outfall at LGR with full flow PIT detection. LGO (2008), and LMN and McNary (2012) have recently constructed new bypass outfalls for benefit of smolt passage and survival, that also benefit adult and kelt passage. Adult salmon and steelhead and debris separation with conveyance and divergence to either a circular tank platform for collection for reconditioning or directly to the tailrace would allow for little or no need for handling kelt which already have compromised condition.

Evaluation – synthesis of current status and future planning to achieve 6% goal

In 2012, nine natural origin B-run steelhead kelts successfully reconditioned and were released into the Snake River, contributing 0.5 percent toward the 6 percent abundance goal. Reconditioning efforts focused on B-run hatchery kelts have been developed and implemented at Dworshak NFH, and this program is expected to move from experimental phase to implementation in the near future. The BPA continued to fund CRITFC to finalize a master plan for the kelt reconditioning program.

Alternative 2: Transportation (Fed & Un-Fed)

2008-2012 Accomplishments and Results by end of CY 2012

Background - Synthesis of alternatives, results

Transporting kelt steelhead is the process of collecting kelt phase fish during their seaward migration, assessing individual fish for condition and color (same gradings as in the long-term reconditioning described above), PIT tagging individuals and then trucking or barging the fish around the hydrosystem and releasing them below Bonneville Dam. From 2008 through 2011, BPA funded transportation studies through project 2007-401-00, implemented by the Columbia River Inter-Tribal Fish Commission (CRITFC) and its member tribes (see Hatch et al. 2012).

Fish for transport studies were collected at Prosser Dam on the Yakima River and Lower Granite Dam on the Snake River. At Prosser Dam two treatments of transported kelts were studied, fed and unfed. The fed fish group involved collecting and holding kelts for 4 to 6 weeks and feeding these fish in a manner similar to long-term reconditioning. After the 4-6 week period, these fed fish groups were trucked and released below Bonneville Dam. Unfed groups included all kelts transported from Lower Granite Dam and groups from Prosser Dam. These fish were collected and a held for a minimum amount of time (a couple of days) and then trucked below Bonneville Dam in the case of Prosser Dam collections and trucked or barged from Lower Granite Dam and released below Bonneville Dam. Over the 2008-2012 period most transport groups were released within a few miles below Bonneville Dam, however some unfed groups from Lower Granite Dam and Prosser Dam collections were released near the upper estuary at approximately RM 60. The estuary releases were paired across the two collection locations (Prosser and Lower Granite dams) and paired with releases immediately downstream of Bonneville Dam. Estuary release studies were conducted in 2010 and 2011.

Transport success was evaluated three ways. First, reach specific lower river survival was measured using detections of acoustic transmitters surgically inserted into body cavities of representative fish from each release group. Second, PIT tag detections at Bonneville Dam of kelt steelhead returning from the sea. Third, we calculated transportation benefits for each group by dividing the return rate to Bonneville Dam for the group by each control group. The control group was the detection rate of PIT tagged kelts collected at the same location and released back into the river (in-river group). This calculation yields a number that represents the relative positive or negative benefit of the treatment. For example if your treatment return rate to Bonneville Dam was 4% and the control rate was 2%, the treatment would benefit kelt 2x (4/2=2) versus leaving the kelts in the river. Comparisons were made within each year and across years using weighted means to account for different sample sizes among years.

Transported treatment groups in 2011 included kelts collected at Lower Granite Dam and Prosser Dam. For each of these treatment collection locations we used two different release locations:

Hamilton Island (below Bonneville Dam where previous transport groups were released) and the estuary.

In 2010, no kelts were detected returning to Bonneville Dam from fish collected at Lower Granite Dam and transported to Hamilton Island or to the estuary (see Hatch et al. 2012 for detailed results). The 6-year mean return rate to Bonneville Dam for fish collected at Lower Granite Dam and transported is 1.12. Two kelts (1 fish from each release location) were detected returning to Bonneville Dam from fish collected at Prosser Dam and transported to Hamilton Island and the estuary. Return rates of Prosser collected fish to Bonneville Dam were 1.00 for the Hamilton Island release and 1.11 for the estuary release. Both of these return rates are lower than the 9-year mean return rate of 4.05.

Only limited transport benefits can be calculated for the 2011 returns because of the low or zero return rates for transport and in-river groups. The kelts collected at Prosser Hatchery and transported to Hamilton Island had treatment benefits of 0.78, 2.63, and 0.60 relative to the control metrics of in-river, the steelhead run at large at Bonneville Dam, and the Hockersmith value of 1.66, respectively. The Prosser kelts released at the estuary showed similar treatment benefits of 0.86, 2.92, and 0.67 relative to in-river, the steelhead run at large at Bonneville Dam, and the Hockersmith value of 1.66, respectively. Remember that any number greater than 1 is a positive benefit and any number less than 1 is a negative benefit. Neither release location resulted in returns to Bonneville Dam substantial enough to yield benefits over control/comparison groups. Transport benefits for Snake River origin kelts collected at Lower Granite Dam are very low and difficult to measure due to very low returns to Bonneville Dam from these treatment groups. In 2011, no fish returned to Bonneville Dam from either the Hamilton Island or estuary release of Snake River origin kelt steelhead.

Survival from release to the ocean was estimated from both collection areas Lower Granite and Prosser dams and both release sites, in 2011 using sequential detections of acoustic tags. For the kelts collected at Lower Granite Dam, survival to the ocean was 6.5% and 29.8% for the Hamilton Island and estuary release sites, respectively. For the Prosser Dam collected kelts survival to the ocean was 34.0% for both the Hamilton Island and estuary release sites. The 7-year mean survival from release at Hamilton Island to the ocean is 44.9%. These low survival rates could be a result of transportation stress on the fish or river environment impacts. For the Snake River origin kelts we found that releasing the fish closer to the ocean resulted in higher survival to the ocean, however the lack of returns to Bonneville Dam has lead us to discontinue evaluating transportation as a management option.

Future Planning (2013-2018)

Transportation benefit among control/comparison groups has been uncertain. There were low returns during the 2008-2012 period, but occasionally a substantially higher SAR rate has been observed among the transported group (Evans et al. 2008). As a result of the limited benefits typically realized from transportation relative to long-term reconditioning, there are no current plans for conducting further tests during the 2013 to 2018 period. However, if rearing space for long-term reconditioning is maximized and kelts are still available at collection sites, we suggest that those fish be transported and released below Bonneville. This is based on the transport benefit being higher than leaving fish in the river.

Research priorities and needs

RPA 33 requires development of a KMP with consideration for potential for the collection and transport (either with or without short-term reconditioning) of kelts to areas below Bonneville Dam.

- In attempting to explain the difference in kelt return rates among transported and in-river groups, we have a fair amount of information on mortality during kelt migration in the river, but almost none on mortality in the ocean. When does most kelt mortality occur during the time from arrival at the estuary to the second spawning migration? Is most mortality associated with ocean reentry? What is the cause? Does predation by marine mammals occur in the estuary? Do steelhead kelts undergo a physiological process similar to smoltification in juvenile salmonids? Is there an optimal window for arrival at the ocean to maximize survival? *(Prospective, 2015-2018)*
- Can we hypothesize that kelt transportation from Lower Granite and Little Goose dams during hot, dry, low flow years have benefits to population productivity? What factors explain the variability in rates of ocean return? *(Prospective 2015-2018)*

Evaluation – synthesis of current status and future planning to achieve 6% goal

➢ No Snake River origin kelt steelhead have returned to Bonneville Dam from 2010 or 2011 releases in the estuary. No Snake River origin kelt steelhead have returned to Bonneville Dam from 2009 through 2011 releases. Evans *et al*. (2008) did report a 2.3 X advantage in survival rates of returning kelts at Bonneville Dam. However, that benefit included returns from 2002, a year with unprecedented kelts returns across a broad number of sites. These very marginal treatment benefits suggest that in most years collecting steelhead kelt then transporting and releasing them below the hydrosystem has very limited benefits. Trucking fish these long distances likely impacts long term survival of transported kelt steelhead.

➢ We recommend revisiting the transport option if kelt collections were to exceed rearing space available for long-term reconditioning.

Alternative 3: Enhanced In-river Migration

2008-2012 (Accomplishments and Results by end of CY 2012)

Background - Synthesis of research results

Surface Passage is available at all 8 projects, commencing with the start of the spring spill season on April 10. The 2012 Fish Passage plan describes the kelt trigger rule for opening the Bonneville powerhouse two corner collector: “Beginning on March 01, JMF personnel will enumerate steelhead kelt at the JMF adult/debris separator. If two kelts per day are observed at the JMF separators for two consecutive days for a cumulative total of 20 kelts, JMF personnel will notify the Control Room and Project Fisheries, and the B2CC will be opened within 1 hour". At Bonneville Powerhouse 1, Ice &Trash sluiceway gates are kept open between 1 December – 28 February to facilitate steelhead kelt passage.

<u>Snake River –</u>

See Appendix A for expanded description of 2012 kelt survival study

The results of this study provide information on the route of passage and subsequent survival for steelhead kelts migrating through the Snake and Columbia rivers from LGR to BON. Specifically, this study is the first to document these metrics since the installation of spillway weirs at many of the dams in the FCRPS. Spillway weirs were the primary route of passage for steelhead kelts in the Snake River, whereas the majority of fish passed through traditional spill routes in the lower Columbia River. Spillway routes (spillway weirs and traditional spill) and the JBS provided the highest estimated survival for steelhead kelts. Passage through turbines resulted in the lowest survival estimates; however, the lowest proportion of kelts passed through this route. Average discharge was higher in 2012 when compared to the 10-year average (2002–2011) and likely contributed to the overall high rate of migration success. The Snake River kelt survival is scheduled to be repeated in 2012, then calculating the 3-dimensional distribution of forebay attraction to passage routes of kelt will be performed in 2013.

Several groups of kelt steelhead have been captured, then tagged and released back into the river and followed to assess survival since 2008. In the Yakima River, an "in-river" group has been PIT tagged and released from Prosser Dam annually since 2008. Return rates to Bonneville Dam of these fish provides a control group to compare with other management actions. Similarly in the Snake River, an in-river group has been PIT tagged and released at Lower Granite Dam annually since 2009.

Additional evaluations of in-river kelt survival were conducted in the Snake River Basin in 2011 and 2012. In 2011, CRITFC oversaw an acoustic telemetry project that captured and tagged kelt steelhead at weir locations in the Clearwater drainage and then followed these fish downstream through the hydro system. In 2012, the USACE funded an additional acoustic telemetry project that evaluated in-river survival and fine scale passage route survival for downstream migrating kelt steelhead.

Since 2008, 445 kelt steelhead in the Yakima River and 5,286 kelt steelhead in the Snake River were PIT tagged and released at Prosser and Lower Granite dams to assess in-river survival. Return rates to Bonneville Dam of PIT tagged kelt steelhead from the Yakima and Snake rivers varied annually and averaged 2.25% and 0.21%, respectively. In 2009, in-river survival from the Yakima River was 5.17%, which was the highest measured and it was 0% in 2012. In-river survival from the Snake River was also the highest in 2009 measured at 1.12% and lowest in 2012 at 0.05%.

Acoustic telemetry results indicated that kelt steelhead migrating from Fish Creek, and the Potlatch River, tributaries of the Clearwater River, demonstrated high survival to Lower Granite Dam. Cumulative survival from Lower Granite Dam to Bonneville Dam was 52.9% among all kelts tagged at LGR in 2012. The survival of kelts originating from Fish Creek declined rapidly in the Snake River, with cumulative survival probability from rkm 636 to 525 of 38.9% (SE=0.8%) in 2012. Kelts captured and tagged at upstream tributary sites (Fish Creek rkm 944 and the Crooked River rkm 961), had the lowest migration success rates. For the kelts from Fish Creek, migration success rate was 11.5% (n = 6 of 52), and none of the fish tagged at the Crooked River (n = 2) were ever detected on a receiver after release (Colotelo et al. 2013).

Lower Columbia River Survival study -

See Appendix B for tables showing results of the 2012 survival study conducted in the lower Columbia River. Lower Columbia River reach survivals, cumulative survival rates, and route-specific survivals through Bonneville Dam were estimated.

Bonneville Dam kelt passage study

- Sluiceway Survival Tests - In 2011, a study to compare the direct injury and mortality of adult steelhead passing through Bonneville Dam's PH1 ice and trash sluiceway (PH1 ITS) and the PH2CC was conducted to confirm the assumption that the two sluiceways provide safe downstream passage. Direct injury and mortality estimates were 100 percent and 99 percent for adult steelhead released into the sluiceway and the CC, respectively (Normandeau Associates 2011). The injury rate for study fish did not exceed 1 percent for either passage route.
- Passage Distribution - In 2012, a study to assess route-specific distribution of steelhead kelts passing through Bonneville Dam was conducted (Rayamajhi *et al.* 2013). At total of 163 steelhead kelts tagged with active transmitters passed Bonneville Dam. Of these, 51 percent (n=83) passed via spill. At PH1, ITS passage efficiency was roughly 49 percent, with 20 kelts passing PH1 ITS, and 21 kelts passing PH1 turbines. Whereas, at PH2, 74 percent of kelts passed via PH2CC, 13 percent via PH2JBS (n=5), and 13 percent via PH2 turbines (n =5) (Weiland *et al*. 2012). These results confirmed that operation of PH2 as the priority powerhouse in combination with early operation of the PH2 CC per the FPP criteria, results in the fewest kelts passing through turbines at Bonneville Dam.

Expanded Winter Operations to protect overwintering fallbacks (TDA).

From the winter of 2008 to the spring of 2009, an evaluation was conducted to assess operation of The Dalles Dam sluiceway from March 1–31 and from December 1–15 as a potential means to provide a safer fallback passage route for overwintering steelhead and kelts. A second year of evaluation was initiated in December 2009 and continued through March 2010, including monitoring of turbine passage during the closed-sluiceway operation of mid-December 2009 through the end of February 2010. Results from two years of evaluations of downstream passage through The dam sluiceway by overwintering summer steelhead and outmigrating steelhead kelts suggested that there is a large enough survival increase (0.9 percent of a 6 percent target for Snake River steelhead) to justify keeping this surface route open later, December 1-15 (Tackley and Clugston 2011). The extended ice and trash sluiceway operation has been included in the FPP as part of standard fish passage operations at The Dalles Dam since 2011.

McNary Dam Winter Passage

In the winters of 2010–2011, the Corps funded a study to enumerate and determine the vertical and horizontal distribution of adult steelhead as they passed through the powerhouse at McNary Dam (Ham *et al*., 2012). Downstream passage of adults through turbines is of greatest concern during winter months when other passage routes are typically unavailable and fish guidance screens are not in place to limit turbine passage. Study results have implications for winter operations as well as the operation or location of surface bypass improvements that may be implemented if warranted at the McNary Dam project. Adult passage was monitored at eight of 14 operating turbine intake A-slots from December 17, 2010, through April 13, 2011. Two of the units that were not monitored were out of service for the duration of the study. Fixed-aspect hydroacoustics were used to estimate the number of fish entering each turbine intake unit. The hydroacoustic transducers detected 68 targets with characteristics consistent with steelhead. The 68 targets were expanded to account for spatial and temporal sample coverage. During the entire sample period, the researchers estimated that 946 steelhead passed through the powerhouse with 95-percent confidence bounds extending from 750 to 1,142 individuals. If a similar rate of passage is assumed through unmonitored intakes, the estimate of total powerhouse passage would be 50 percent higher at 1419 individual steelhead. The horizontal distribution was skewed toward the outer turbine units (i.e., units 3, 4, 11, and 13). The distribution could be different if all units were operating. What would remain unchanged is the relatively low passage numbers near the center of the powerhouse where sample coverage was complete (Ham *et al*., 2012). A DIDSON device was used to monitor the region just upstream of the trash rack at units 5C and 6A o verify the presence of adult steelhead and other similar sized individuals of other species. The researchers used DIDSON cameras to sample during the first 15 minutes of every hour from December 17, 2010, through January 20. From January 20 through April 15 the cameras sampled for 20 minutes at the beginning of every hour. The bulk of steelhead observed with the DIDSON camera were moving and behaving in ways that were not suggestive of turbine passage. The steelhead were observed milling around and slowly swimming upstream of the intake and trash rack with much less movement across the powerhouse than shad. It was not possible to determine whether a particular steelhead or other fish passed downstream of the trash racks because a fish could exit the volume sampled by the DIDSON in more than one direction. During much of the latter portion of the study, atypically-high river flows resulted in forced spill, which created an unexpected and unmonitored passage route through the dam. As a result, turbine passage estimates in the present study are likely less than would occur in a typical year without spill. This research was continued in the winter of 2011–12 to gather baseline turbine passage estimates for overwintering steelhead. Study results were presented to the Studies Review Workgroup and the FFDRWG to determine the magnitude of fallback at McNary in the winter months and to potentially develop alternative routes to safely pass overwintering steelhead downstream.

Future Planning (2013-2018)

Research priorities and needs

RPA 33 calls for measures to increase the in-river survival of migrating kelts. The Action Agencies would like to support research which will help managers better understand in-river survival through the hydrosystem. In the near term (2013-2014) Action Agencies will:

- Follow-on to FY 12 JSATS test (if necessary and feasible). Repeat 2012 Snake River JSAT study for dam and reach passage survival estimation for A-run and B-run kelt collected at Lower Granite and subbasin tributary weirs. Although 2012 study data can be compared to previous radio-tag survival studies performed in the early and mid-2000 years when surface passage only existed at LGR, there remains some variability as to what is best route of passage survival for both LGR-collected kelt and subbasin weir collected kelt.
  - Determine direct injury and route survival of adults passing turbines.
  - Determine direct injury and route survival of kelts passing spill weirs.
  - Impacts of spillway ogee, chute, and/or deflectors for RSWs, TSWs, and traditional spill routes for those dams that show high acceleration or separation of flow on their ogees.
- Conduct adult steelhead survival test through turbine and TSW routes at McNary Dam in winter 2013/2014, to aid in cost/benefit analysis of providing a winter surface passage route for overwintering and overshoot steelhead or outmigrating kelts. Not many overwintering kelt of Snake River stocks are likely mixed in with the remaining pre-spawn steelhead observed around Snake River dams. Since Snake River kelt predominantly outmigrate post-spawn overlapping with spring smolts, then only some small portion of the hopefully 0-1-2% returning repeat spawners would be available to return late enough to overwinter The Corps of Engineers white paper summarizing recent kelt downstream passage survival studies should be reviewed before proceeding with additional tests.
- Determine optimal operation points, configuration, and operations to facilitate life history expression for overwintering steelhead and kelts.
- Determine Spring Powerhouse priorities at BON.
- Continue to PIT tag and release back to the river a representative number of kelts annually to establish baseline survival and repeat spawner rates.

Infrastructure and Operation needs

- The Corps Configuration and Operation Plans (COPs) could prioritize surface passage structures such as additional HI/LO crest TSWs for operation for kelt passage during off-season smolt passage time periods if warranted for survival benefit following in-river kelt passage and survival studies. Kelt survival and production through more readily downriver passage (egress) would benefit from continual operation of the Little Goose TSW at low crest instead of flow-determined switching of the TSW crest elevation from springtime high to summertime low.
- A kelt separator/diversion, and handling, holding, and bypass facility at Little Goose Dam should be constructed into the existing JFF if warranted for survival benefit and kelt collection. Compare program and RPA success with Bellerud *et al*. (2007) or subsequent 2014 FCRPS BiOp RPA.

Evaluation – contribution of hydropower strategies to achieve 6% goal

As part of the overall package to increase the number of adult B-run Snake River steelhead above Lower Granite Dam, the Action Agencies, along with NOAA Fisheries, developed a benefit analysis based on the 2008-2010 research at The Dalles Dam (Tackley and Clugston 2011). Results from those studies allowed the Action Agencies to conclude that by extending the operating season of the ice and trash sluiceway to include December 1-15 and March 1-April 9, a 0.9 percent increase in adult returns would be realized. NOAA Fisheries concurred in benefits to B-run Snake River steelhead, and the operation was implemented. In addition to The Dalles Dam operation, the Bonneville Dam PH2 corner collector was opened nearly one month early (March 14, 2010) in an effort to provide a safer route of passage for early-migrating (primarily lower Columbia River) steelhead kelts.

Summary and Conclusions

Recommendations and actions to be implemented

In earlier years, the Action Agencies lacked high quality estimates of the distributions and survival rates of kelts passing through powerhouse, deep spill and surface spill routes. These critical uncertainties lead to the adoption of spread-the-risk strategies including transporting a significant portion of kelts collected at Lower Granite Dam. Multiple years of experimental reconditioning and transportation studies have been conducted during the past decade comparing treatments of kelts transported from the mid-Columbia and lower Snake to the estuary, kelt provided short-term reconditioning and transportation, and long-term reconditioning. Two kelt studies of in-river kelt outmigration survival were conducted in 2012. The variance observed among FCRPS hydropower dams in survival rates through powerhouse and spillway routes may allow the Action Agencies to optimize spring and winter operations and better target future in-river survival research.

The Action Agencies recommend seeking cost-effective approaches using existing infrastructure to address RPA 33. Between 2008-2012, returns of transported kelts to Bonneville Dam were not significantly higher than control treatment groups. Reconditioned kelts did return at higher rates than controls, with some interannual variability, particularly from some hatchery programs (Hatch *et al.* 2012). Earlier studies conducted between 2000-2008 only episodically resulted in appreciable kelt returns. Overall, these results suggest that transportation has been a less successful and cost-effective strategy for increasing kelt returns compared with long-term kelt reconditioning . If the number of kelts available exceeds rearing space at reconditioning facilities it could be feasible to additional available fish to experimental treatment groups transported below Bonneville. The Action Agencies may opt to continue to research uncertainties related to yearly variation in kelt reconditioning and transportation success, and approaches to aquaculture and hydrosystem management which would lead to greater kelt abundance. Such factors could include the effects of ocean conditions and freshwater conditions or duration of reconditioning on the annual variation in survival.

Upgrading and improving kelt handling reconditioning facilities at Lower Granite Dam, Clearwater River and other hatchery locations should be the top priority for reaching the target of a 6% increase in B-run steelhead reaching Lower Granite Dam, as specified under RPAs 33 and 42 of the BiOp.

The Action Agencies will implement the following actions in 2013-2018:

- Facility upgrades will proceed at Dworshak Dam as described in the Memorandum of Understanding between the Action Agencies regarding Snake River Steelhead Kelt Management, including improvements to the water supply, and coordination of live spawning activities.
- Additional holding tanks will be installed at Dworshak, and Prosser and Bonneville hatcheries to facilitate reconditioning. The Kelt Master Plan drafted by the Nez Perce Tribe/CRITFC details the long-term plan for kelt reconditioning at Dworshak.
- Design plans will proceed for upgrading of the adult fish facility and juvenile fish facility at Lower Granite Dam, which includes a temporary kelt holding facility where a significant proportion of kelts are collected for the reconditioning program. Phase 1 plans under development include modification of the juvenile bypass to reduce head injuries for kelts, relocation of the bypass outfall, and redesign of the gatewell to the existing JFF low velocity separator. The phase 2 plans focus on the transportation facility, including a kelt holding facility where a significant proportion of kelts are collected for the reconditioning program. A high priority is placed on construction of an adult/debris separator and the in-line smolt high velocity sort-by-size separator because it can reduce direct handling of kelt.
- An investigation into direct injury and route-specific survival rates through the FCRPS hydropower projects which are involved in juvenile performance standard testing will be repeated in spring of 2012. A special investigation of survival rates through the TSW and turbine routes at McNary Dam will be conducted in winter of 2013. The Corps of Engineers is preparing a whitepaper to summarize recent kelt downstream passage survival studies. The relationship between adult returns and kelt outmigration experience should be reviewed before proceeding with additional tests.

- Funding will be provided for CRITFC's program of PIT tagging of kelts collected at Lower Granite Dam to help assess return rates.
- BPA Project 2008-485-00 covers a kelt reconditioning program implemented by the Yakama Confederated Tribes in the mid-Columbia River. It will be continued and expanded.
- BPA project 2007-401-00 will be continued to evaluate the success of reconditioned kelts in Omak Creek, Yakima River, Warm Spring River and the Clearwater River. This project will hopefully continue to produce relevant research results pertaining to the basic physiology and life history of steelhead.
- The Action agencies will continue to operate surface passage outlets on all mainstem dams during the spring passage season, and to operate the B2CC and the Dalles sluiceway during parts of the winter season according to rules defined in the Fish Passage Plan.

References

Bellerud, B., R. Graves, and G. Fredricks. 2007. Assessment of the likely survival improvement resulting from enhancement strategies for steelhead kelts (B-run kelts in particular). NOAA Fisheries Kelt Analysis Memorandum to Bruce Suzumoto, September 25, 2007.

Colotelo, A.H., B.W. Jones, R.A. Harnish, G.A. McMichael, K.D. Ham, Z.D. Deng, G.M. Squeochs, R.S. Brown, M.A. Weiland, G.R. Ploskey, X. Li, and T. Fu. 2013. Passage distribution and Federal Columbia River Power System survival for steelhead kelts tagged above and at Lower Granite Dam. Draft Final Report prepared by Battelle - Pacific Northwest Division, Richland, WA for the U.S. Army Corps of Engineers, Walla Walla District, Walla Walla, WA. Contract No. W912EF-08-D-0004. 52 pp with 72 pp of Appendices.

Hatch, D.R., R. Branstetter, J. Stephenson, A. Pierce, J. Whiteaker, and B. Bosch. 2012. Steelhead Kelt Reconditioning and Reproductive Success. Columbia River Inter-Tribal Fish Commission Technical Report to the Bonneville Power Administration. Project Number 2007-401-00, Contract Number 0030769.

Hatch, D.R., D.E. Fast, W.J. Bosch, J.W. Blodgett, J.M. Whiteaker, R. Branstetter, and A.L. Pierce. 2013. Survival and traits of reconditioned kelt steelhead Oncorhynchus mykiss in the Yakima River, Washington. North American Journal of Fisheries Management, 33:3, 616-625.

Normandeau Associates 2011 Estimate of direct effects of steelhead kelt passage through the first powerhouse ice-trash-sluice and second powerhouse corner collector at Bonneville Dam. Contract W912EF-08-D-0005 US Army Corps of Engineers. https://www.salmonrecovery.gov/Files/2011%20APR%20files/New%20Folder%203/Normandeau_2011_Bonneville_Kelt_Study_Final.pdf

Null, R.E., K.S. Niemela, and S.F. Hamelberg. 2012. Post-spawn migrations of hatchery-origin *Oncorhynchus mykiss* kelts in the Central Valley of California. Environmental Biology of Fishes. DOI 10.1007/s10641-012-0075-5.

Rayamajhi B, G.R. Ploskey, C.M. Woodley, M.A. Weiland, D.M. Faber, J Kim, A.H. Colotelo, Z. Deng, and T. Fu. 2013. Route-Specific Passage and Survival of Steelhead Kelts at The Dalles and Bonneville Dams, 2012. PNNL-22461, Pacific Northwest National Laboratory, Richland, Washington.

Tackley S. and D.Clugston. 2011. Estimated benefits of operating the Ice and Trash Sluiceway (ITS) at The Dalles Dam from December 1-15 and March 1-April 10 for overwintering steelhead and out-migrating steelhead kelts. http://www.salmonrecovery.gov/Files/2011%20APR%20files/New%20folder%20(2)/Tackley_and_Clugston_2011_Justification_for_TDA_sluiceway_operation_FEB2011.pdf

---

Appendix A – Results of 2012 Passage studies in the Snake and Columbia rivers

2012 Snake River Kelt passage survival study

Colotelo, A.H., B.W. Jones, R.A. Harnish, G.A. McMichael, K.D. Ham, Z.D. Deng, G.M. Squeochs, R.S. Brown, M.A. Weiland, G.R. Ploskey, X. Li, and T. Fu. 2013. Passage distribution and Federal Columbia River Power System survival for steelhead kelts tagged above and at Lower Granite Dam. Draft Final Report prepared by Battelle - Pacific Northwest Division, Richland, WA for the U.S. Army Corps of Engineers, Walla Walla District, Walla Walla, WA. Contract No. W912EF-08-D-0004. 52 pp with 72 pp of Appendices.

Objectives

Colotelo *et al*. presents demographic summaries, survival estimates, and passage metrics of Snake River steelhead kelts tagged with acoustic transmitters at Lower Granite Dam (LGR) and several tributary sites within the Snake River Basin upstream of LGR. The field study period was from 18 April to 31 August 2012. The objectives were as follows:

- Estimate the annual kelt population abundance arriving at and passing LGR.
- Estimate the route survival and passage probabilities at each FCRPS dam where acoustic transmitter detection capabilities existed.
- Estimate the following passage metrics and timing of acoustic-tagged kelts:
  - forebay residence time: travel time between the entrance to the forebay of the dam and passage through the dam.
  - tailrace egress time: travel time between passage through the dam and exit from the tailrace of the dam.
  - project passage time: travel time between entrance to the forebay and exit from the tailrace of the dam.

Methods

The study area spanned the lower Snake and Columbia rivers as well as selected tributary sites within the Snake River basin upstream of LGR. Steelhead kelts were captured and tagged at the LGR juvenile fish facility (JFF; rkm 695 measured from the mouth of the Columbia River) and at weirs located on Asotin Creek (rkm 761), the Potlatch River (three weirs on tributaries of the Potlatch River at rkm 795, 797, and 836), Joseph Creek (rkm 804), Fish Creek (rkm 944), and the Crooked River (rkm 961).

Single-release survival estimates were calculated for each main route of passage (e.g., spillway weir, traditional spill, turbine, juvenile bypass system [JBS]) using detections on downstream arrays. *Results*

Overall, the estimated survival from all release locations to rkm 156 in the Columbia River estuary was 0.407 (standard error (SE) = 0.028) for the 324 kelts included in this study. Survival estimates ranged from 0.891 (SE = 0.022) to 1.002 (SE = 0.001) for individual river reaches within the FCRPS studied in 2012. Survival per kilometer was high (>0.97) for all reaches. Acoustic-tagged steelhead kelts most frequently passed through spillway routes (spillway weirs or traditional spill) during this study. Spillway weirs were used by the majority of kelts in the Snake River, whereas most kelts passed through traditional spill in the lower Columbia River at those dams with and without spillway weirs. Survival estimates were highest for kelts that passed through spillway weirs at LGS (0.967; SE = 0.014) and JDA (0.986; SE = 0.014) and through traditional spill at LGR (0.906; SE = 0.052) and TDA (0.941; SE = 0.020). Kelts that passed through the JBS at LMN, MCN, and BON had the highest survival estimates when compared to all other routes (1.000; SE = 0.000); however, a low percentage of kelts passed through this route (2.2%–6.9%). The percentage of kelts that passed through turbine routes was also low at all dams (1.5%–6.5%), and the survival estimates were generally lower (0.500–0.875) than for all other routes of passage. For the two kelts that passed through the B2 turbines, survival was 1.000 (SE = 0.000); however, the sample size represented 1.5% of the tagged kelts that passed BON in 2012.

Table A1. Mean, maximum, and minimum discharge values (kcfs) and percentage spill at Lower Granite (LGR), Little Goose (LGS), Lower Monumental (LMN), Ice Harbor (IHR), McNary (MCN), John Day (JDA), The Dalles (TDA), and Bonneville (BON) dams for the time period between the tagging of the first kelt (18 April 2012) and the detection of the last kelt at any acoustic arrays (6 July 2012). Also shown are the 10-year averages (2002–2011) for the same dates. All discharge data were obtained from the DART website (Data Access in Real Time; http://www.cbr.washington.edu/dart/).

	2012	2012	2012	2012	10 Year Ave	10 Year Ave
	Mean Discharge (kcfs)	Max. Discharge (kcfs)	Min. Discharge (kcfs)	Mean Percent Spill (%)	Mean Discharge (kcfs)	Mean Percent Spill (%)
LGR	101.5	186.3	48.4	33.1	92.8	30.1
LGS	97.4	178.4	49.1	34.9	90.1	28.5
LMN	100.6	192.6	49.8	30.7	92.1	25.2
IHR	102.5	192.2	50.9	60.0	94.5	57.1
MCN	349.2	414.4	279.5	55.0	266.1	45.2
JDA	352.8	432.2	275.7	38.3	265.6	32.6
TDA	335.6	414.5	257.8	39.9	259.7	39.3
BON	358.3	442.1	279.1	39.0	275.6	40.6

Table A2.. Reach survival estimates for all acoustic-tagged steelhead kelt detected in 2012 throughout the Federal Columbia River Power System

Location	n	Survival (SE)
LGR reservoir	127	0.953 (0.019)
LGR forebay to LGR	129	0.985 (0.011)
LGR to LGS forebay	124	0.895 (0.028)
LGR tailrace to LGS forebay	292	0.952 (0.013)
LGS forebay to LGS	274	1.000 (0.000)
LGS to mid-LMN reservoir	290	0.943 (0.014)
LGS tailrace to mid-LMN reservoir	268	0.955 (0.013)
Mid-LMN reservoir to LMN forebay	261	0.969 (0.011)
LMN forebay to LMN	260	0.996 (0.004)
LMN to mid-IHR reservoir	263	0.940 (0.015)
LMN tailrace to mid-IHR reservoir	246	0.959 (0.013)
Mid-IHR reservoir to IHR forebay	244	0.951 (0.014)
IHR forebay to Burbank	234	0.979 (0.010)
Burbank to MCN forebay	229	0.948 (0.015)
MCN forebay to MCN	218	0.996 (0.005)
MCN to mid-JDA reservoir	212	0.929 (0.018)
MCN tailrace to mid-JDA reservoir	211	0.957 (0.014)
Mid-JDA reservoir to JDA forebay	202	0.891 (0.022)
JDA forebay to JDA	180	1.002 (0.001)
JDA to mid-TDA reservoir	173	0.925 (0.020)
JDA tailrace to mid-TDA reservoir	156	0.981 (0.011)
Mid-TDA reservoir to TDA	165	0.982 (0.010)
TDA to BON forebay	163	0.902 (0.023)
BON forebay to BON	148	0.997 (0.007)
BON to Knapp	138	0.897 (0.027)
BON tailrace to Knapp	103	0.929 (0.027)

There appears to be a distance travelled from origin relationship to migration success (survival) through the Snake River hydrosystem when comparing the tributary weir populations (Table 1 and Figure 3.2).

Cumulative survival probability of acoustic-tagged kelts varied among tagging locations from rkm 636 to rkm 156 (Figure 3.2). Overall, the cumulative survival probability from rkm 636 to rkm 156 of kelts tagged at LGR JFF (0.529; SE = 0.039) was higher than for fish tagged in the various tributaries (0.320; SE = 0.045). Of those fish tagged in the various tributaries, the survival probability from rkm 636 to rkm 156 was highest for Potlatch River kelts (0.519; SE = 0.083). The survival probability of Fish Creek kelts declined rapidly in the Snake River, as cumulative survival probability decreased from 1.000 (SE = 0.000) between rkm 636 and rkm 635 to 0.389 (SE = 0.081) between rkm 636 and rkm 525.

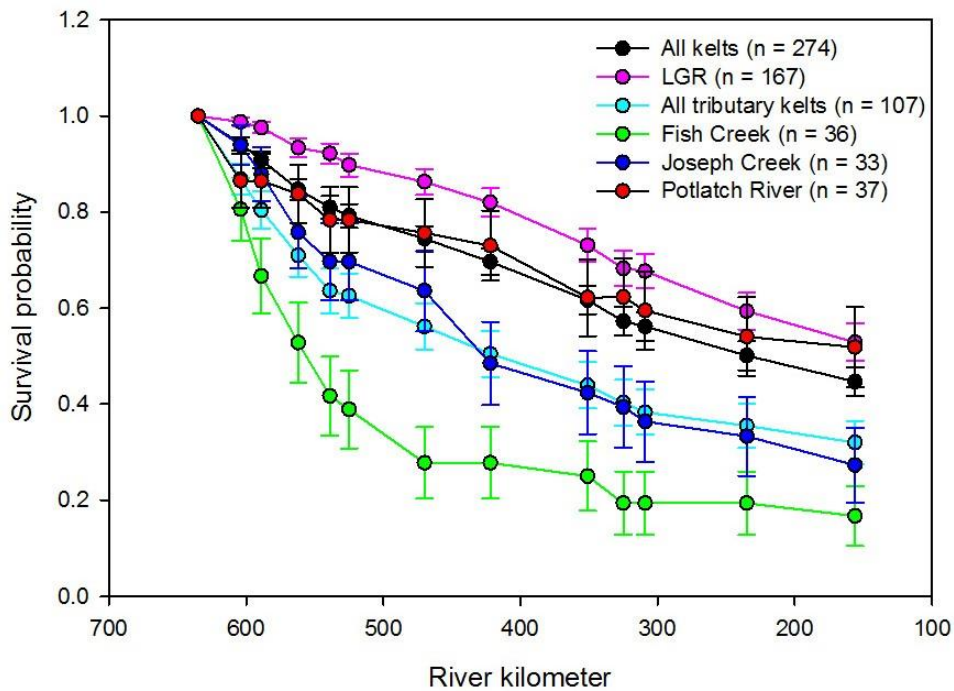

Figure A1. Cumulative survival probabilities of steelhead kelts from the Little Goose Dam Forebay array (rkm 636) to Knapp (rkm 156) by tagging location (i.e., Lower Granite Dam Juvenile Fish Facility (LGR), Potlatch River, Joseph Creek, and Fish Creek). Rkm for each dam is LGR 695, LGS 635, LMO 589, IHR 538, MCN 470, JDA 349, TDA 309, BON 234. Survival probabilities were presented for the cabled array at each dam and autonomous arrays located mid-reservoir in the FCRPS.

Overall, a high proportion of JSATS-tagged steelhead kelts successfully migrated through the FCRPS in 2012. Similar to smolt survival, a positive flow/survival relationship appears reasonable for kelt post-spawn outmigration. Of the 324 kelts in this study, 120 (37.0%) were detected at rkm 113 or rkm 86 (the most downstream arrays). This system-wide migration success was substantially higher than that reported for 2001 and 2002 (4.1% and 15.6%, respectively; Wertheimer and Evans 2005). However, these results are comparable to those from 2003 when 34.4% of externally radio-tagged kelts released into the LGR tailrace were detected in the BON tailrace (Boggs and Peery 2004).

Previous studies showed lower migration success rates for kelts classified as in fair condition (15.5%) at the time of tagging when compared to good-condition kelts (44.0 %; Boggs and Peery 2004). However, during this research, a higher percentage of fair-condition kelts (57.6%; n = 19 of 33) were detected at the most downstream arrays (rkm 113 and 86) than good-condition kelts (34.7%; n = 101 of 291). The lower proportion of fair-condition fish sampled in this study (9.9%) compared to those sampled by Boggs and Peery (26.4%; 2004) may explain the difference in migration success between years and condition categories, as Boggs and Peery (2004) sampled a larger number of fish in fair condition. Although the method used to grade steelhead kelts is employed throughout the CRB, it is subjective, and differences in grading may contribute to the differences observed in 2002 and 2012.

In 2012, survival was found to be lower through reaches that included a dam than through river reaches between dams. In contrast, Wertheimer and Evans (2005) found that in 2001 and 2002, radiotagged kelts had higher migration success rates through JDA (0.95), TDA (0.94), and BON (0.93) when compared to the river reaches between dams (e.g., 2001: JDA to TDA = 0.67; TDA to BON = 0.76; BON to rkm 156 = 0.89). One possible reason for the differences in survival between our study and their studies was the location of the survival arrays. Wertheimer and Evans (2005) assumed dam-passage survival when kelts were detected on the tailrace arrays, whereas in this study a detection array 24 to 78 km downstream of the dam was used to calculate the single-release survival estimates.

The majority of acoustic-tagged kelts that passed through FCRPS dams in 2012 did so through spillways. This result is similar to those of previous studies that examined the route of passage of kelts (Boggs and Peery 2004; Wertheimer and Evans 2005; Wertheimer 2007). However, this study was the first to examine the route of passage for kelts since the installation of spillway weirs at most dams in the Snake and Columbia rivers (i.e., LGR, LGS, LMN, MCN, and JDA). The percentage of fish that passed through spillway weirs was 31.5%–47.5% greater than through traditional spill at LGR, LGS, and LMN. Conversely, passage through traditional spill was 59.1% and 4.1% greater than the percentage that passed through spillway weirs at MCN and JDA, respectively. The proportions of kelts that passed through turbines, JBS, and sluiceways in 2012 were relatively low at all dams, as has been observed in other studies (Boggs and Peery 2004; Wertheimer and Evans 2007).

This study was the first to identify route-specific survival estimates for steelhead kelts that passed FCRPS dams. Survival estimates were higher for steelhead kelts that passed through spillway weirs compared to all other passage routes at LGS, LMN, and JDA. Survival of kelts that passed through the spillway weir at LGR was also high (90.1%), and only 0.5% lower than survival estimates for kelts that passed through traditional spill (90.6%). At JDA, survival of kelts that passed through the spillway weirs was 98.6%. However, spillway weir survival estimates have been mixed at JDA in previous studies that examined the route-specific survival of juvenile salmonids.The percentage of kelts that passed through the JBS was generally low at all dams (2.2%–10.1%).

Overall, travel rates observed in this study were higher than have been observed in previous studies that investigated the downstream migration of steelhead kelts in the FCRPS. Wertheimer and Evans (2005) reported that travel from LGR (rkm 694) to downstream of BON (rkm 181) took a median time of 27 and 19 days in 2001 and 2002, respectively. These travel times represented median travel rates of 19.0 and 27.0 km/day. Fish moved faster in 2012, as travel from the LGR tailrace (rkm 693) to BON tailrace (rkm 233) took a median time of 9.0 days, representing a median travel rate of 51.3 km/day. In addition, travel rates of steelhead kelts through the forebays and tailraces of FCRPS dams were faster in 2012 than those observed in 2001. Median forebay residence times were 1.3 and 3.0 hours at TDA and BON in 2001, respectively, whereas they were 50% lower at TDA (0.60 hour) and reduced by over 80% at BON (0.48 hour) in 2012. Mean river discharge was higher in 2012 compared to 2001 and 2002, and spill rates were very low in 2001, likely explaining some of the differences in travel rates. For example, at LGR mean river discharge was approximately 47 kcfs in 2001 and 85 kcfs in 2002, whereas mean discharge was 101.5 kcfs in 2012.

Travel rates observed in this study are comparable to travel rates observed for steelhead kelts as they moved downstream through unimpounded rivers in British Columbia. English *et al*. (2006) found that Skeena River steelhead kelt travel rates were 42.3 and 54.3 km/day in 1994 and 1995, respectively. The results of this study suggest that water velocity is an important factor in the travel rate of steelhead kelts, as travel rates were faster in the tailraces of dams when compared with other river reaches, particularly forebays of dams.

An estimated 45,338 (SE = 12,921; Lincoln mark-recapture estimate) steelhead kelts passed LGR in 2012 using the Lincoln index. This estimate represents 26.6% of the number of pre-spawn steelhead that moved upstream through the adult fish ladder at LGR between 1 July 2011 and 30 November 2011 (170,624). These estimates should be interpreted with caution as not all steelhead kelts that passed LGR had the same chance of being marked in this study, which violates an assumption of this population estimation method. Efforts were focused on five main tributaries of the Snake River where downstream weirs were operated in 2012, whereas many of the kelts that passed LGR likely spawned in tributaries we did not sample. Sampling was also limited for periods of time due to high spring run-off flows, further violating the assumptions of the population estimate. Another way of approximating how many kelts have passed LGR based on the assumption that the steelhead kelts captured on the separator at LGR JFF in 2012 (n = 2235) represented 5.6% of the total kelt population that passed LGR (as determined using acoustic telemetry passage data in this study), it could be estimated that 39,910 (2235/0.056) kelts passed through all routes.

Appendix B

Steelhead kelt passage and survival through the lower Columbia River- 2012

MA Weiland ,GR Ploskey, CM Woodley, and DM Faber

Project Manager Bob Wertheimer: USACE, Portland District Corp of Engineers

Table B1. Kelt Tagged for LCR Study

Creek/River	N	Sex (F :M :Unknown)	Rear Type (Wild:Hatchery)	Female FL (cm) Mean (range)	Male FL (cm) Mean (range)
Bakeoven	7	2 : 5 : 0	7 : 0	69 (67 to 71)	66 (55 to 73)
Buck Hollow	17	11 : 5 : 1	11 : 6	66 (50 to 81)	65 (56 to 72)
15 Mile	14	7 : 6 : 1	13 : 1	62 (52 to 70)	61 (52 to 70)
Hood	18	9 : 9 : 0	18 : 0	-	-
Neal	2	0 : 2 : 0	2 : 0	-	74
Total	**58**	**29: 27 : 2**	**51 : 7**	**65 (50 to 81)**	**64 (52 to 74)**

Table B2. Single-Release Survival of SR Kelt Through the Lower Columbia River Dams

River Reach	rkm	Distance (km)	Survival (SE)
MCN to Crow Butte	470 to 422	48	0.926 (0.018)
Crow Butte to JDA	422 to 349	73	0.890 (0.023)
JDA to Celilo	349 to 325	24	0.933 (0.020)
Celilo to TDA	325 to 309	16	0.979 (0.013)
TDA to BON	309 to 234	75	0.900 (0.028)
BON to Knapp	234 to 156	78	0.894 (0.031)

Table B3. Cumulative Single-Release Survival of SR Kelt Through the Lower Columbia River Dams

River Reach	rkm	Distance (km)	Survival (SE)
MCN to Crow Butte	470 to 422	48	0.926 (0.018)
MCN to JDA	470 to 349	121	0.824 (0.027)
MCN to Celilo	470 to 325	145	0.769 (0.030)
MCN to TDA	470 to 309	161	0.752 (0.031)
MCN to BON	470 to 234	236	0.674 (0.034)
MCN to Knapp	470 to 156	314	0.602 (0.035)

Rayamajhi B, GR Ploskey, CM Woodley, MA Weiland, DM Faber, J Kim, AH Colotelo, Z Deng, and T Fu. 2013. ***Route-Specific Passage and Survival of Steelhead Kelts at The Dalles and Bonneville Dams, 2012*****. PNNL-22461, Pacific Northwest National Laboratory, Richland, Washington.**

Table B4. Passage proportions and survival rates with standard errors (SEs) for all kelts (combining SR and LCR kelts), SR kelts, and LCR kelts through Bonneville Dam. After dam passage survival at BON, major passage routes are listed based upon the ranked order of point estimates from highest to lowest passage survival although all estimates have overlapping 95% CIs.

	All Kelts				Snake River Kelts				Lower Columbia River Kelts			
Route	(N)	(%)	Survival	SE	(N)	(%)	Survival	SE	(N)	(%)	Survival	SE
BON	163		0.87	-0.03	138		0.90	-0.03	25		0.68	-0.09
Spillway	83	50.9	0.91	-0.03	74	53.6	0.93	-0.03	9	36.0	0.78	-0.14
B1 and B2	80	49.1	0.82	-0.04	64	46.4	0.87	-0.04	16	64.0	0.63	-0.12
B1	41	25.2	0.79	-0.07	33	23.9	0.79	-0.07	8	32.0	0.75	-0.15
B2	39	23.9	0.86	-0.06	31	22.5	0.95	-0.05	8	32.0	0.50	-0.18

B2CC	29	17.8	0.95	-0.05	26	18.8	0.94	-0.06	3	12.0	1.00	0.00
Spillway	83	50.9	0.91	-0.03	74	53.6	0.93	-0.03	9	36.0	0.78	-0.14
Surface flow outlets B1	49	30.1	0.89	-0.05	43	31.2	0.87	-0.05	6	24.0	1.00	0.00
Sluiceway	20	12.3	0.80	-0.09	17	12.3	0.76	-0.10	3	12.0	1.00	0.00
B1 Turbine	21	12.9	0.77	-0.09	16	11.6	0.83	-0.10	5	20.0	0.60	
All turbines	26	16.0	0.74	-0.09	18	13.0	0.84	-0.09	8	32.0	0.50	-0.18
B2 JBS	5	3.1	0.60		3	2.2		2.00	8			
B2 Turbine	5	3.1	0.60		2	1.5		3.00	12			

Table B5. **Passage proportion and survival estimates with standard errors (SEs) for all kelts (combining SR kelts and LCR kelts), SR kelts, and LCR kelts through The Dalles Dam.**

	All Kelts				Snake R. Kelts				L Columbia R. Kelts			
	(N)	(%)	Survival	(SE)	(N)	(%)	Survival	(SE)	(N)	(%)	Survival	(SE)
TDA Dam	177		0.88	-0.03	163		0.90	-0.02	14	0.75	-0.13	
Spillway	149	84.18	0.91	-0.02	139	85.28	0.94	-0.03	10	71.43	0.70	-0.14
Powerhouse	28	15.82	0.72	-0.09	24	14.72	0.69	-0.10	4(a)	28.57	0.75	-0.22
Turbine	16	9.04	0.53	-0.13	14	8.59	0.54	-0.14	2	14.29		
Sluiceway	12	6.78	0.93	-0.08	10	6.13	0.93	-0.12	2	14.29		

(a) Among the four kelts passing through powerhouse, two of the kelts passing through sluiceway were detected below CR234, whereas only one of the kelts passing through the turbine was detected below CR234.