2013 Snake River Kelt Management Plan

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Executive Summary

The 2013-14 Kelt Management Plan describes the current status of actions carried out to improve the survival of steelhead kelts, in order to meet goals of increased spawner abundance defined in the 2008 FCRPS Biological Opinion (RPA Actions 33 and 42). The FCRPS BiOp RPA Action 33 identifies three strategies to meet these goals: 1) Hydrosystem actions to improve in-river migration. 2) Transportation of kelts through the hydrosystem via barge or truck. 3) Reconditioning or aquaculture based rehabilitation programs for post-spawn female steelhead.

Several research studies were carried out on in-river enhanced migration topics. The Corps completed the second year of its in-river dam route and river reach survival study, using acoustic tags, at three of the lower Snake dams. Survival per kilometer was lowest in dam forebays, and system survival from Lower Granite to below-Bonneville Dam was lower in 2013 (34.2%) than in 2012 (51.4%). Kelts most frequently passed through spillway routes (spillway weirs or traditional spill) during this study. Four of the 324 (1.2%) kelts that were tagged with acoustic transmitters in 2012 were detected making upstream migrations in the summer and fall of 2013. The Corps also conducted a direct survival test of hatchery origin steelhead passing through the TSW and turbine routes at McNary Dam and commissioned an analysis of PIT data to assess trends in kelt iteroparity rates of winter and summer steelhead from subpopulations throughout the Columbia Basin, hatchery and wild origin spawners, and 'a' and 'b' run kelts originating from the Snake River.

No transportation of kelts occurred in 2013. In-river migration and reconditioning strategies are currently prioritized over the transportation strategy when there is a shortage of kelts available for full program implementation. The Action Agencies and relevant coordinating entities, reserve the option to resume transportation when the number of collected kelts exceeds the capacity of reconditioning programs.

In 2013, the reconditioning facility for Snake River B-run kelts at Dworshak National Fish Hatchery became equipped for full program implementation after completing several years of experimental treatments with short-term and long-term approaches. 69 reconditioned wild female b-run kelts were returned to the Snake River from an original group of 110 kelts collected at Lower Granite Dam and 24 kelts retained after air-spawning for hatchery broodstock collection. Facility space is currently considered less limiting than the number of kelts which can be collected for the program, designed to meet the objectives of RPA 33. Reconditioning was also continued for Middle and Upper Columbia steelhead subpopulations prioritized under RPA Action 42. Several categories of research were continued including assessments of fish culture techniques such as diet composition, monitoring of ocean return rates of kelts released from different reconditioning programs, experimental treatments, and stock origins, and estimation of reproductive success rates including long-term reconditioned kelts which did not undergo a repeat ocean migration. Ocean return rates of steelhead in all categories of experimental and control treatments was low in 2013, with only 0.05% of adults tagged in 2012 returning, which may exclude skip spawners which return after one year. The average return rate of kelts tagged since 2002 has been 0.34%.

In future years, there will be increased prioritization of expanding collection of post-spawn steelhead at tributary weirs, because this is a limiting factor for each of the three BiOp kelt strategies. Design plans for enhanced adult passage will receive special focus at Lower Granite, Bonneville, and the Dalles dams.

Background

The 2008 FCRPS Biological Opinion (BiOp) identified the capability among steelhead for iteroparity (repeat spawning) as an important life history strategy for increasing steelhead population abundance and stability. Two Reasonable and Prudent Alternative Actions (RPAs) proposed a set of actions to improve the survival and abundance of steelhead kelts, and in addition, preparation of an annual Kelt Management Plan was included among the five major BiOp hydro strategies. 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 Action 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.

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 sub-basins (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.

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. Progress towards meeting the objectives of RPA 42 is detailed in the annual reports for CRITFC's Kelt Reconditioning project (BPA projects 2007-401-00 and 2008-458-00). 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 ESA listed steelhead populations in the Upper and Middle Columbia Distinct Populations Segments (DPS).

Estimates of annual returns of repeat steelhead spawners vary from 2.9 – 9.0% for kelts tagged at lower Columbia River dams and from 0.5 – 1.2% for kelts for Snake River (Keefer et al. 2008). NOAA (2008) concluded that rates of productivity for upper Columbia River (UCR) naturally-reproducing steelhead populations must increase by 2 to 6 fold in order to escape imminent risk of extinction. Increasing the survival of kelts and their eventual return as repeat spawners can be considered one component in improving the abundance and productivity of ESA listed steelhead populations in the Snake River and Upper and Middle Columbia River. An analysis included in the 2008 FCRPS BiOp evaluated the likelihood of prospective actions for improving kelt survival and abundance, including transportation, kelt reconditioning, and in-stream passage improvements (e.g. spill-flow modifications) (Supplemental Comprehensive Analysis Steelhead Kelt Appendix- Bellerud et al. 2007). Given available data, the evaluation concluded that a combination of these actions could increase kelt returns enough to increase the number of returning Snake River B-run steelhead spawners to Lower Granite Dam by about 6%, or in the 0.4 –9% range depending on the strategies adopted. A value greater than 1.0 for *adult progeny* (Recruits) to *repeat spawner* (surviving kelt) ratio of a steelhead population could be used as a partial measure of productivity improvement in a steelhead population. Therefore in this plan, a recruit per spawner (R/S) ratio greater than 1.0 is considered as an improvement in population productivity that conserves and builds genetic resources of Mid- and Upper-Columbia River populations; and a 6% increase in the abundance of adult steelhead returning to Lower Granite Dam will be assumed to represent a concurrent increase in productivity for an aggregate of the B-run component of the Snake River DPS.

Three BiOp strategies to improve steelhead productivity

Three strategies to specifically improve b-run steelhead productivity and abundance are being evaluated. In years when large numbers of kelts that are in good condition can be collected, kelt reconditioning could likely meet the BiOp goal of increasing b-run steelhead abundance by 6%. Enhanced in-river migration strategies have resulted in marginal increases of repeat spawners that are annually consistent. A prudent approach would be to collect and recondition as many kelt steelhead as possible, continue to make in-river improvements, and in years when reconditioning facilities are at capacity implement a transport and release strategy.

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. Short-term reconditioning is conducted over the 3-12 weeks needed for kelts to initiate post-spawn feeding, followed by transportation of kelts around mainstem hydro projects for release into the Columbia River downstream of Bonneville Dam and maturation in the Pacific Ocean (Branstetter et al. 2007), see collection and transportation strategy for more information and status of short-term reconditioning. However, the reconditioning approach primarily being utilized is long-term reconditioning, which consists of holding post-spawned kelts for 6-10 months while they reinitiate feeding, and subsequently display positive growth rates and gonadal development. The only proposed transportation component would be that level of truck transport required to convey pre- and post-reconditioned kelts to and from the location of collection and release. Re-maturing kelts that have experienced long term reconditioning are released in the fall, typically in mid-to-late October, coincident with run-timing of adult steelhead migrating into upper Columbia tributaries as stream temperatures are declining. Reconditioned fish are typically released near or downstream of their collection location so that they may over-winter and return to spawning locations on their own volition. Baseline success rates (kelt ocean return) for short and long term reconditioning are detailed in the 2009-10 KMP (http://www.salmonrecovery.gov/Files/Hatchery/2009-2010%20Kelt%20Plan_Final%20Draft.pdf).

The 2012-13 Kelt Management Plan presents extensive research results from the first five years of the reconditioning program sponsored by Nez Perce Tribe/CRITFC, as facilities were developed and significant progress was made in aquaculture techniques. Both the per capita success rate, and kelt capacity at key facilities is substantially larger than five years ago. The Action Agencies reason that the Long Term Reconditioning strategy has the potential to meet or exceed the 6% increased B-run steelhead abundance goal in years when kelt collections are high. However, in years with low kelt collection availability, this technique alone may not meet BiOp objectives. (http://www.salmonrecovery.gov/Files/Hatchery/2012%20Snake%20River%20Kelt%20Management%20Plan_Final.pdf)

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. It should be noted that 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.

Collection and Transportation Strategy

Transportation of kelts around the hydro-system is hypothesized as a means of increasing kelt survival and iteroparity of natural populations by decreasing dam and reservoir passage mortality and conserving the already taxed energy reserves of emigrating kelts (Wertheimer and Evans, 2005). This strategy involves the collection and transportation of kelts by either barge or tank truck around the mainstem hydro projects, prior to release downstream of Bonneville Dam. Once kelts are collected, they can be transported and released or held for reconditioning. Reconditioning has produced much higher return rates than transport and release (Hatch et al. 2013b), thus the Action Agencies are currently recommending that collected kelts be retained for reconditioning until hatchery capacity is reached. The 2011-12 and 2012-13 Kelt Management Plans describe kelt relative return rates estimated during transportation research studies conducted during the past decade. (http://www.salmonrecovery.gov/Hatchery/KeltReconditioning.aspx)

Objectives of the 2013 KMP

The Kelt Management Plan for 2013-2014 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. The 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. In addition to describing implementation of BiOp Actions (33 and 42) this Plan will also coordinate approaches with those implemented in the kelt reconditioning programs that were committed to under the 2008 Fish Accords with the Three Lower River Treaty Tribes and the Columbia River Inter-Tribal Fish Commission (CRITFC). Starting with the original framework introduced in the 2009-2010 plan, subsequent annual plans have progressed using approaches of adaptive management.

Evaluation of 2013 Progress for three BiOp strategies

The goal of kelt management actions is to improve survival and productivity of listed steelhead by allowing kelts to successfully survive and spawn in a subsequent year. The 2013 version of the KMP builds upon the framework of previous plans, but also identifies future direction through the remainder of the BiOp (2014-2018). The 2013 KMP reviews the goals of the plan and summarizes progress on reconditioning efforts as well as in-river kelt migration studies performed during 2012 and 2013.

Several research studies were carried out on in-river enhanced migration topics. The Corps completed the second year of its in-river dam route and river reach survival study, using acoustic tags, at three of the lower Snake dams. Survival per kilometer was lowest in dam forebays, and system survival from Lower Granite to below-Bonneville Dam was lower in 2013 (34.2%) than in 2012 (51.4%). Kelts most frequently passed through spillway routes (spillway weirs or traditional deeper spill) during this study. Four of the 324 (1.2%) kelts that were tagged with acoustic transmitters in 2012 were detected making upstream migrations in the summer and fall of 2013. In addition, the Corps commissioned an analysis of PIT data to assess trends in kelt iteroparity rates of winter and summer steelhead from subpopulations throughout the Columbia Basin, hatchery and wild origin spawners, and ‘a’ and ‘b’ run kelts originating from the Snake River that indicated some benefit to in-river passage and survival has been attributable to installation of surface spill weirs at all FCRPS projects, except The Dalles and Bonneville dams. Keefer and Caudill (2013) concluded that surface spilling weirs have increased the passage efficiency of kelt, but not necessarily the route survival between surface and deeper spill due to annual variation within and between flow year operations. The influence of surface weir hydraulics on faster egress of kelt past the dam and tailwaters is likely as important as direct route survivals. Keefer and Caudill (2013) evaluated migration histories from 53,282 adult steelhead detected at Bonneville Dam over 11 adult migration years (2000-2010) that included winter- and summer-run life history types, wild- and hatchery-origin fish, and were from a wide variety of populations and management groups. In total, 7 winter steelhead and 132 summer steelhead were considered to have initiated a second spawning migration based on appropriately-timed detections at Bonneville Dam in two migration years. Six of the seven winter steelhead were consecutive year spawners and the seventh was a skip year spawner. The summer group was half consecutive spawners and half skip spawners. With all years combined, Bonneville-to-Bonneville iteroparity estimates for the primary life history×origin groups were: 2.78% (winter, wild), 0.44% (winter, hatchery), 0.56% (summer, wild), and 0.16% (summer, hatchery).

Reconditioning efforts focused on B-run hatchery kelts have been developed and implemented at Dworshak NFH. In 2013, 69 natural origin female B-run kelts were released from the reconditioning program; this annual release represents a substantial 2.3% towards meeting the 2018 6% target. Combined with the annual reoccurring credit received from winter operations at the Dalles dam (0.9%), in 2013 the Action Agencies realized a 3.2% benefit of towards Snake River B-run kelts. To promote further development of the Snake River kelt reconditioning program, the BPA continued to fund Columbia River Inter-Tribal Commission (CRITFC) and the Nez Perce Tribe (NPT) to prepare a master plan for the Snake River kelt reconditioning program. This Snake River kelt master plan will provide a guide to complete the Council's 3-Step process for capital projects and ultimately result in the construction of a permanent kelt reconditioning facility to assist in meeting the BiOp goal of increasing B-run steelhead productivity by 6%.

The 2013 KMP references previous analysis of the benefits of transport which suggest that transport would be best utilized as an alternative option. In short, this strategy would be best employed once the collection of kelts for reconditioning has exceeded holding capacity. Due to collection constraints in 2013, the transport strategy was not employed.

Current status and research results

Strategy 1: Long term reconditioning

The Kelt Steelhead Reconditioning and Reproductive Success Evaluation Project 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-spawning steelhead, first it assesses reconditioning processes and strategies, and second, it measures reproductive success of artificially reconditioned kelt steelhead. It associates with RPAs 33 and 64 in the Federal Columbia River Power System Biological Opinion. RPA Action 33 requires the Action Agencies to develop, in cooperation with regional salmon managers, and to then 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 stage steelhead. This project focuses on the reconditioning component. RPA 64 involves resolving artificial propagation critical uncertainties primarily through relative reproductive success studies. This project is working toward evaluating reproductive success of artificially reconditioned kelt steelhead. This research contributed three papers to the published literature in 2013 (Caldwell et al. 2013; Hatch et al. 2013; Penney and Moffitt 2013) and an additional four papers are in review (Buelow et al. in review; Caldwell et al. in press; Penney and Moffitt in review a.; Penney and Moffitt in review b.). Our team presented 14 project presentations in 2013 at basin, regional, national, and international levels.

<u>Reconditioning Process</u>

Kelt steelhead reconditioning process evaluations involve fish culturing practices, studying alternative management strategies, and implementing research scale reconditioning programs. Refinements in fish culturing practices this year included a diet experiment that investigated the benefits of top dressing pellets with fish oil or cyclopeeze, and evaluating the effectiveness of ivermectin and emamectin benzoate for parasite control. Effectiveness was measured with survival and rematuration metrics. We used fish in long-term reconditioning for a feeding trial that compared an “orange” diet that was comprised of a mix of customized Bio-Oregon brood pellets top coated with a mix of cyclopeeze and Alaskan fish oil versus the standard diet (customized Bio-Oregon diet and krill) (Hatch et al 2003a). Both groups received krill at the start of reconditioning for the same duration of time. The diet study just recently concluded in 2013 and data is currently being analyzed. Preliminary results found in the 2012 trial, fish fed the orange diet had higher muscle lipid levels at release than fish fed the standard diet. The orange diet median muscle lipid levels increased by 0.4% in 2013, and 0.6% in 2012. The increase in muscle lipid levels was modest and may be explained due to either increased feed consumption or the higher lipid level in the orange diet. If feasible, the current feeds should have increased lipid content and appetite stimulants added before further diet studies are undertaken. Emamectin benzoate (emamectin) is an alternative to ivermectin that has been developed for control of sea lice (marine copepod ectoparasites) in Atlantic salmon aquaculture, and both drugs have been adapted for use in steelhead kelt reconditioning to reduce *Salmincola* is a genus of parasitic copepod that can inhibit oxygen uptake and gas exchange at the gill lamellae/water surface interface. We compared the post treatment mortality rates of kelts that were administered ivermectin via gavage as well as a group that was injected. Results demonstrated a dramatic reduction in mortality that was substantial and consistent between years: after 90 days, mortality in emamectin treated fish was 33.2% less than ivermectin treated fish in 2011, and 34.8% in 2012. This experiment did not attempt to quantify levels of copepod infestation in emamectin versus ivermectin treated fish. However, very few fish were observed with significant numbers of copepods at release, suggesting that both ivermectin and emamectin treatment controlled copepods adequately.

Plasma estradiol was extracted and analyzed from long-term reconditioned kelt steelhead to assess rematuration levels. Samples are currently being processed in the laboratory so the final results are not yet available.

Alternative management strategies for kelt steelhead studied thus far include: long-term reconditioning, where fish are collected during out migration, held and feed through the summer and released in the fall; collect and transport kelt steelhead, where fish are collected and immediately transported (unfed) and released below Bonneville Dam, or collected, fed for 4-6 weeks (fed) then transported and released below Bonneville Dam; and direct release, where fish are collected, PIT tagged and released back to river as a control group.

Experimental scale long-term kelt reconditioning survival data was compared from 3 locations including; the Okanogan, Snake, and Yakima rivers, where survival rates in long-term reconditioning was 8.2%, 51.8%, and 48.7% respectively. We also published a manuscript detailing the long-term kelt reconditioning program at Prosser Hatchery (Hatch et al. 2013b).

Specific to Snake River B-run steelhead (addressing RPA 33), our collection locations included kelts at the Lower Granite Dam juvenile bypass separator, air-spawned steelhead being used for the South Fork Clearwater River naturalized broodstock project, and Dworshak National Fish Hatchery returns. Fish collected from Lower Granite Dam were either transported to Dworshak Hatchery for reconditioning, or PIT tagged and released back into the Snake River is represent a control group. Fish collected from the South Fork Clearwater were reconditioned and released, and Dworshak Hatchery fish were used for experiments and not released. Kelt stage steelhead were collected at Lower Granite Dam as they passed through the juvenile bypass system. A total of 110 wild female B-run steelhead were collected at Lower Granite Dam from April to June and transported to Dworshak National Fish Hatchery for reconditioning. Fifty-seven of these fish survived reconditioning and were released downstream of Lower Granite Dam in October 2013. Additionally, 24 B-run kelt steelhead were retained for reconditioning after air spawning at Dworshak Hatchery. These fish were part of project that is developing localized broodstock for the South Fork Clearwater River. Following reconditioning 12 of these fish were released back into the South Fork Clearwater River. In total 69 wild B-run steelhead were reconditioned and released back into the Snake River system aimed at addressing RPA 33.

To establish a control group for management action comparisons, we continue to collect and PIT tag the kelt steelhead run at large to estimate baseline in-river survival. In 2013, we tagged 827 steelhead collected from the Lower Granite Dam juvenile bypass system. None of these fish were detected returning at any FCRPS dam as sequential spawners in 2013. It is possible that some fish from this release will exhibit a skip spawner life history pattern and return in 2014 after spending an additional winter in the ocean. Similar tagging in 2012 resulted in the return of a single fish out of 2,098, resulting in a return rate to Bonneville Dam of 0.05%. Since 2002, we have PIT tagged 9,325 kelt steelhead at Lower Granite Dam and detected 32 (0.34%) of them returning upriver at Bonneville Dam. The 2013 Yakima River control group release included 52 PIT tagged fish. None of these fish were detected returning to Bonneville Dam as sequential spawners. From 2005 through 2013, 669 kelt steelhead were PIT tagged and released in the Yakima River representing the control group and so far 21 (3.4%) fish were detected returning to Bonneville Dam.

The genetic stock structure of Snake River Basin kelt steelhead was examined using 187 SNP markers extracted from emigrating fish collected at Lower Granite Dam. The kelt steelhead population composition at the Lower Granite Dam Juvenile Bypass Separator from 2009-2012 was Upper Salmon (0.39); Grande Ronde/ Lower Snake (Tied) (0.16); Middle Fork Salmon (0.09); and, Imnaha (0.06), reporting groups based on a sample size of 4,138.

Reproductive Success of Artificially Reconditioned Kelt Steelhead

We have investigated reproductive success of artificially reconditioned kelt steelhead at a variety of scales. Experiments have been conducted at the natural stream level, in a hatchery environment, and at the individual fish level.

This evaluation program is designed to investigate the reproductive success of artificially reconditioned kelt steelhead. Since direct examination of reproductive success in the field has proven very difficult, we are concentrating on measuring physiological and endocrinological parameters as an index to rematuration and reproductive success. Additionally, we are evaluating gamete and progeny viability and conducting reproductive success studies in Omak Creek using pedigree analysis. This project is a collaborative effort among four tribes (Nez Perce, Warm Springs, Yakama Nation, and Colville), the University of Idaho, and the Columbia River Inter-Tribal Fish Commission.

At the natural stream level, we have conducted experiments on Omak Creek a tributary to the Okanogan River for several years. We have determined that at least 4 of 11 reconditioned kelt steelhead have successfully produced offspring in Omak Creek. This site has proven challenging for this evaluation primarily due to low kelt steelhead collection numbers and then ultimately few reconditioned fish. Additionally, the reconditioned fish must be released in the Okanogan River to overwinter adding mortality and difficulty to tracking these fish to spawning grounds in Omak Creek. An additional 22 juveniles assigned to reconditioned kelts in the Yakima River. As a result of these challenges, we may transfer future efforts to the Cle Elem Hatchery spawning channel (described below).

At Parkdale Fish Facility, we conducted experiments to compare performance of maiden and repeat spawnings of artificially reconditioned kelt steelhead using metrics of fecundity, fertilization rates, and early juvenile growth. A total of 21 fish were successfully reconditioned and repeat spawned from a collection of 134 steelhead. Summer-run steelhead had higher fecundity levels in their repeat compared to maiden spawning, and all other metrics showed no significant difference between repeat and maiden spawnings. Winter-run steelhead showed no significant differences in fecundity, fertilization rates, and growth in terms of length and weight, there were significant differences in fry starting length and weight with maiden spawnings resulting in larger fry starting sizes.

To better understand the physiological processes that influence post-spawn steelhead recovery, we published two manuscripts, the first used histological analysis of Snake River steelhead as a model to assess the cellular architecture in the pyloric stomach, ovary, liver, and spleen in sexually mature and kelt steelhead (Penney and Moffitt 2013). The second identified metabolic endocrine factors involved in spawning recovery and rematuration of iteroparous female rainbow trout (Caldwell et al. 2013).

Prioritization of collected steelhead

Since the implementation of spillway weirs, there has been a reduced supply of good condition kelts collected at dam facilities. Collection of steelhead kelts at tributary streams and at the bypass facilities of the lower Snake River dams is an essential step for the kelt reconditioning (Hatch et al. 2013b) and transport strategies. In addition, collection, PIT tagging, and release of kelts is necessary for monitoring and research related to the enhanced in-river migration strategy (Colotelo et al. 2013). Keefer et al. (2008) reported that kelts in good or fair condition were > 25 and > 10 times respectively more likely to return as repeat spawners than those in poor condition. They also reported that early emigrating, bright colored, wild, and smaller bodied kelts were also significantly more likely to return as repeat spawners.

The 2011-2012 and 2012-2013 Kelt Management Plans explain the current rationale for dividing available dam collected kelts between reconditioning programs and transportation, prioritizing allocation of higher quality wild kelts to reconditioning until available tank space is filled, and directing any additional kelts to transport (http://www.salmonrecovery.gov/Hatchery/KeltReconditioning.aspx). This is based on the success rate of the long-term reconditioning program during its pilot stages. Kelt transportation will be considered a higher priority during dry years (defined in the 2010 Adaptive Management Implementation Plan as years falling in the lowest 20% of spring flow volume) when in-river survival rates are expected to be lower.

The 2008 BiOp estimated 7% collection efficiency at LGR during traditional spill operations and 22% collection efficiency without spill (Bellerud et al. 2007). The installation and operation of surface spillways at Lower Granite and other dams are believed to divert a substantial fraction of adults during the kelt outmigration and may reduce the collection rate although this has not been formally estimated by NOAA. Tributary based kelt collection has increased in the Clearwater River and other spawning streams by the Nez Perce Tribe and IDFG, and this collection approach may become more valuable in the future if collection rates continue to decline at dam bypass facilities.

Strategy 2: Transportation

CRITFC did not conduct any transport experiments in 2013 due to their relatively lower benefits compared to long-term reconditioning and the overall lower availability of kelt steelhead. From 2002 through 2011 we collected and transported kelt steelhead from Lower Granite Dam to below Bonneville Dam. These studies collected and transported 2,698 kelt steelhead, of which 29 (0.01%) were detected returning upstream at Bonneville Dam.

We are developing a spreadsheet model of management scenarios to address “what if” simulations. This model will be completed during the first half of 2014.

Strategy 3: Enhanced in-river migration

The Bonneville Dam PH2 corner collector was opened nearly one month early (March 17, 2014) in an effort to provide a safer route of passage for early-migrating steelhead kelts, primarily originating from the lower Columbia River.

The Corps of Engineers funded a couple studies and initiated a couple evaluations in 2013 that focused on in-river migration of kelts through the hydrosystem. Colotelo et al. (2014) completed a second year of kelt route and reach passage and survival through the Snake River from JSATs implanted kelt collected and released from Clearwater and Snake river tributaries above Lower Granite reservoir and kelt tagged out of the Nez Perce Tribe reconditioning collection tanks at Lower Granite Dam. For a synopsis, Lower Granite passage is emphasized in the following paragraphs, as excerpted out of Colotelo et al. (2014).

At present, all adult fish (including kelts) are passed through 10 inch orifices from the turbine galleries through a collection channel, then through a downwell-pressurized pipe-upwell plumbing that exists onto the single stage separator. The adult fish pass over the juvenile separator bars to the end of the separator, where either a manually-operated gate opens and drops the fish into a chute return to the river or a technician manually nets each kelt off the separator and transfers that kelt to a chute (through a wetted pipe) that terminates into a holding tank. Debris too large to pass through the separator bars is manually picked off the bars or moved along the top of the bars for discharge back into the river with the adult fish.

The collection and transport of kelts (either with or without short-term reconditioning) are targeted in RPAs 33 and 50. Long-term plans being developed as part of the 2008 FCRPS BiOp's required Kelt Management Plan (RPAs 33 and 50) cannot be implemented efficiently at Lower Granite due to problems in handling and managing the kelts at the facility. Kelts selected for reconditioning are truck transported to Dworshak National Fish Hatchery. Two years of kelt dam passage and reach survival evaluations with acoustic-telemetry (JSATs by Colotelo et al. 2013 and 2014) indicate that downriver migrating kelts behave similar to smolts relative to timing (dates) and route of passage and flow proportionality at most FCRPS dams (Table 1 and Figures 1 and 2) to the point where route survival improvements due to modified operations and/or configurations are likely required to fully exceed the 6% increase in B-run female spawners required by the 2008 FCRPS BiOp. Reducing residence time and rate of passage out of the forebay and through the tailwaters appears to be a limiting factor for kelts as well as smolts, especially for Lower Granite Dam and reservoir (the first FCRPS dam encountered, Table 2) (Colotelo et al. 2014).

Overall, 27.3% (n = 133 of 487) of kelts that were tagged at tributary weirs and Lower Granite dam successfully migrated to Martin Bluff (rkm 126), which is located downstream of all FCRPS dams. Within individual river reaches, survival probability estimates ranged from 0.657 (SE = 0.042) to 1.003 (SE = 0.001). Dam passage survival was lowest at Lower Granite (S= 0.657; SE = 0.041) and highest at Little Goose (S = 0.911; SE = 0.015). Because river reaches varied in length, the survival per kilometer was also determined and found to be lowest in the immediate forebay of FCRPS dams. Forebay survival was lowest at Little Goose (S = 0.958; SE = 0.010) and highest at Lower Granite (S = 0.978; SE = 0.013). Survival per kilometer was substantially lower in the immediate forebays of all three dams evaluated in 2013 compared to any other reach.

Acoustic-tagged steelhead kelts most frequently passed through spillway routes (spillway weirs or traditional spill) during this study. Although spillway weirs were used by the majority of kelts in the Snake River similar to the 79.9% at Lower Granite Dam in 2013 (Figure 2 and Table 3), survival estimates during the lower flow year of 2013 were highest for kelts that passed through traditional spill (70.6%; SE= 11.1) at Lower Granite when a spillway weir (66.7%; SE = 4.6%) was available for passage (Table 3 compared to the higher flow year 2012 estimates of 57.3% passage percent for spillway weir with 90.1% survival; SE = 3.5% and passage percent for traditional spillway of 25.8% with 90.6% survival; SE = 5.2%).

Table 1. Dates that the first and last acoustic-tagged kelt passed at Lower Granite (LGR).

	Kelt Passed	First Kelt Passed	10% Passed	25% Passed	50% Passed	75% Passed	90% Passed	Last Kelt Passed
2012	124	21 April	26 April	30 April	10 May	11 June	19 June	30 June
2013	144	14 April	17 April	23 April	28 April	21 April	5 June	17 June

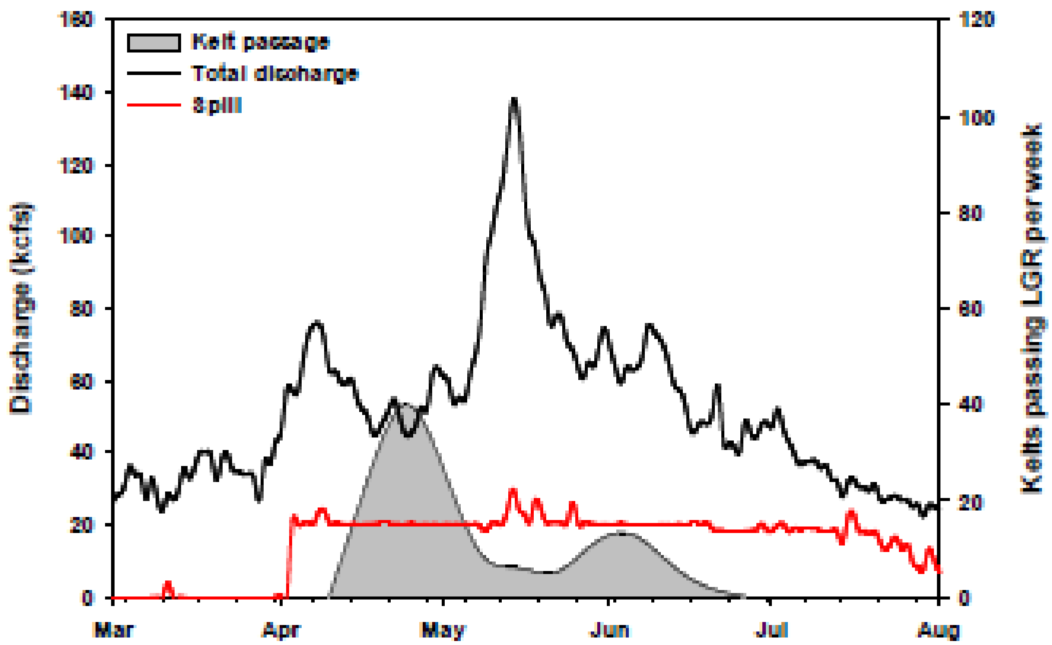

Figure 1. Average daily discharge and spill (kcfs) at LGR from 1 March to 1 August 2013 overlaid with numbers of kelt per week (Monday-Sunday) detected passing LGR during that same period.

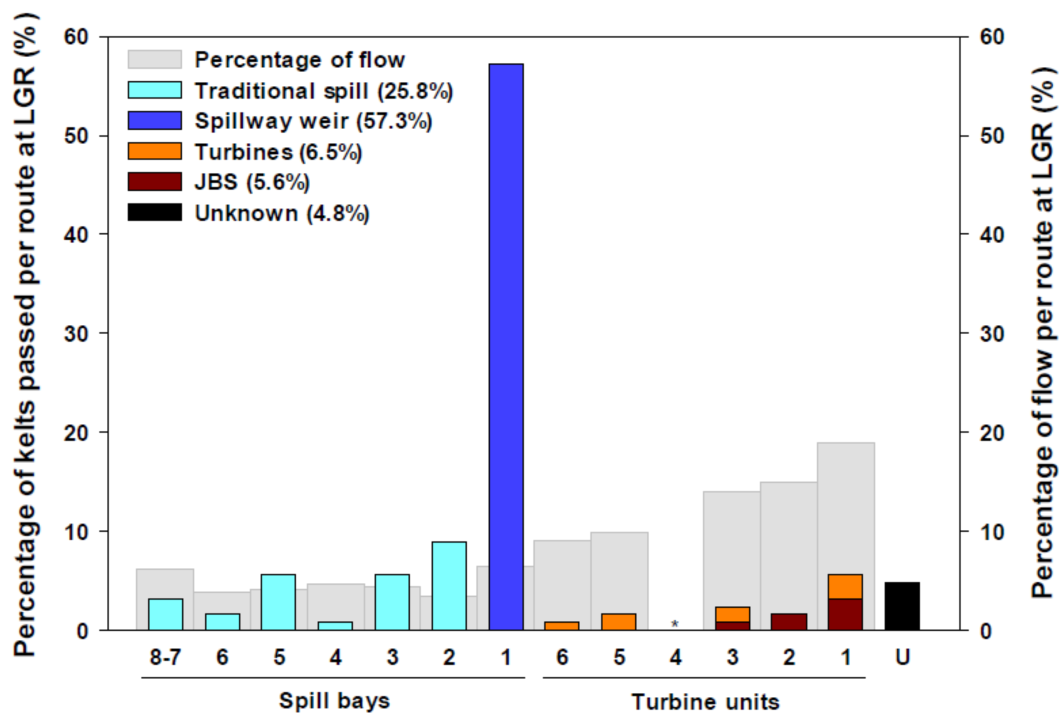

Figure 2. Percentage of kelt passing LGR via each passage route (colored bars) and percentage of flow through each route (grey bars) during the period of tagged kelt passage at LGR 21 April to 30 June, 2013.

Table 2. Forebay residence time, Tailrace egress time, and Project passage time for acoustic-tagged kelts passing LGR during 2012 and 2013.

	Forebay residence time (1 km in hrs). Median (range)	Tailrace egress time (2 km in hrs) Median (range)	LGR Project passage time (3 km in hrs) Median (range)
2012	1.25 (0.32-84.69)	0.40 (0.18-22.70)	1.73 (0.55-85.47)
2013	1.87 (0.26-59.91)	0.60 (0.22-99.19)	3.06 (0.77-103.42)

Table 3. Route-specific passage proportions and survival estimates (SE) of acoustic tagged kelts that passed through Lower Granite Dam during April through June 2012 and 2013 (Colotelo et al. 2014).

2013	Traditional Spill	Spillway Weir	Turbine	JBS	Unknown
Passage Proportion	0.125	0.799	0.014	0.049	0.014
Survival	0.706 (0.111)	0.667 (0.046)	1.000 (0.000)	0.333 (0.193)	----

Two independent estimates of LGR kelt abundance passing LGR in 2013 were derived by Colotelo et al (2014) from the available acoustic tagging and separator passage data. Dividing the number of kelts sampled on the LGR JBS separator by probability of tagged kelts passing LGR via the JBS produced a population estimate of 18,683 kelts that passed LGR. Using the Lincoln-Petersen mark-recapture method on kelts marked at the tributary weirs and recaptured (via acoustic detection) at LGR, an estimated 22,499 kelts were present at the time of tagging. Multiplying this estimate by the pooled survival probability from the tributary weirs to LGR, Colotelo et al. (2014) obtained an estimate of 18,796 kelts that arrived at LGR. Agreement of these two independent estimates led Colotelo et al. (2014) to believe they are relatively accurate and precise. These estimates indicate that 17% of the 110,675 adult steelhead estimated to have passed LGR on their way to the spawning grounds in 2012 returned as kelts in 2013.

Four of the 324 (1.2%) kelts that were tagged with acoustic transmitters in 2012 were detected making upstream migrations in the summer and fall of 2013. One of the returning fish, a female, was tagged in 2012 at the Joseph Creek weir, and the remaining three were tagged at LGR. The kelt tagged at Joseph Creek was detected in August 2013 at the PIT-tag detection array near the mouth of the Deschutes River (rkm 328). The Deschutes River is a tributary of the Columbia River and Snake River steelhead commonly use it as a thermal refuge during summer months because it generally has cooler water temperatures than the Columbia River. This kelt was detected in November 2013 as it passed LGR. The other three returning kelt (two females and one male) were detected moving upriver in August (female) and September (male and female) 2013.

Although the results of this study contribute to understanding the impact of hydropower on steelhead kelt migration in the FCRPS, future research is warranted. Future studies should focus on sampling throughout the full kelt emigration period, specifically prior to the opening of the spill bays, and on tagging a larger proportion of kelts in fair and poor condition. Such studies should also collect kelts from additional locations in the Snake River basin to acquire information that is applicable to a larger proportion of the Snake River steelhead population.

In addition to Colotelo et al. (2014), comparison of passage and survival study metrics between the average flow year of 2012 and the low flow, high temperature year of 2013 was initiated. PNNL (Colotelo and Harnish 2014 In Prep) have begun statistical diagnostic evaluations to elucidate route specific and environmental variable importance. Preliminary results are shown below. These evaluations are designed to inform important and cost-effective probable configuration and operational actions for future planning, especially for kelt migration and production during perceived increase in lower seasonal flow and higher temperature regimes possibly destined for the lower Snake River.

PNNL is diagnosing the effect of several individual and environmental variables on kelt travel time and survival in the Snake and Columbia rivers in 2012 and 2013. Migration success was calculated as the percentage of acoustic-tagged kelts released at LGR that were detected by arrays located downstream of BON. It should be noted that migration success rate is not a true survival estimation, but was calculated to allow for comparison to previous studies that have used this metric. The single release-recapture model, first presented by Cormack (1964), Jolly (1965), and Seber (1965), and later by Skalski et al. (1998) was implemented using the program SURPH (SURvival under Proportional Hazards; version 3.5.2) to estimate survival and array detection probabilities for groups of kelts.

Individual variables included sex [variable name = sex], condition at the time of tagging [condition], weight [weight], fork length [FL], Fulton's condition factor [K], day of release for the Snake River or day of detection at the rkm 525 array for the Columbia River [day], and clipped or unclipped status of the adipose fin [adipose]. Environmental variables included river discharge [discharge] and water temperature [temperature]. For the Snake River, each kelt was associated with the mean daily discharge and water temperature as measured in the LGR tailrace on the day of their release. For the Columbia River, each kelt included in the virtual release formed at rkm 525 was associated with the mean daily discharge and water temperature as measured at McNary Dam on the day they were detected at rkm 525.

Factors that affected the survival probability and travel rate of steelhead kelts in the Snake and Columbia rivers were examined using a combination of analyses. Categorical variables (sex, condition, adipose) were first evaluated by comparing nested models of equal and unequal survival probability for variable groups (male vs. female, fair vs. good condition, clipped vs. unclipped adipose) using likelihood ratio tests (LRT; α =

0.05). All quantitative variables were first fit to the response variable independently to evaluate the direction and magnitude of their effect on the response metric. The effect of each quantitative predictor variable on survival was evaluated using the program SURPH, whereby survival probabilities of individual fish were modeled as a function of each individual-based covariate (i.e., quantitative predictor variable) using the hazard link (Skalski et al. 1993; Smith et al. 1994). Nested models of the covariate effect versus no effect were compared using LRTs (α = 0.05).

A total of 497 kelts were implanted with JSATS transmitters and released from the LGR JFF in 2012 and 2013. At the time of tagging, the median fork length of kelts was 580 mm in 2012 and 600 mm in 2013. Females were significantly longer than males in both 2012 and 2013 (Mann-Whitney test, $P < 0.001$). Across both study years, 78% of kelts were in good condition at the time of tagging and 22% were in fair condition. A larger percentage of fair condition kelts was tagged in 2013 (24%) than in 2012 (17%). A higher percentage of kelts with a clipped adipose fin, indicating hatchery origin, was tagged in 2013 (47%) compared to 2012 (35%).

In 2012, 51.4% (93 of 181) of the kelts implanted with acoustic transmitters at LGR successfully migrated beyond BON. This success rate was considerably higher than the migration success observed in 2013 when only 34.2% (108 of 316) of the acoustic-tagged kelts were detected by arrays located downstream of BON. Combining both years resulted in an overall migration success rate of 40.4% (201 of 497).

In 2012, all kelts that were detected below Bonneville Dam arrived within 18.2 days of their release. In 2013, all implanted kelts that passed the final detection array did so within 21.4 days from their release.

Overall, kelts tagged at LGR had a survival probability of 0.59 (SE = 0.04) to BON in 2012, which was substantially higher than the 0.36 (SE = 0.03) survival probability observed in 2013. Breaking it down by system, kelts had an estimated survival probability of 0.88 (SE = 0.02) in the Snake River (from release to the mouth) in 2012, compared to 0.55 (SE = 0.03) in 2013. In the Columbia River (from the mouth of the Snake River to BON), survival was similar in 2012 (S = 0.67; SE = 0.04) and 2013 (S = 0.65; SE = 0.03). Survival probability-per-kilometer was higher in the Snake River (S/km = 0.9992) than in the Columbia River (S/km = 0.9986) in 2012. However, this relationship was reversed in 2013 when survival probability-per-kilometer was 0.9964 in the Snake River and 0.9985 in the Columbia River.

In 2012, kelts had a median travel rate of 49 km/d (range = 27–76 km/d) from the LGR tailrace to the BON forebay array. The median travel rate was slightly lower through the system in 2013 at 45 km/d (range = 23–71 km/d). Calculating median travel rates for each river separately revealed that, on average, kelts traveled about twice as fast in the Columbia River compared to the Snake River.

Several candidate variables were removed prior to the model-building procedure to reduce multi-collinearity among predictor variables in the final model. Fork length and weight were highly correlated (r = 0.96) for kelts released in the LGR tailrace (rkm 694) and for those included in the virtual release at the mouth of the Snake River (rkm 525). Because water temperature generally increased linearly throughout the study period in 2012 and 2013, daily mean water temperature at LGR was highly correlated with the day of release in the LGR tailrace (r = 0.79). Fitting each of the correlated variables independently to the survival data indicated fork length provided a better fit to kelt survival than weight in both the Snake (ΔAIC

= 11.39) and Columbia (ΔAIC = 2.28) rivers. Additionally, day provided a better fit than water temperature to the kelt survival data of the Snake (ΔAIC = 0.10) and Columbia (ΔAIC = 3.33) rivers. Therefore, water temperature was removed from the survival model-building process.

Combining data from both 2012 and 2013, kelts tagged at LGR had a 0.67 (SE = 0.02) probability of survival from release into the LGR tailrace to the mouth of the Snake River. Likelihood ratio tests indicated survival within the Snake River differed significantly between kelts that were classified as being in fair (S = 0.44; SE = 0.05) versus good (S = 0.74; SE = 0.02) condition at the time of tagging (χ^2 = 32.01; P < 0.001; Table 2). We observed no difference in survival between male (S = 0.70; SE = 0.04) and female (S = 0.66; SE = 0.02) or clipped (S = 0.65; SE = 0.03) and unclipped (S = 0.69; SE = 0.03) kelts in the Snake River ($\chi^2 \leq 1.31$; $P \geq$ 0.253). Strong, positive correlations were observed between survival of kelts in the Snake River and K (χ^2 = 23.84; P < 0.001), between survival and discharge (χ^2 = 78.72; P < 0.001), and between survival and day of release (χ^2 = 5.86; P = 0.016; Figure1). Survival of kelts in the Snake River was also negatively correlated with fork length (χ^2 = 31.61; P < 0.001).

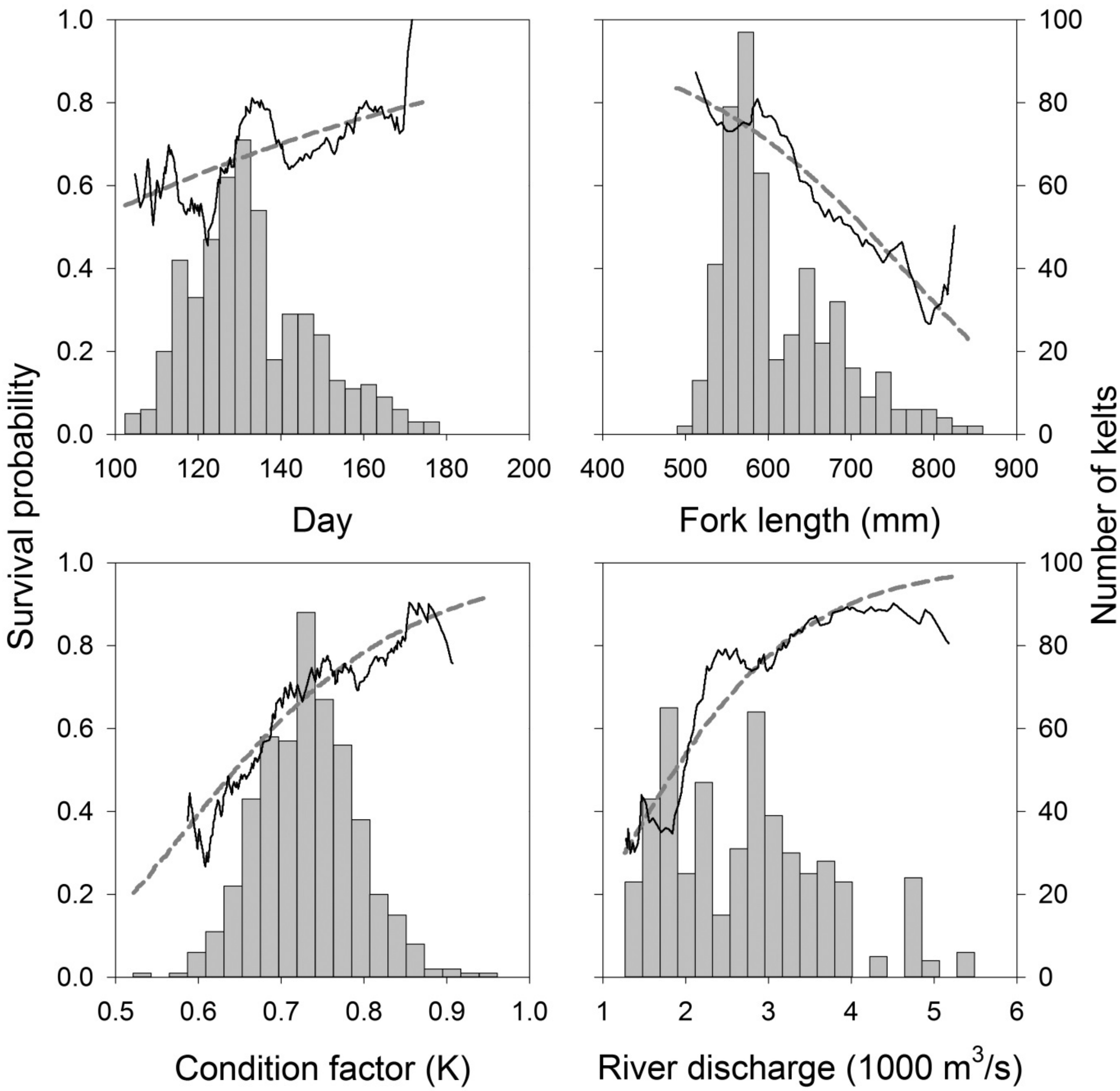

Figure 3. Covariate analysis results displaying non-parametric (black line) and modeled (dashed grey line) survival probabilities of steelhead kelts in the Snake River in relation to release day (Day), fork length, Fulton's condition factor (K), and discharge as measured at Lower Granite Dam. Frequency histograms (grey bars) display the number of kelts in each bin of the independent variables.

Among the possible multiple logistic regression models constructed using the backward stepwise approach to predict survival of steelhead kelts in the Snake River, the model that included discharge, condition, release day, K, and fork length had the lowest AIC value Likelihood ratio tests indicated there was a significant difference between this model and all other models that contained fewer variables ($\chi^2 \geq 6.98$; $P \leq 0.008$). Therefore, this model was retained as the most parsimonious model. This final model had an R^2 value of 0.20 and indicated survival of steelhead kelts in the Snake River was positively correlated with discharge, day, and K, negatively correlated with fork length, and higher for kelts deemed to be in better condition at the time of tagging. The range odds ratios indicated that the odds of survival improved by a factor of 34.8 as discharge increased from the minimum observed discharge (1,274 m^3/s) to the maximum observed discharge (5,276 m^3/s). Good condition kelts were 3.1 times more likely to survive from release into the tailrace of LGR to the mouth of the Snake River than were kelts in fair condition. Kelts that were released the latest in the study period (mid- to late-June) were 6.7 times more likely to survive to rkm 525 than the earliest (mid-April) releases. Kelts at the upper end of the range of K values (K = 0.94) were 8.9 times more likely to survive than those at the lower end of the range (K = 0.52). Finally, kelts at the lower end of the fork length range (FL = 490 mm) were 4.5 times more likely (calculated as the reciprocal of the 0.22 range odds ratio) to survive migration from the LGR tailrace to the mouth of the Snake River than those at the upper end (FL = 840 mm) of the size distribution.

Combining data from 2012 and 2013, acoustic-tagged kelts had an overall survival probability of 0.66 (SE = 0.03) from the mouth of the Snake River to Bonneville Dam. Survival within the Columbia River differed significantly between female (S = 0.63; SE = 0.03) and male (S = 0.75; SE = 0.05) kelts (P = 0.038). There was no difference in survival between fair (S = 0.60; SE = 0.07) and good (S = 0.67; SE = 0.03) condition kelts or between clipped (S = 0.69; SE = 0.04) and unclipped (S = 0.64; SE = 0.03) kelts in the Columbia River . We observed positive correlations between kelt survival within the Columbia River and K (χ^2 = 6.89; P = 0.009) and between survival and day of detection at rkm 525 (χ^2 = 4.73; P = 0.030; Figure 2). Survival of kelts in the Columbia River was negatively correlated with fork length (χ^2 = 4.40; P = 0.036). Discharge was negatively and weakly correlated with kelt survival in the Columbia River (χ^2 = 0.36; P = 0.548), which was in contrast to the results obtained from the Snake River covariate analysis.

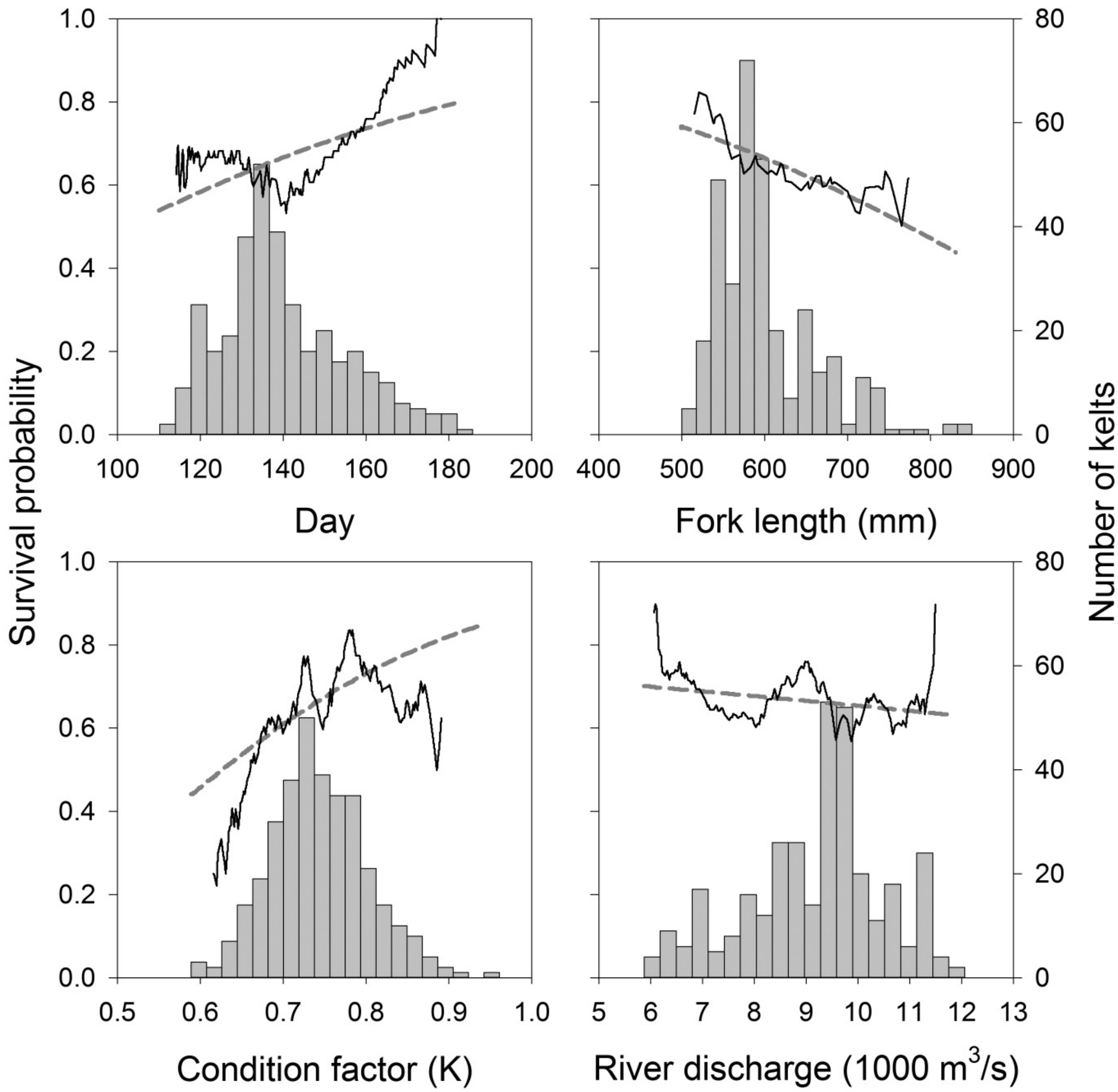

Figure 4. Covariate analysis results displaying non-parametric (black line) and modeled (dashed grey line) survival probabilities of steelhead kelts in the Columbia River in relation to day of detection at the mouth of the Snake River (rkm 525; Day), fork length , Fulton's condition factor (K), and river discharge as measured at McNary Dam. Frequency histograms (grey bars) display the number of kelts in each bin of the independent variables.

None of the multiple logistic regression models created using the backward stepwise approach to explain kelt survival in the Columbia River had substantial predictive power. All models had R^2 values ≤ 0.05. The model that included K, day, condition, adipose, and sex had the lowest AIC. However, results from LRTs indicated there was no difference between this model and the reduced model that included only K, day, and condition (χ^2 = 4.92; P = 0.086). Additionally, the ΔAIC value of this reduced model was just 0.92. Therefore, this reduced model was selected as the most parsimonious, had an R^2 value of 0.03, and indicated survival of steelhead kelts in the Columbia River from the mouth of the Snake River to BON was positively correlated with K and day and was higher for kelts that were deemed to be in better condition at the time of tagging . The range odds ratios indicated that kelts at the upper end of the range of observed K values were 6.6 times more likely to survive from the mouth of the Snake River to BON than those at the lower end of the range. Good condition kelts were 1.8 times more likely to survive from the mouth of the Snake River to BON than were kelts in fair condition. Finally, the latest-migrating kelts, those that were detected at the mouth of the Snake River in late June, were 4.4 times more likely to survive to BON than the earliest (late April) migrants.

Male kelts had a median travel rate of 22.19 km/d, which was significantly faster than the 19.96 km/d females traveled in the Snake River ($H = 5.80$; $P = 0.016$). We observed no significant differences in travel rate between good and fair condition, or clipped and unclipped kelts ($H \leq 2.57$; $P \geq 0.109$). We did observe a relatively strong, positive relationship between travel rate and Snake River discharge ($t = 9.27$; $P < 0.001$), and weak, negative relationships between travel rate and length ($t = -3.97$; $P < 0.001$) and between travel rate and release day ($t = -2.28$; $P = 0.023$; Figure 3). No relationship was observed between K and kelt travel rate in the Snake River ($t = -0.38$; $P < 0.702$).

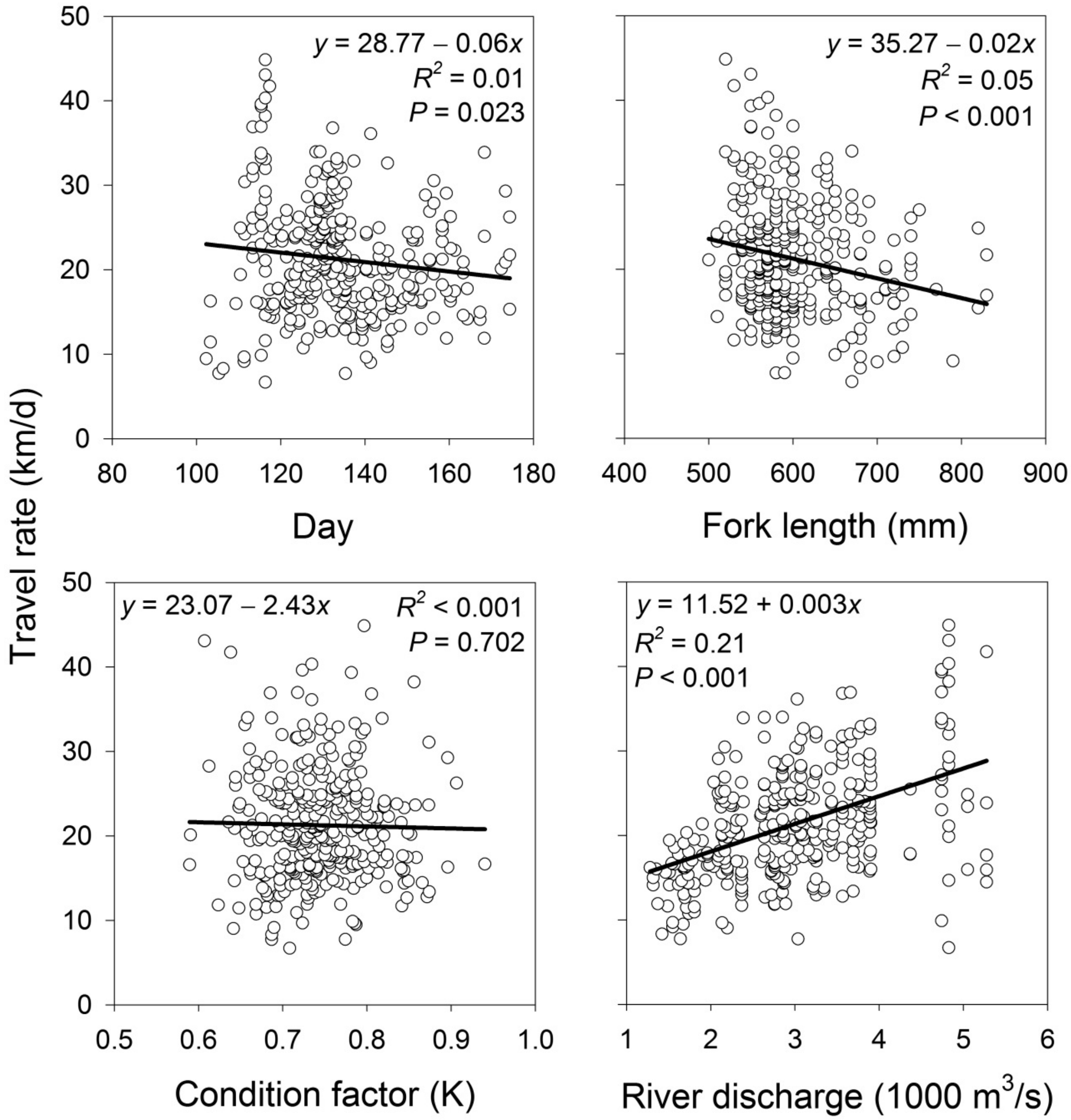

Figure 5. Simple linear regression relationships between travel rate of kelts from release into the Lower Granite Dam tailrace to the mouth of the Snake River and release day (Day), fork length, Fulton's condition factor (K), and river discharge as measured at Lower Granite Dam.

Of the potential general linear models constructed using the backward stepwise approach to predict travel rate of kelts in the Snake River, the model that included discharge, FL, sex, K, and adipose had the lowest AIC. Results from LRTs indicated the model was significantly better at predicting travel rate than any of the models that contained fewer variables and thus, was not reduced any further ($\chi 2 \geq 3.96$; $P \leq 0.047$). This model had an R^2 of 0.28 and was retained as the most parsimonious model. The model also suggested that the travel rate of kelts in the Snake River was positively correlated with discharge, negatively correlated with kelt length, and negatively correlated with K.

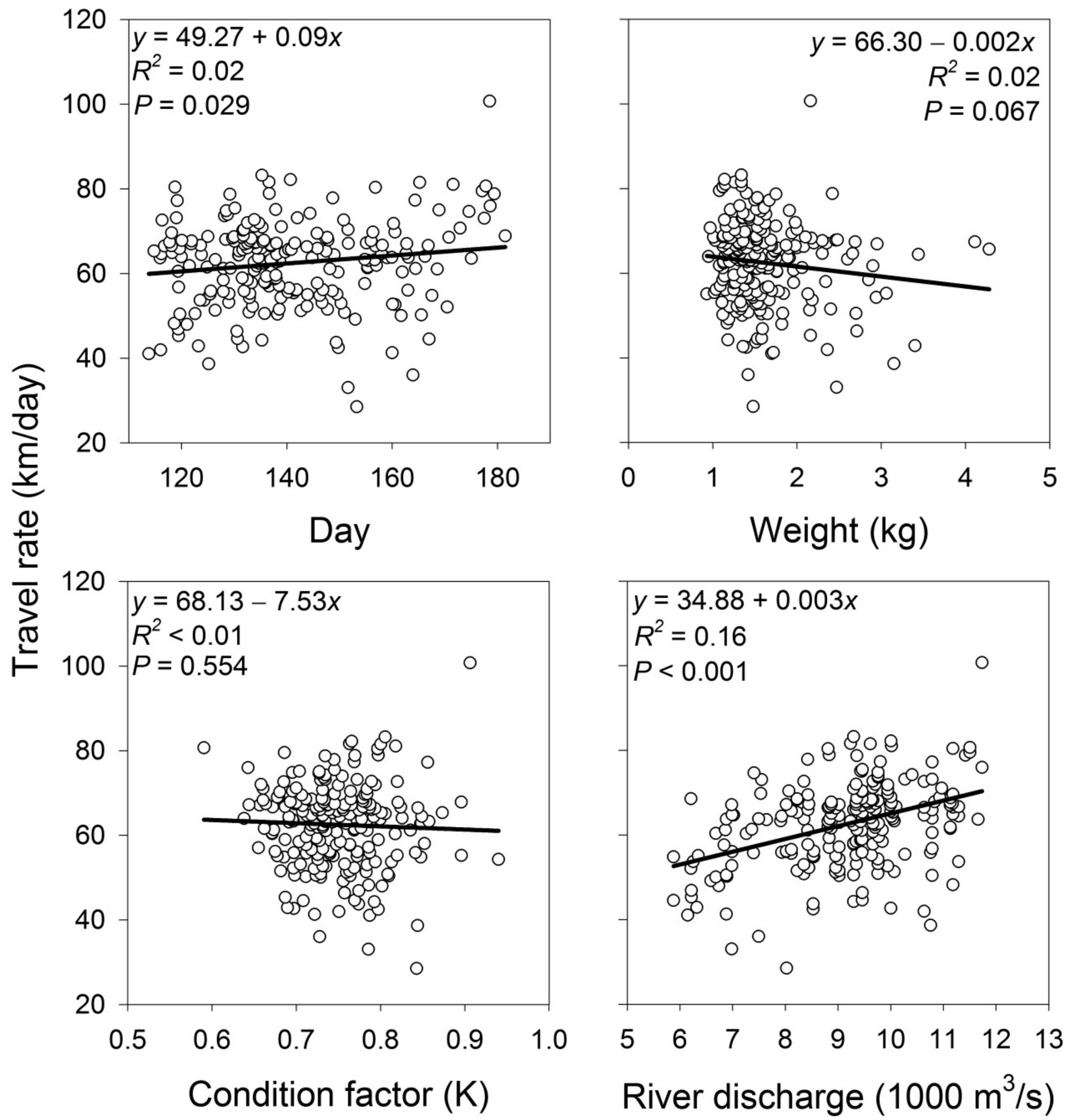

Figure 6. Simple linear regression relationships between travel rate of kelts in the Columbia River from the mouth of the Snake River to Bonneville Dam and day of detection at the mouth of the Snake River (Day), weight, Fulton's condition factor (K), and river discharge as measured at McNary Dam.

Combining data from both 2012 and 2013, kelts that were detected at the array located near the mouth of the Snake River and at the BON forebay array had a median travel rate of 63.79 km/d. Kelts deemed to be in good condition at the time of tagging traveled significantly slower through the Columbia River than those in fair condition (H = 8.04; P = 0.005). Travel rates were similar between females and males and between clipped and unclipped kelts in the Columbia River ($H \leq 1.81$; $P \geq 0.178$). Similar to the results obtained from the bivariate models constructed for the Snake River, a relatively strong, positive relationship existed between travel rate and discharge in the Columbia River (t = 6.39; P < 0.001; Figure 4). We also observed a weak, positive relationship between Columbia River travel rate and day (t = 2.20; P =

0.029; Figure 4). There was no significant relationship between travel rate of kelts in the Columbia River and weight (t = -1.84; P = 0.067) or between travel rate and K (t = -0.59; P = 0.554).

Of all potential general linear models created using the backward stepwise approach to predict travel rates of kelts in the Columbia River, the model that included discharge, day, and sex had the lowest AIC. Likelihood ratio tests indicated the reduced model that included just discharge and day was not significantly different from the model that minimized AIC (χ^2 = 2.59; P = 0.108). Additionally, the reduced model had a ΔAIC value of just 0.59 and an R^2 of 0.24. Therefore, the reduced model was selected as the most parsimonious model and predicted that kelt migration rate in the Columbia River was positively correlated with discharge at MCN and day of detection at the mouth of the Snake River.

The Corps also received a report submitted by Keefer and Caudill (2013) on analyzing for iteroparity rates via PIT retro-analysis**.** The primary objective in this study was to use the steelhead migration histories stored in the Columbia River PIT Tag Information System (PTAGIS) to generate 'baseline' iteroparity rate estimates for a variety of Columbia and Snake River steelhead populations and management groups.

Within this broad objective, five hypotheses were assessed: (1) winter steelhead have higher iteroparity rates than summer steelhead; (2) wild steelhead have higher iteroparity rates than hatchery steelhead; (3) 1-sea (i.e., 'A-group') steelhead have higher iteroparity rates than 2-sea (i.e., 'B-group') steelhead; (4) iteroparity rates decrease as freshwater migration distance increases; and (5) iteroparity rates in the Columbia River basin have increased as SFO installation and operation has increased.

The adult PIT tag detections at dams upstream from Bonneville Dam were used to estimate 'adjusted' iteroparity rates that accounted for upstream migration mortality during the first steelhead migration year. This essentially reduced the denominators in calculations by excluding fish that likely had no opportunity for repeat spawning (with the exception of strays). Unlike the Bonneville-to-Bonneville estimates, the adjusted estimates were not directly comparable across populations because different groups had to pass different dams and had different opportunities for straying. Keefer and Caudill (2013) calculated the percentages of steelhead that were detected at McNary, Priest Rapids, or Lower Granite dams on their first migrations that were subsequently detected at Bonneville Dam on their second migrations (i.e., McNary-to-Bonneville, Priest Rapids-to-Bonneville, and Lower Granite-to-Bonneville). Only the years 2004-2010 were included (Priest Rapids PIT antennas were fully operational in 2004 and relatively small samples in 2000-2003 reduce the value of these data).

Lastly, they calculated kelt-to-adult iteroparity estimates for the much smaller sample of PIT-tagged steelhead detected during outmigration. This metric was defined as the percentage of kelts that were detected at main stem dams during outmigration that were subsequently detected on second spawning migrations at Bonneville Dam. These estimates were more directly comparable to the PIT-tagged kelt-to-adult iteroparity estimates reported by Keefer et al. (2008).

It is important to note that many of the repeat spawners Keefer and Caudill (2013) identified in the PTAGIS dataset were not detected at any site as kelts (i.e., they passed dams via turbines, spillways, or other unmonitored routes) and were thus excluded from kelt-to-adult iteroparity estimates and conservatively limits these iteroparity estimates to that proportion of kelts that were bypassed.

Migration histories from 53,282 adult steelhead detected at Bonneville Dam over 11 adult migration years (2000-2010) included winter- and summer-run life history types, wild- and hatchery-origin fish, and were from a wide variety of populations and management groups. In total, 7 winter steelhead and 132 summer steelhead were considered to have initiated a second spawning migration based on appropriately-timed detections at Bonneville Dam in two migration years. Six of the seven winter steelhead were consecutive year spawners and the seventh was a skip year spawner. The summer group was half consecutive spawners and half skip spawners. With all years combined, Bonneville-to-Bonneville iteroparity estimates for the primary life history×origin groups were: 2.78% (winter, wild), 0.44% (winter, hatchery), 0.56% (summer, wild), and 0.16% (summer, hatchery).

At several geographic scales, wild steelhead had iteroparity estimates that were several times higher than those for hatchery steelhead. This was likely the result of more liberal harvest regulations for hatchery fish and the collection of hatchery adults for broodstock (i.e., limited survival to kelting). Younger steelhead (i.e., 1-sea, or 'A-group') tended to have higher iteroparity estimates than older steelhead (i.e., 2-sea, or 'B-group'), though this pattern was not universal across populations. Winter steelhead had higher iteroparity than summer steelhead, but there were no direct comparisons of life history groups within individual tributaries. Iteroparity rates for wild steelhead decreased as freshwater migration distance increased, presumably reflecting higher kelt mortality for interior Columbia and Snake River populations.
Annual iteroparity estimates for wild steelhead were positively correlated with river discharge during the kelt outmigration. After accounting for this effect, Keefer and Caudill found indirect but limited evidence that installation and increased operation of surface flow outlets (SFOs) at Columbia and Snake River dams may have contributed to increasing steelhead iteroparity rates during the study period. However, Keefer and Caudill also concluded that the PTAGIS dataset was not particularly well suited to address this management question because sample sizes in the response variable (repeat-spawners) were small in several years and there was high year-to-year variability in which steelhead populations were PIT-tagged. No management groups (e.g., wild steelhead from individual populations or Snake River 'B-group' steelhead) had sufficient numbers of PIT-tagged fish in all study years. We provide several recommendations for evaluating the efficacy of SFOs for increasing iteroparity.

The PTAGIS-based iteroparity estimates do provide important baseline data, both as a time series of estimates for aggregated steelhead populations and as estimates for a range of individual management groups.

Sample Summary
A total of 53,282 maiden steelhead detected inside adult fishways at Bonneville Dam were included in repeat spawner analyses (Table 1). Annual sample sizes ranged from 298 in 2000 to 11,775 in 2009 (*annual mean* = 4,843, SD = 3,558). The life historyXorigin components were: 144 (winter, wild), 676 (winter, hatchery), 12,114 (summer, wild), and 40,348 (summer, hatchery) steelhead. Winter fish were released at 6 sites in two tributaries to the Bonneville reservoir (Hood River and Fifteenmile Creek). Summer fish were released at 193 locations upstream from Bonneville Dam. Within year, the PIT-tagged steelhead used in the analyses were 0.1-2.2% (*mean* = 1.2%) of the total steelhead counts at Bonneville Dam, which ranged from 275,806-636,460 (*mean* = 403,202). Mean percentages of PIT-tagged fish in annual samples were 0.9% (*range* 0.1-1.7%) for wild steelhead and 1.4% (*range* = 0.1-2.8%) for hatchery steelhead.

Repeat Spawner Identification and Timing
A total of 49 winter and 320 summer steelhead were detected at Bonneville Dam adult fishways in two calendar years. Detection histories and migration dates for 86% (*n* = 42/49) of the winter and 59% (*n* = 188/320) of the summer fish suggested that they overwintered somewhere in the lower Columbia River prior to their first spawning attempt. Detections of overwintering fish at Bonneville in the second year

were mostly in January-March, suggesting that overwintering occurred both upstream and downstream from Bonneville Dam. The remaining 7 (14%) winter and 132 (41%) summer fish were likely repeat spawners.

The seven repeat spawners in the winter group were detected inside Bonneville Dam fishways from 5 April through 19 August (*median* = 22 June) on their first migration year. Six of the seven were consecutive spawners that were detected on their second migration from 25 February through 3 September (*median* = 20 July). The seventh was a skip spawner. The detection dates suggest that some may have been summer or hybrid fish.

The 132 repeat spawners in the summer group were first detected at Bonneville Dam from 4 June through 17 October (*median* = 4 August; Figure 2). This distribution was earlier than the steelhead run at large (2000-2010 *median* = 14 August). The repeat group was half consecutive spawners (n = 66) and half skip spawners (n = 66). Most consecutive spawners were detected later in the run during their second migration (*median* = 29 August, *range* = 18 June to 29 October) than skip spawners (*median* = 2 August, *range* = 20 June to 19 October).

The ratios of consecutive:skip repeat spawners differed slightly by region and more substantially by ocean age. Consecutive spawners were proportionately more common among older fish and in populations originating closer to the Pacific Ocean. Consecutive:skip repeat spawner ratios for 1-sea steelhead were 12:10 (lower Columbia), 11:16 (upper Columbia), and 15:24 (Snake). Ratios for 2-sea steelhead were 3:1 (lower Columbia), 7:2 (upper Columbia), and 8:4 (Snake). Ratios for unknown-sea fish were 2:2, 7:7, and 1:0, respectively.

Bonneville-to-Bonneville Iteroparity by Life History Type and Origin

Winter Run.– The 144 wild winter steelhead were from Fifteenmile Creek. In total, 2.78% (*annual mean* = 1.88%) of this group was detected on a second spawning migration (Table 1, Figure 3). The 676 hatchery winter steelhead from the Hood River had a total repeat spawning estimate of 0.44% (*annual mean* = 0.37%).

Summer Run.– Across all years and all summer steelhead populations, total iteroparity estimates were 0.56% (*annual mean* = 0.55%) for wild fish and 0.16% (*annual mean* = 0.11%) for hatchery fish. Total estimates for the group of populations downstream from the Columbia River–Snake River confluence were 1.27% (wild) and 0.35% (hatchery). Estimates were 1.12% (wild) and 0.20% (hatchery) for Columbia River populations above the Snake River confluence and 0.38% (wild) and 0.09% (hatchery) for Snake River populations.

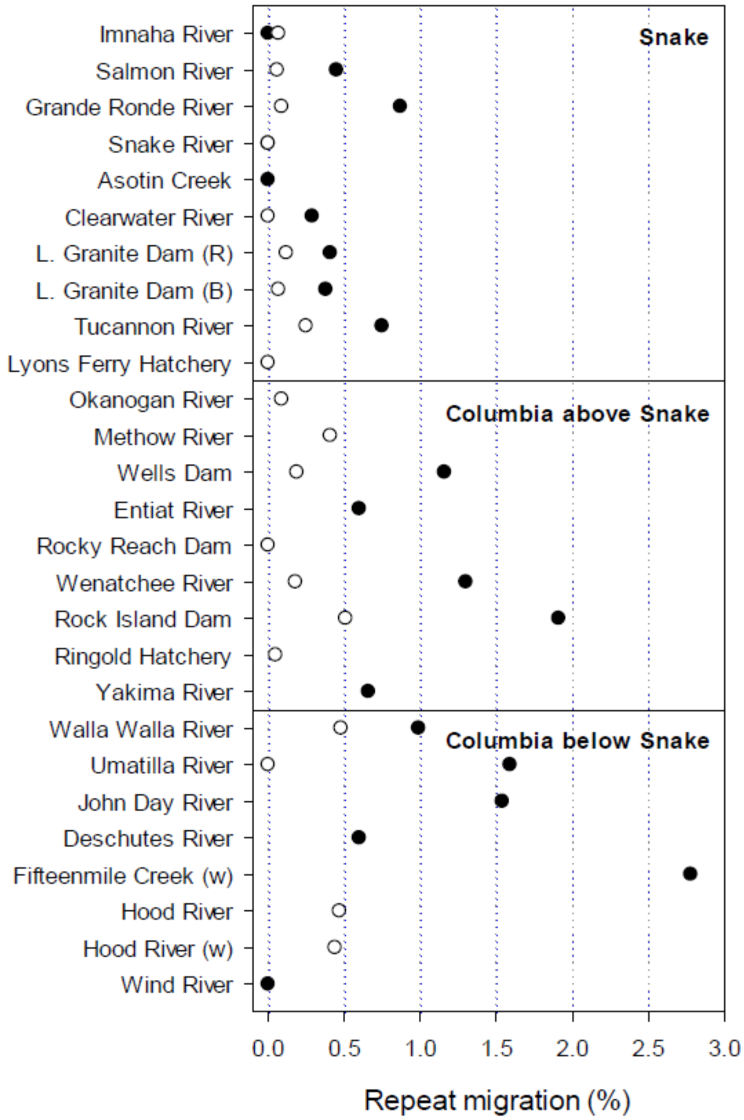

Figure 7. Percentages of wild (●) and hatchery (○) steelhead that were estimated to have made two spawning migrations based on PIT-tag detections at Bonneville Dam. All years, age classes and release groups were combined within individual sub-basins, main stem release sites and hatcheries. "w" indicates winter steelhead. "R" and "B" indicate in-river and barged juveniles at Lower Granite Dam.

Iteroparity was also consistently higher for wild steelhead than hatchery steelhead from individual sub-basin populations and for groups PIT-tagged at main stem dams (Keefer and Caudill Figure 3). In tributary sub-basins where both wild and hatchery fish had non-zero estimates, rates for wild fish were 2.1-9.7 times higher than rates for hatchery fish. Similarly, rates were 3.4-5.4 times higher for wild versus hatchery fish PIT-tagged at Snake and upper Columbia River dams. The only exception to this pattern was for Imnaha River steelhead, which had estimates of 0.00% (wild) and 0.09% (hatchery).

Unknown Life History.– One group of presumed wild-origin steelhead with unknown life history type was excluded from all analyses but warrants mention. This was the 346 steelhead from the Wind River for which the total iteroparity estimate was 4.05%, among the highest for any category. Maiden migration timing for the repeat Wind River spawners ranged from late April through October (*median* = 1 July), suggesting a mix of winter and summer life history types.

Bonneville-to-Bonneville Iteroparity by Migration Distance

The relationship between freshwater migration distance and repeat migration was not the same across origin and sea-age classes (Figure 4). The predicted probability of repeat migration decreased as migration distance increased for wild 1-sea (logistic regression, $\chi 2 = 14.9$, $P < 0.001$) and wild 2-sea steelhead ($\chi 2 = 10.0$, $P < 0.001$), with summer and winter run fish combined. In contrast, the predicted probability increased with migration distance for 2-sea hatchery fish ($\chi 2 = 5.3$, $P = 0.022$). The relationships were equivocal ($P > 0.05$) for 1-sea hatchery, unknown-sea hatchery, and unknown-sea wild fish ($\chi 2 \leq 0.5$, $P \geq 0.47$).

Bonneville-to-Bonneville Iteroparity through Time

Small sample sizes, especially for the response variable 'repeat spawners', precluded many meaningful comparisons of how iteroparity rates changed (or did not change) through time. At the broadest scale of all populations combined, annual iteroparity estimates for wild steelhead generally increased from 2000 to 2007 and then declined in 2008-2010 (quadratic regression, $r2 = 0.48$, $P = 0.073$; Keefer and Caudill Figure 5). A similar quadratic relationship was observed for all hatchery steelhead ($r2 = 0.63$, $P = 0.020$). When the models were weighted by the number of maiden steelhead in each year, model fit was reduced for wild steelhead ($r2 = 0.26$, $P = 0.293$) but increased for hatchery steelhead ($r2 = 0.72$, $P = 0.006$).

Columbia River discharge during the kelt outmigration period of April-June was positively associated with wild steelhead iteroparity rates (Keefer and Caudill Figure 6). The relationship was statistically significant ($r2 = 0.51$, $P = 0.014$) in an unweighted linear regression but was not significant ($r2 = 0.21$, $P = 0.153$) when the regression was weighted by annual maiden steelhead abundance. Neither weighted nor unweighted linear models were significant ($P > 0.05$) for hatchery steelhead (Figure 6). Residuals from the flow×iteroparity regressions were not associated with migration year for either wild or hatchery fish (Keefer and Caudill Figure 6). The lack of a linear year effect was also evident in regression models that included both flow and year as predictor variables (all $P > 0.05$ for year effects). Notably, the residual analyses suggest that iteroparity was lower than expected once accounting for flow in 2000-2002, higher than expected from 2004-2008, and lower again in 2009-2010. This pattern may indicate multi-year effects that were unaccounted for in the model (e.g., ocean conditions, composition of the PIT-tagged sample, etc…), a quadratic effect like the one evident in the year-only models, or merely statistical noise.

A similar set of evaluations for the Snake River steelhead groups produced qualitatively similar results. Iteroparity rates for both hatchery and wild Snake River steelhead were positively correlated ($P < 0.05$) with flow in the kelt emigration season and year effects were non-significant ($P > 0.05$) in models that included flow and year.

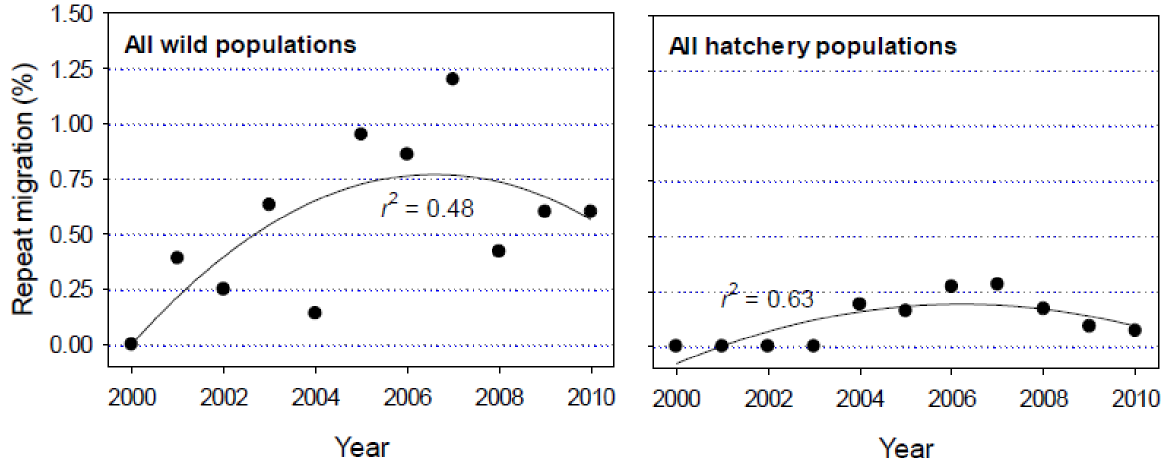

Figure 8. Quadratic relationships between maiden migration year and the percentage of repeat spawning steelhead. Solid lines show unweighted quadratic regression results.

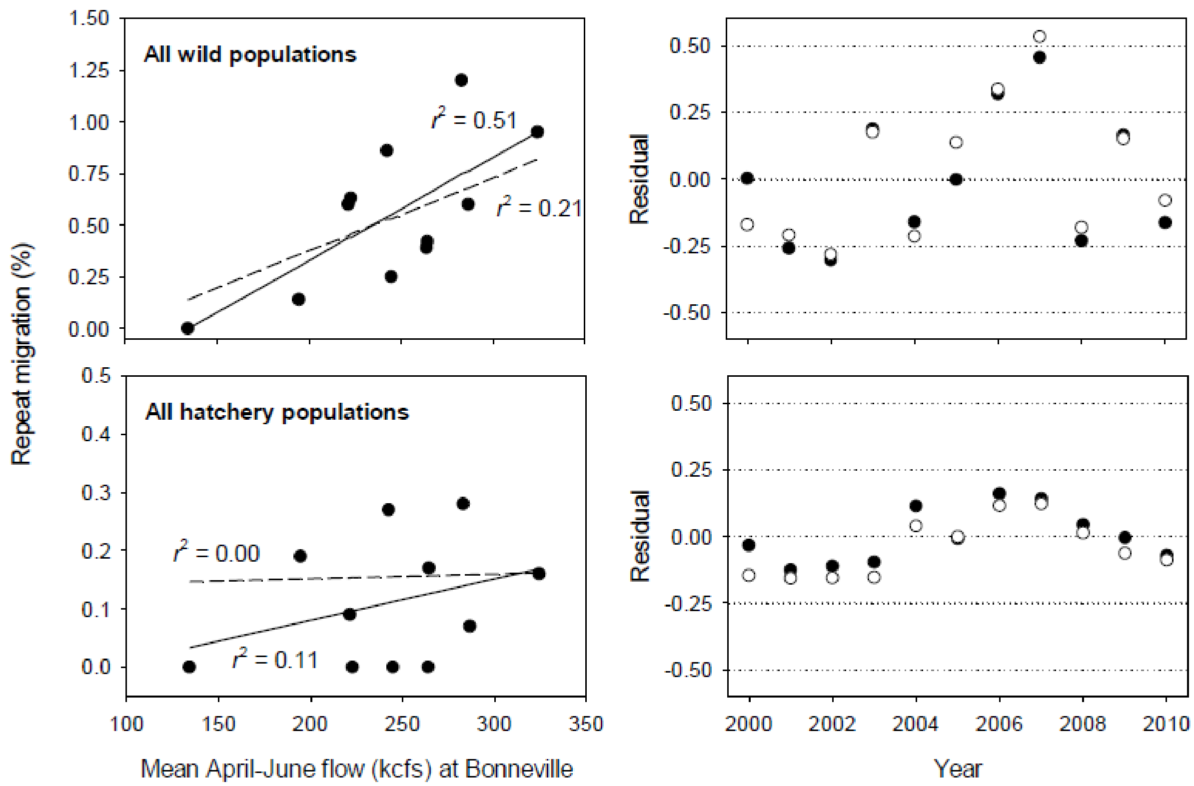

Figure 9. Relationships between mean April-June Columbia River flow and the percentage of repeat spawning steelhead (left panels). Solid lines show unweighted linear regression results and dashed lines show linear regressions weighted by the number of maiden steelhead each year. Right panels show the relationship between migration year and the residuals from the unweighted (●) and weighted (○) flow models. Flow data were from Bonneville Dam in the kelt outmigration year (i.e. maiden spawners from the 200 migration were matched to flow data from April-June 2011).

McNary-to-Bonneville iteroparity estimates for wild steelhead were ~25% higher than Bonneville-to-Bonneville estimates for the upper Columbia and Snake River wild groups (Table 3). Similarly, McNary-to-Bonneville estimates were higher than Bonneville-to-Bonneville estimates by 43% for the upper Columbia group and 22% for the Snake group. The Priest Rapids-to-Bonneville estimate for upper Columbia wild steelhead (1.24%) was higher than the Bonneville-to-Bonneville (0.91%) estimate by 36%. The Priest Rapids-to-Bonneville estimate for upper Columbia hatchery fish (0.43%) was more than double the Bonneville-to-Bonneville estimate (0.21%). In contrast, Lower Granite-to-Bonneville estimates were only slightly higher (11-15%) than Bonneville-to-Bonneville estimates for wild and hatchery groups that originated above Lower Granite Dam.

Of note is that the PIT retro-analysis of Keefer and Caudill (2013) identified kelt from the Middle Columbia River steelhead DPS population of Fifteenmile Creek (southshore confluence across the river from The Dalles Dam east ladder entrance and sluiceway exit) to have the highest detected percent of repeat migrations (Keefer and Caudill Figure 3). They also detected that these Fifteenmile Creek kelt have expressed some very low travel times or very high residence times passing Bonneville reservoir, consistent with the ODFW annual reporting over the past 3 years (Poxon et al. 2013).
The Smolt-to-Adult return (SAR) rates to Fifteenmile Creek were estimated for the 2007-2010 smolt outmigration years and ranged from a low 1.9% in 2009 to a high of 3.68% in 2008. ODFW found significant differences ($p<\alpha=0.05$) between SAR rates to Bonneville Dam and SAR rates to Fifteenmile Creek in both 2008 and 2009, which is consistent with the survival observed between Bonneville Dam and Fifteenmile Creek. Survival of returning adults from Bonneville Dam to Fifteenmile Creek for spawning years 2010, 2011 and 2012 were estimated to be 60%, 52%, and 44% (95%cL, 43%-47%) respectively. These are alarmingly low survival rates for the 45 mile journey from Bonneville Dam to the mouth of Fifteenmile Creek, and necessitates further investigation.

Table 4.

Smolt-to-Adult Return Rates	Estimate	95% CI Low	95% CI High
2007	2.62	1.27	4.35
2008	3.68	2.85	4.62
2009	1.90	1.48	2.32
2010	0.63	0.38	0.95

Stray rate (PIT) of Fifteenmile steelhead 2011-12 = 3.1%, 2012-13 = 6.5%; into Fifteenmile = 0.6%
Hatchery Fraction 2011-12 = 4.9%

The Fifteenmile Creek upstream-migrant weir was operated from 13 December 2011 to 25 June 2012 for a total of 183 days during the 2011-2012 season. Adult steelhead began arriving at the weir in February, and arrivals peaked in April (Figure 4). A total of 122 wild steelhead adults and six hatchery- origin adult steelhead were caught at the weir during the season. The female-to-male sex ratio of adult steelhead captured in the weir live-box and kelt trap during the 2011-2012 season was 1.5:1. The kelt trap portion of the weir was operated from April 12 through June 25 2012. A total of 2 wild steelhead kelts and three hatchery-origin steelhead kelts were trapped during the season. Six of the wild kelts were PIT-tagged recaptures from earlier in the season. ODFW also recovered the carcasses from a total of 36 wild adult steelhead above the weir. Four of these were PIT-tagged recaptures from earlier in the season, while two of them were recaptures that were originally tagged in previous seasons at the Fifteenmile Creek screw trap.

Possibly influenced through straying combined with seasonal obscured dam passage hydraulic cues and water withdrawal practices in Fifteenmile Creek a mix of winter-run characteristic steelhead have been increasing with this lowest river extent summer-run characteristic life history. The life history strategy also makes Fifteenmile Creek steelhead vulnerable to anthropogenic impacts within the Bonneville pool and at the mouth of Fifteenmile Creek (multiple-year bridge and road replacement construction in recent years), including sport and commercial fisheries, in addition to prolonged exposure to potential adverse environmental conditions. Fifteenmile Creek steelhead spend between 6 and 9 months in the Columbia River above Bonneville Dam before entering Fifteenmile Creek (Poxon et al. Figure 7). Through Poxon et al. (2013) observations of fish detected at Bonneville Dam, and subsequently detected in Fifteenmile Creek, the apparent survival in the Bonneville Pool has been decreasing in recent years, from a high in the 2009-2010 season of 60% to 44% in the 2011-2012 season. These are low survival rates for the relatively short trip from Bonneville Dam to Fifteenmile Creek which deserves further investigation.

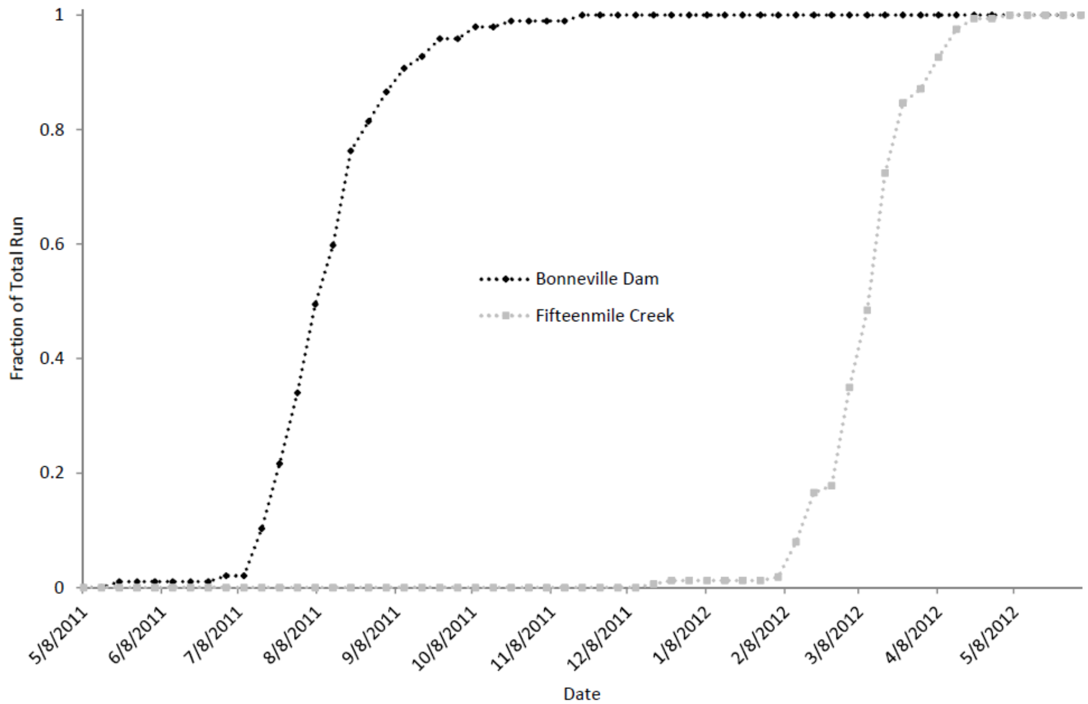

Figure 10. Timing of 2011-2012 Fifteenmile Creek adult steelhead run at Bonneville Dam and at Fifteenmile Creek. The timing at Fifteenmile was produced from initial capture date for fish captured at the weir or initial detection date of tagged fish detected on the in-stream PIT array.

The Corps began a multi-year biological evaluation of the prototype 14 inch orifices and overflow weir that diverts fish from the turbine gatewells into a proposed new Juvenile Fish bypass and Facility (JFF) at Lower Granite dam. The Year 1 evaluation concentrated on smolt travel times out of the turbine unit 5 gatewell past the existing bypass system PIT detectors and did not release adult fish for comparison until Year 2 during May 2014 (O'Connor et al. 2014). The only adult passage information on prototype gatewell orifice and overflow weir effects can be derived out of the very small number of Colotelo et al. (2014) kelt that passed through the LGR JBS during the 2013 configuration conditions. About 75% of the JBS-route kelt passed through the prototype structures in the 2013 overflow weir test's priority turbine 5 resulting in a much lower route survival for those JSATs-tagged kelt in 2013 (~33% survival) compared to the larger sample of 2012 study kelt that passed through the non-prototype turbine gatewell environment (~87% survival). Colotelo et al. (2014) results were also confounded by the lower flow year consequential operations that occurred in 2013, of which the above mentioned Colotelo and Harnish (2014 in prep) evaluation is designed to diagnose contribution of variable effects between the years.

Future Planning (2014-2018) for infrastructure and research

Strategy 1: Long term reconditioning

From an adaptive management standpoint in 2015, the experimental spawning channel at Cle Elum Hatchery will be available, so we are currently drafting a proposal and study plan to use the channel in an evaluation of reconditioned steelhead reproductive success. Additional components such as resident rainbow trout contribution and maiden steelhead reproductive success may also be added. We are also searching for potential stream locations to conduct a relative reproductive success study.

In 2013, we radio tagged 70 long-term reconditioned kelt steelhead prior to release in the Yakima River. These fish were known rematuring based on elevated levels of estradiol. We are partnering with the Yakima River Steelhead VSP project to track these fish to spawning beds. Later we will target electrofishing efforts downstream of known reconditioned kelt spawners in an attempt to identify their progeny. In addition, 21 of these radio tagged fish have known detection histories from prior spawnings. These histories are from in-stream PIT tag detection or from previous radio tags. Relocating these fish will provide data on repeat homing fidelity of artificially reconditioned kelt steelhead.

The primary limitation on long term reconditioning in the Snake River is availability of good condition kelt steelhead. In 2014, collections will be made at the Lower Granite Dam juvenile bypass, and at the Fish Creek weir, a tributary of the Lochsa River, where an additional 50 fish should be collected. Future years will seek collections at additional tributary locations and at Little Goose Dam, where approximately 100 good condition b-run kelts are observed annually. The Corps' JFF1A project designed for Lower Granite Dam passage of smolts should complete final design for a full flow adult fish and debris separator in addition to replacement of the existing separator with a fish size/collection separator. These two additions to the new JFF1A are warranted in order to satisfy the RPAs required for kelt, adult fish passage, and smolt passage and should be targeted for implementation by 2017 in order to provide for more kelt maintained at or above the good condition through a decrease in amount and duration of kelt handling compared to the physical removal means of the existing separator and diversion to holding tanks

We are also considering plans to utilize the Adult Captive Rearing Facility located at Bonneville Hatchery to rear skip spawner kelts for a second season to facilitate re-maturation. Logistics including necessary permits, infrastructure, transport, and rearing needs are being investigated.

The Nez Perce Tribe Master Kelt Plan should be completed and vetted in order to decide warrant for implementation of future collection and rearing sites and/or modifications to existing sites.

Strategy 2: Transportation

In the next year, the Action Agencies will work to develop a low flow kelt outmigration and return spawner passage plan for FPP in collaboration with juvenile salmon and adult salmon passage survival modifications.

Strategy 3: Enhanced in-river migration

In the next year, the Corps of Engineers research will complete the third year of the in-river kelt survival study (Colotelo et al. 2012, 2013, 2014 [analysis only]). On conclusion of the study, they plan to update the survival rates and production metrics used in the 2008 BiOp (Bellerud et al. 2007), reflecting the current configuration of the hydrosystem with surface passage routes installed at the eight lower Snake and lower Columbia River dams. The results from the three year Colotelo et al study will also be used to develop a low flow contingency response plan for the Fish Passage Plan (FPP).

Completion of design in 2014 of the juvenile fish facility (JFF1A) at Lower Granite Dam is important to poise for awarding several construction contracts for 2015-2016 implementation (JFF1A without adult/debris or new smolt size separation). The Corps will include plans for an adult fish and debris separator when the regional forum warrants funding beyond the current preliminary designs. The Corps Lower Granite Configuration and Operation Plan (LGR COP) is in draft for review at present date, but warrants adult/debris and smolt size separation as highly beneficial infrastructure that would likely be required to exceed the juvenile salmon dam survival performance standards of the 2008 FCRPS BiOp as well as the 6% increase in B-run female spawners through kelt respawners. One of the objectives of the redesign of the 10” orifices passing fish from the dam gatewells, and the routing and curvature of the bypass and primary dewatering channels after exit from the powerhouse is to reduce the injury rate to adults, where in some years up to 30% adult fallback and kelt have been observed with an elevated rate of head injuries following passage through the exiting downwell-pressurized pipe-upwell conveyance system (Corps’ Annual Fish Passage Reports 1991-2012) based on evaluations of fallback adults conducted by Wagner and Hillson (1993).

Corps’ RM&E in-season research and investigative results from the summer of 2013 when a thermal block in August and September impeded the movement of adult salmon through the fish ladder (TMT Archive Web Files for primarily sockeye and summer-run Chinook; AFEP Study ADS-W-13-1 reporting on Chinook and steelhead radio-tracking passage and conversion) will be used in conjunction with physical hydraulic modeling at the Corps’ Engineer Research and Development Center (ERDC) to help develop an adult passage plan at Lower Granite to be used during hot water, low flow conditions.

In 2014, researchers at UC Davis/Blue Leaf will complete their study of Lower Granite gatewell orifice expansion and overflow weir design. They are comparing biological response to 10” vs. 14” diameter orifices and sharp crested vs. broad crested weirs. Adult steelhead and kelts provided by the Nez Perce Tribe will be tested for direct injury and survival rates because in 2013, adult survival through the bypass decreased, and head injuries were observed despite capping of the exposed rebar in the downwell.

In March 2014, a second year of direct injury and survival study will be carried out with adult steelhead at McNary Dam, with a special focus on comparing the surface weir and turbine routes. Wild surrogate hatchery origin steelhead were available for this study from the Round Butte hatchery in 2013. The Corps AFEP is seeking the agency ranking to duplicate a comparable direct injury and passage efficiency estimation in 2015 at Lower Granite Dam for RSW versus deep spill versus turbine, as well as spill treatments in March for early spring outmigrating kelt based upon Colotelo et al. (2012 and 2013) results. In early spring or late-winter 2015, the Corps AFEP also plans to estimate passage efficiency of turbine versus surface weir routes at McNary Dam for adult steelhead with hydro-acoustic deployment in the forebay. Considering Colotelo et al (2013, 2014) results for kelt passing Lower Columbia River FCRPS dams, deep spill passage efficiency of adult steelhead should be included as a treatment. An similar early spring 2015 surface weir passage efficiency study for adult overwintering steelhead and kelt should be scheduled for Lower Granite or Little Goose dams.

The Poxon et al (2014) annual report on Fifteenmile Creek steelhead showed kelt conversion from Bonneville ~44%, decreasing from 60% 2 years ago. This study should be updated with travel times, possibly with an active tag study. There is a possibility of kelt migrant overshooting The Dalles, and fallback through turbines instead of the sluiceway. The Dalles sluiceway analysis should be updated now that adult PIT antennae at The Dalles were installed in the ladder in 2013, in order to confirm the need to continue spring sluiceway operations at TDA for kelt (Khan et al 2009, 2010, Tackley & Clugston 2007).

Adaptive Management Synthesis of current status and future planning

With a total estimated increase of 3.2 percent toward the 6 percent abundance goal in 2013, significant improvement has been made since the previous year when a total 1.2 percent improvement was estimated. The progress achieved by the reconditioning program at Dworshak NFH is responsible for all of the calculated abundance improvements since 2011. This program is considered to be ready for full implementation in the near future. Annual variability in kelts available via collection at the dams and at tributary sites may set an upper limit on expansion of the long-term reconditioning program. For this reason, the Action Agencies will need to continue research on further development of the kelt transportation and in-river operations alternatives.

Surface Flow Operations at Dams

Although wild steelhead iteroparity estimates generally increased over the study periods for pre- versus post-surface spill weir operations (Keefer and Caudill 2013), the correlative nature within the analysis made it impossible to attribute the increase to increased surface spill installation and operation. Many environmental and biological factors may influence repeat spawning rates and Keefer and Caudill (2013) stated that their analysis of covariates was limited. They accounted for inter-annual variability in Columbia River discharge in the spring because previous research has shown that flow is positively correlated with steelhead kelt survival (Wertheimer and Evans 2005). This makes intuitive sense because kelt residence times in reservoirs are reduced and more water may be passed via surface flow routes during high flow. However, residuals from their flow × iteroparity rate relationship did not indicate a clear increase in iteroparity rates for wild aggregate populations over the 2000-2010 study period. Instead, the residual analysis suggested a possible multi-year periodicity in iteroparity rate, which may be related to unmeasured covariates. Keefer and Caudill (2013) did not conduct a more comprehensive analysis (i.e., one that included other potential covariates like spill volume, surface spill operations, or measures of ocean productivity) upon kelt re-entry into salt water because steelhead in the PTAGIS samples were not consistent from year to year. Even the largest sample groups (e.g., steelhead PIT-tagged at Lower Granite Dam, Ringold Hatchery, and the Methow River) had small samples or no samples in some years.

It was also difficult to assess the timing and consistency of surface spill operations across years and at individual dams (R. Wertheimer, *personal communication*). Keefer and Caudill (2013) considered the co-varying environmental conditions and surface spill operations, along with small kelt sample sizes and inconsistent PTAGIS samples across years to be sufficiently confounding to preclude a full data mining exercise, particularly given the low observed sample sizes for repeat spawners. To better understand and potentially model the effects of surface spill operations on steelhead iteroparity in the Columbia River basin Keefer and Caudill (2013) recommend:

● consistent use of clearly defined study populations, such as PIT-tagged wild steelhead from populations of management concern; year-to-year consistency is important for detecting trends and for evaluating effects of environmental and operational covariates;

● increased PIT monitoring at downstream migration routes to detect a higher proportion of outmigrating kelts; sites like the Bonneville corner collector provide valuable kelt detection data and similar systems should be considered at other surface spill operations to compliment kelt detections in juvenile bypass systems;

● increased PIT-tagging of kelts at collection facilities (e.g. Keefer et al. 2008; Evans et al. 2008; Hatch et al. 2013); kelt-to-adult iteroparity estimates are more useful for operations-related questions than adult-to-adult estimates based on fish tagged as juveniles;

● better estimation of kelt abundance along the outmigration route; the scope of any iteroparity-related conservation efforts depends upon the available kelt population;

● experimental designs that directly address surface spill operations in relation to route-specific kelt passage and survival at dams; studies that use kelts tagged with active transmitters (e.g. Wertheimer 2007; Colotelo et al. 2013) can provide the route-specific estimates needed to model potential population-level benefits of surface spill operations.

Recommendation and actions to be implemented 2014-2018

- Availability of good condition, female wild b-run steelhead kelts at collection sites is a challenge. Condition of kelts collected in tributaries is typically better than among the group collected at mainstem dams and tributary collection may have the greatest potential for expansion. The technique of air spawning broodstock at hatcheries has allowed adult steelhead to remain in good condition, successfully go through rehabilitation, and reach maturity as kelts. Given the annual variability in returning steelhead spawners, and the declining capability to collect kelts at Lower Granite Dam due to factors such as spill operations, development of tributary collection should be addressed in addition to the redesign and planning of the Lower Granite bypass system in 2014-15. The Action Agencies recommend including size selective sorting capability, with an adult and debris separator. Adult collection efforts could be increased at Lower Monumental and Little Goose dams which currently can do size selective sorting at their bypass facilities.

- Extend and enhance TDA sluiceway operations and other alternate non-turbine or bypass routes. An evaluation of operations during previous years may be necessary to estimate the expected benefits of alternative scenarios.

- Develop enhanced BON reservoir egress plans (i.e., Poxon et al. 2013). Conduct an evaluation of enhanced passage improvements and conversion rates through other reservoirs (i.e., LGR).

- Assess the effect of low flow and corresponding warm upper surface passage water conditions on summer outmigrating kelt through Lower Granite reservoir and dam, specifically the later outmigrating B-run populations of the Clearwater River basin such as Fish Creek in order to develop a contingency plan for enhancing adult passage. The Corps will be working with NOAA Fisheries to verify operational scenarios and is looking at infrastructure improvements for 2015. The Corps has indicated that all three pumps, including new emergency pump (if feasible) will be operational for 2014.(3/27 SRCHF Coordination Mtg notes) .

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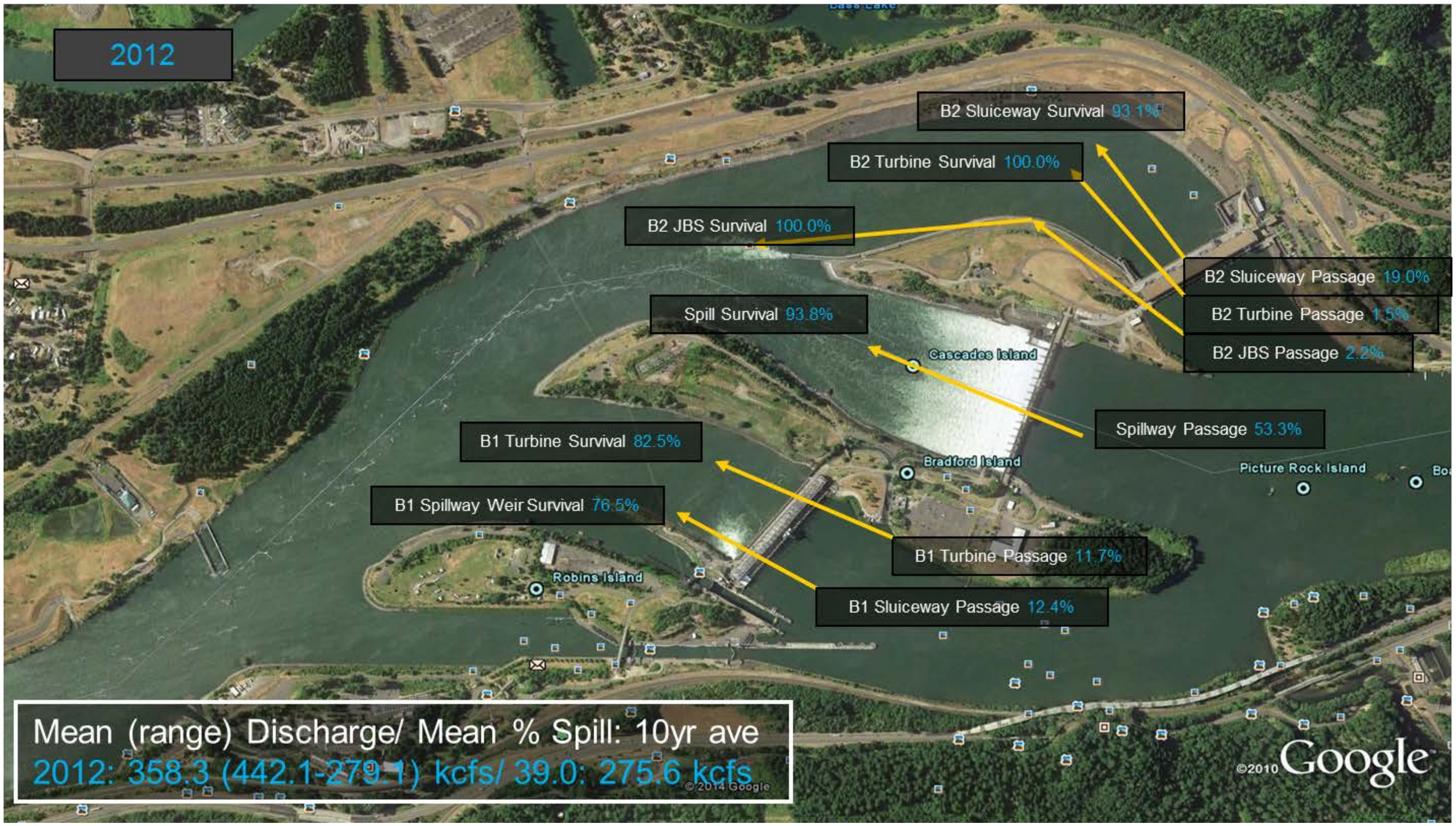
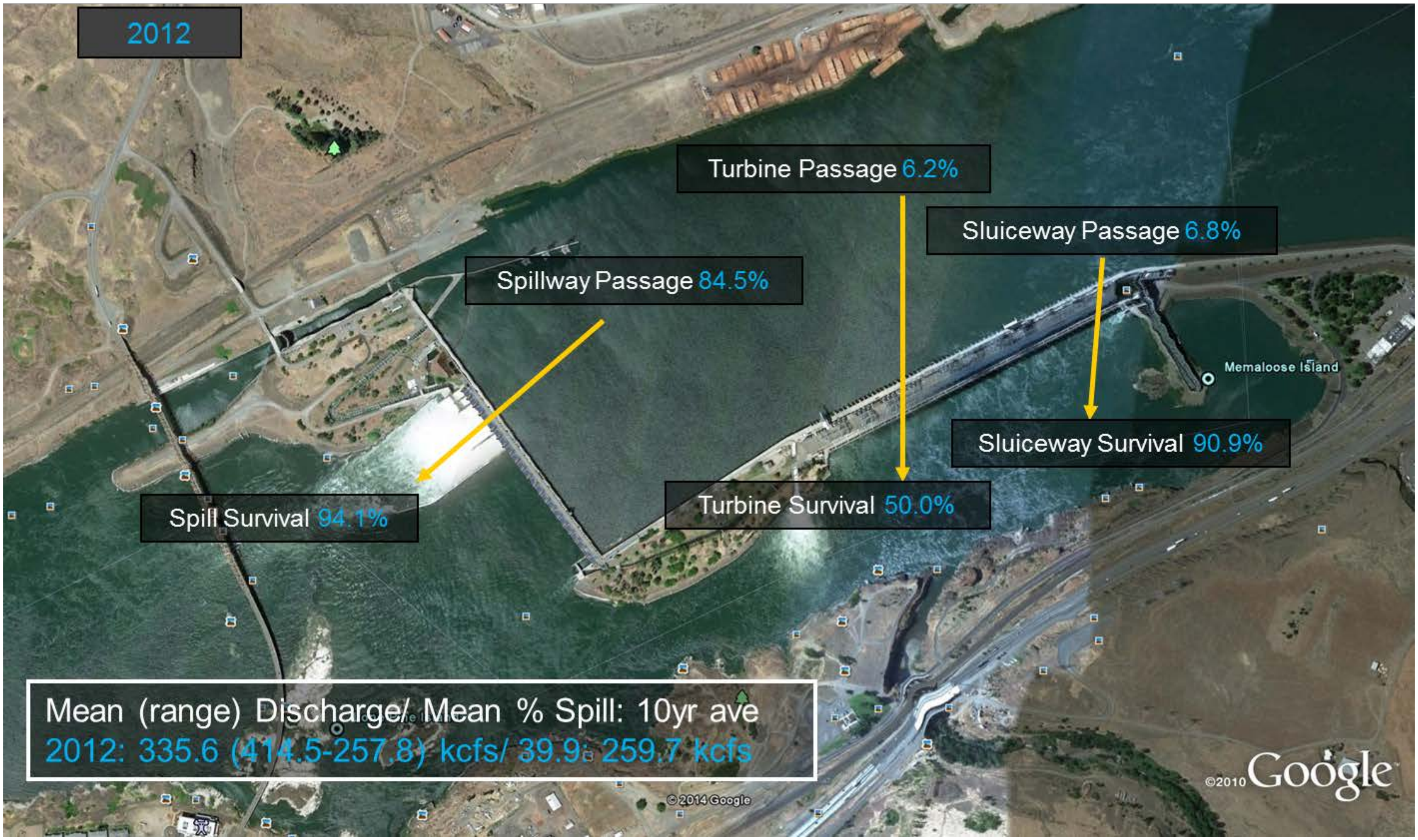
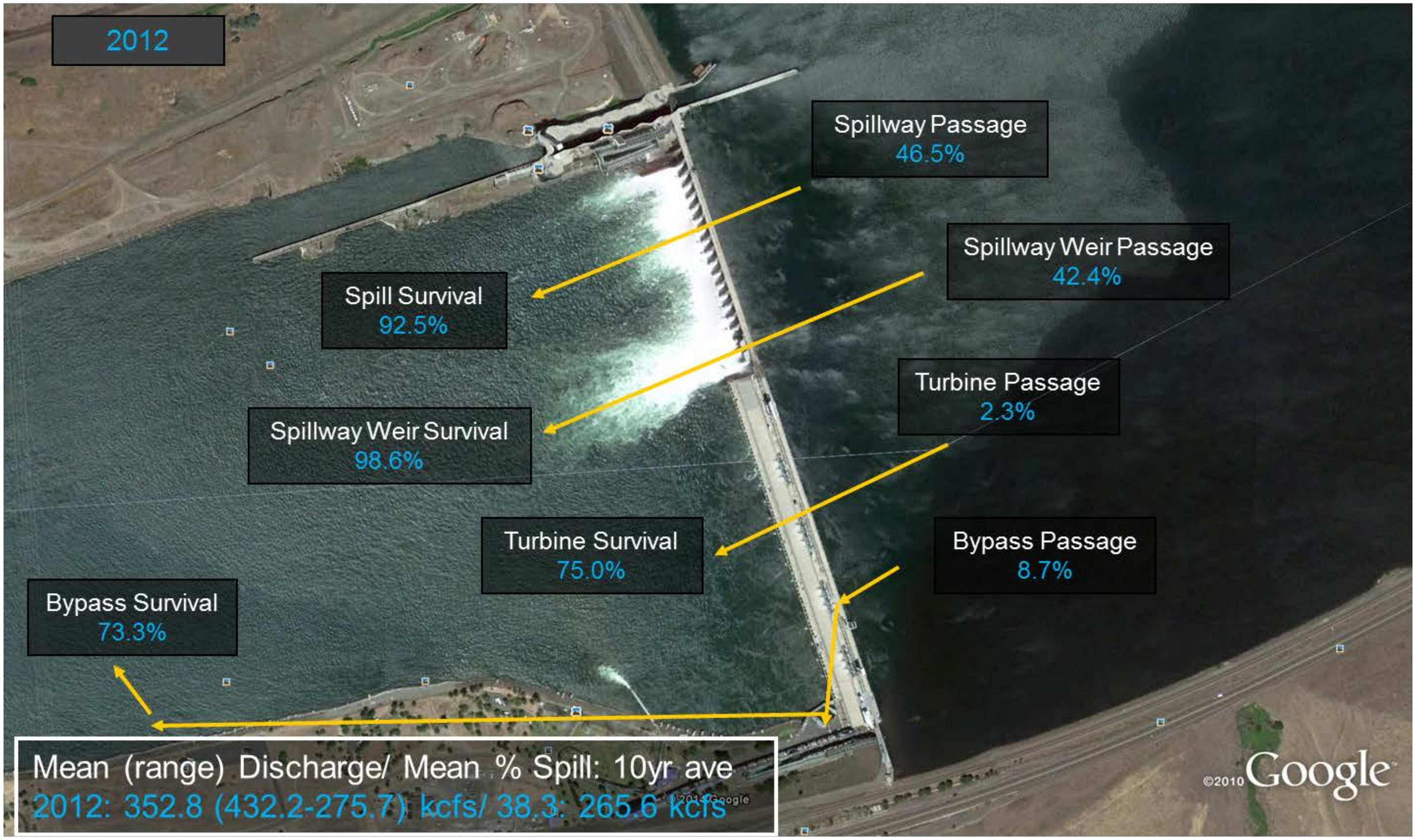
Bonneville Dam
Steelhead Kelt Passage & Survival Estimates



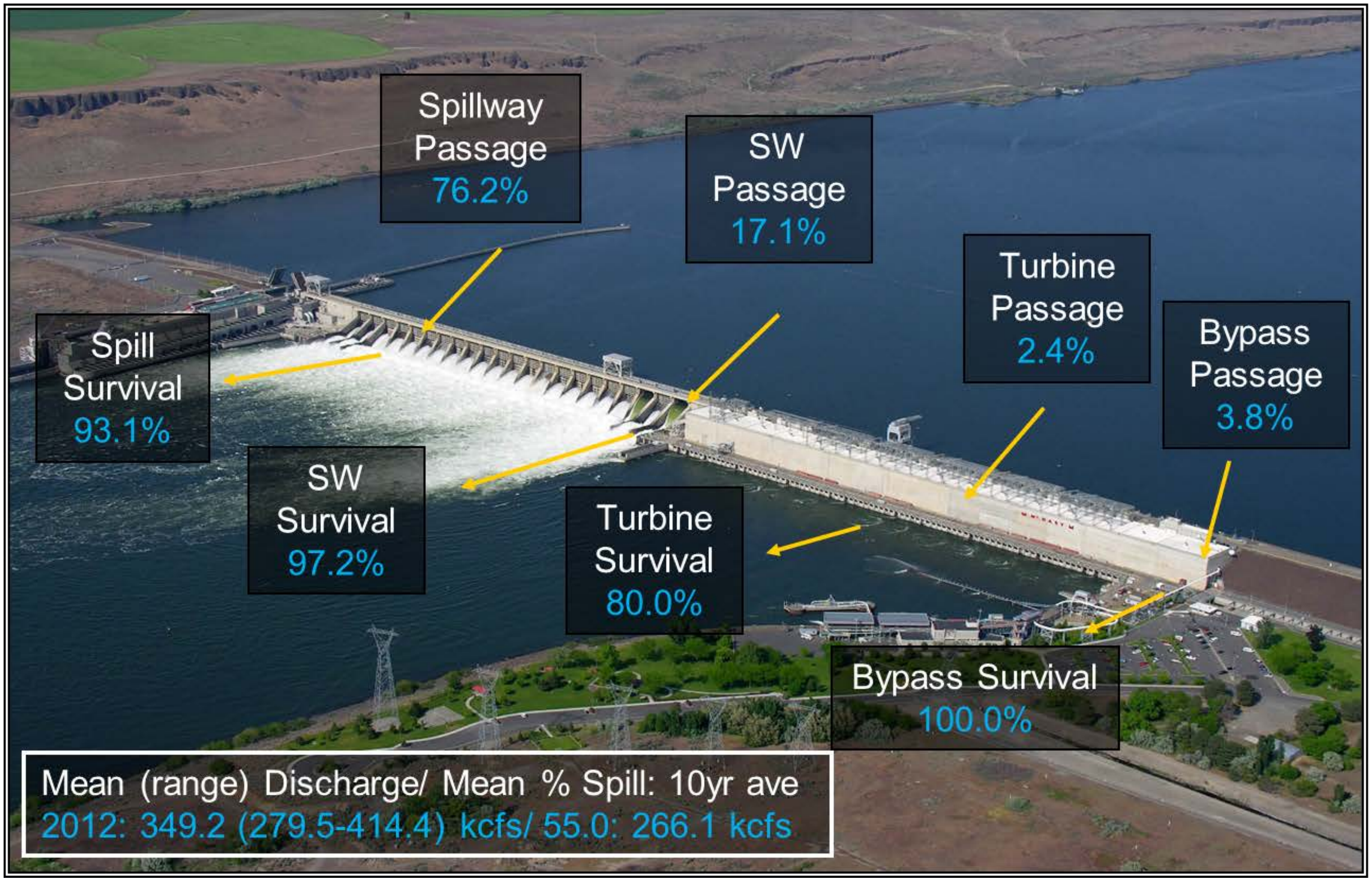
The Dalles Dam
Steelhead Kelt Passage & Survival Estimates



John Day Dam
Steelhead Kelt Passage & Survival Estimates



McNary Dam
Steelhead Kelt Passage & Survival Estimates



Ice Harbor Dam
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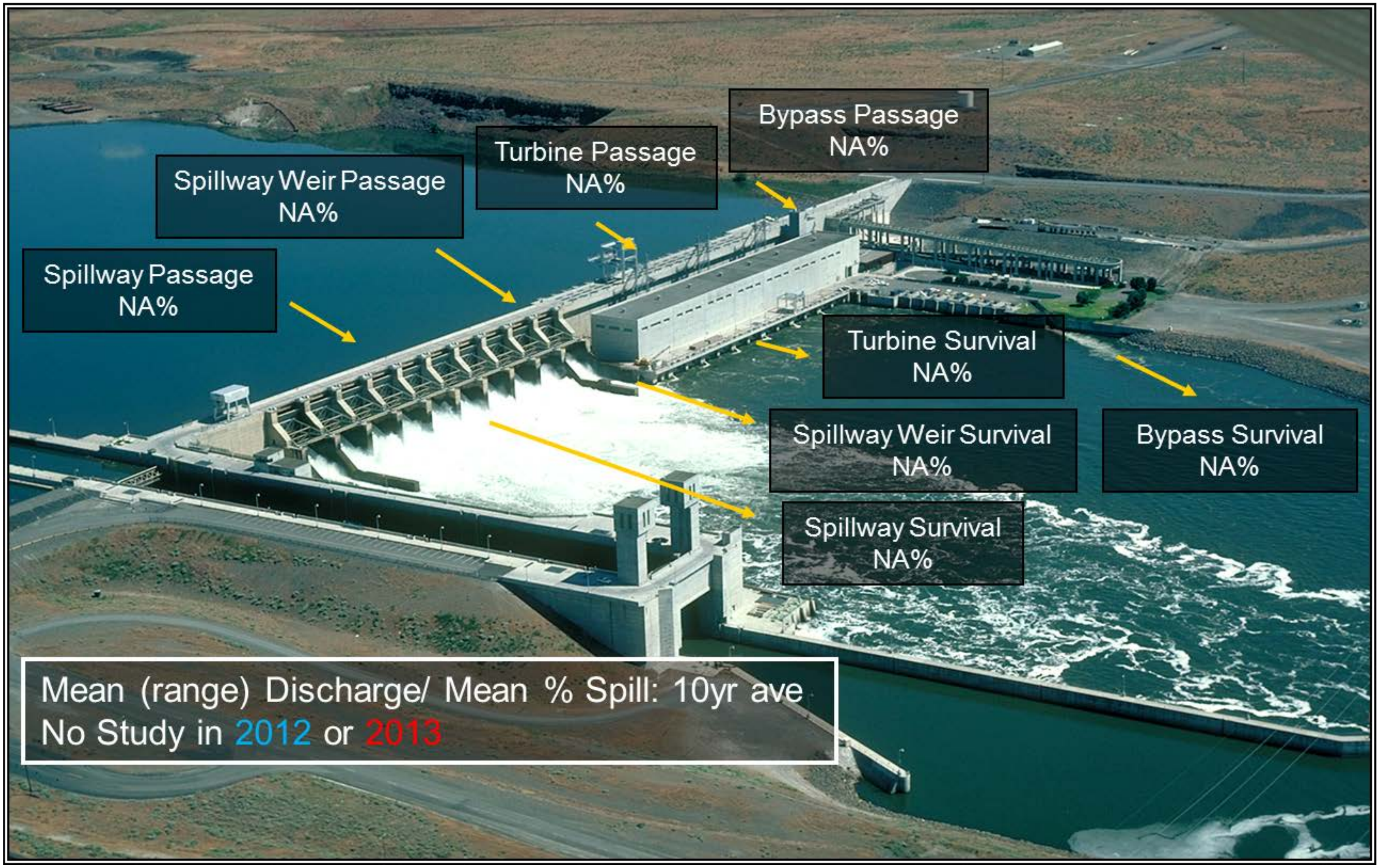
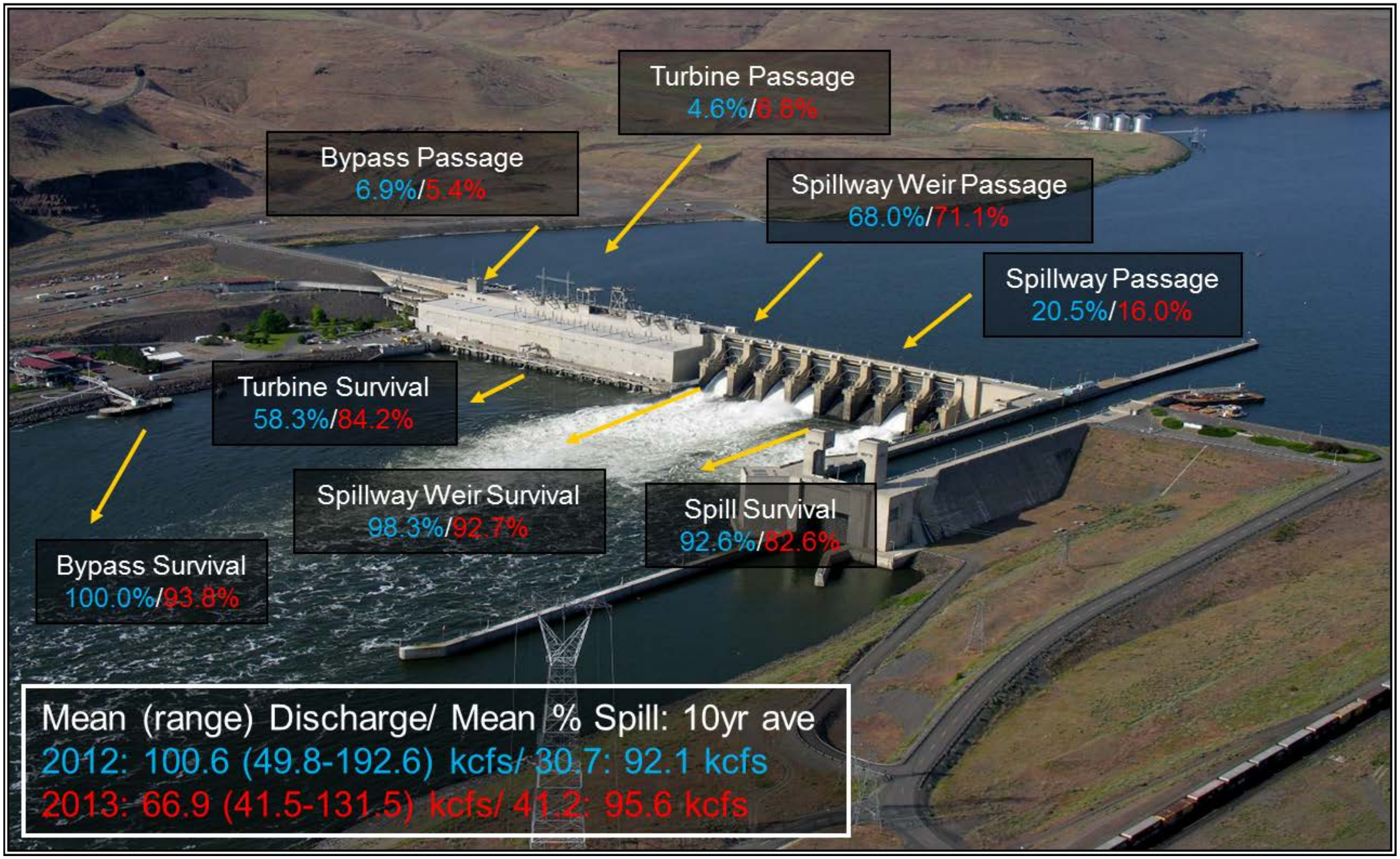
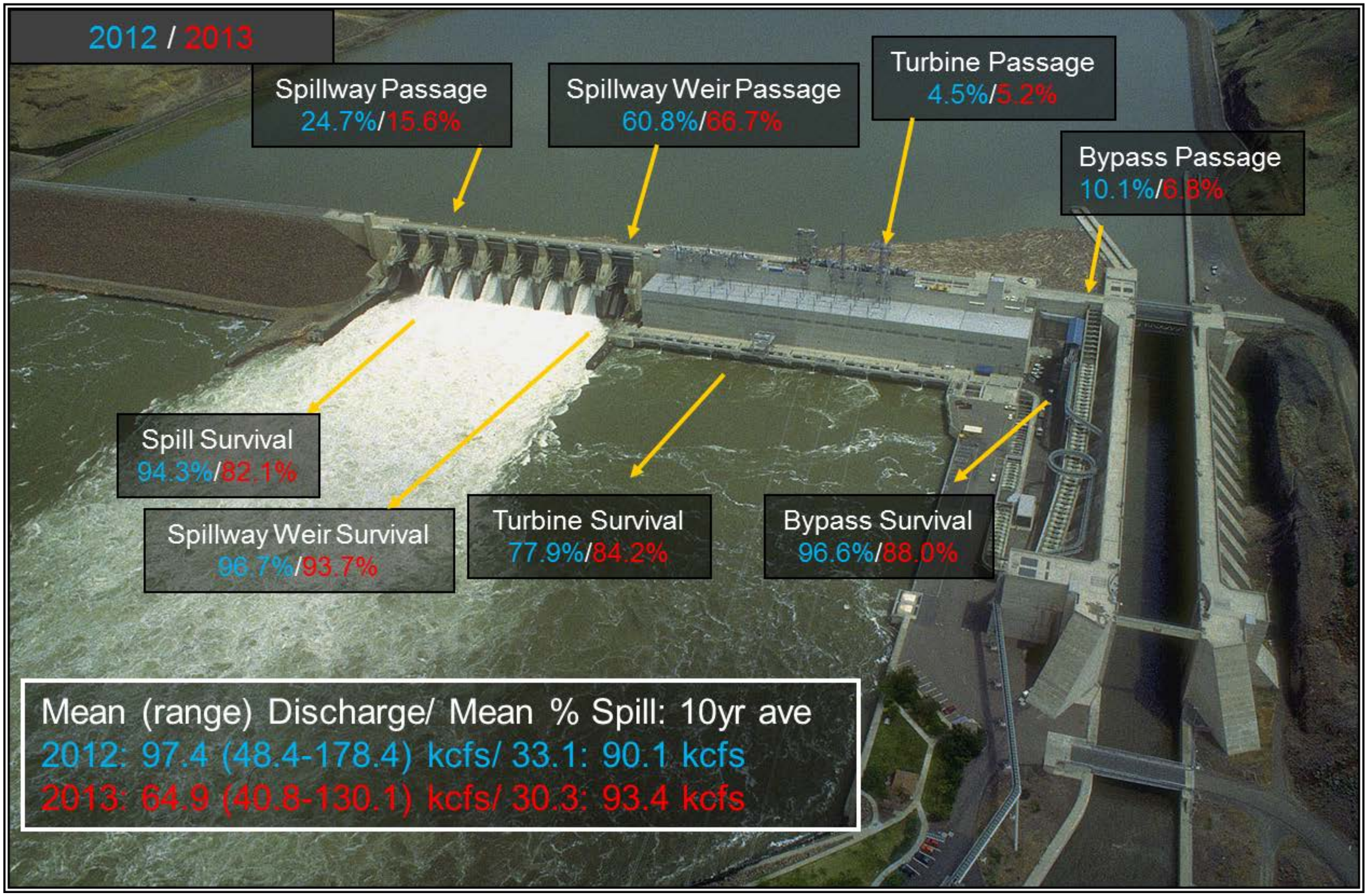


Lower Monumental Dam
Steelhead Kelt Passage & Survival Estimates



Little Goose Dam
Steelhead Kelt Passage & Survival Estimates



Lower Granite Dam
Steelhead Kelt Passage & Survival Estimates