2017 Supplemental Recovery Plan Module for Snake River Salmon and Steelhead
Mainstem Columbia River Hydropower Projects

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Contents

1. Introduction

This document incorporates by reference and supplements NMFS' *Recovery Plan Module, Mainstem Columbia River Hydropower Projects* (Hydro Module, dated September 24, 2008) for Snake River anadromous fish species listed under the Federal Endangered Species Act (ESA): Snake River spring/summer and Chinook and Snake River fall Chinook salmon, Snake River steelhead, and Snake River sockeye salmon (NMFS 2008a).[1] NMFS prepared this module to assist in recovery planning for listed Columbia basin species. The 2008 Hydro Module overviews limiting factors and threats, summarizes current recovery strategies, and provides estimates of juvenile and adult survival rates associated with the Columbia and Snake River hydropower and water storage projects. This 2017 Supplemental Module updates the scientific and technical information relevant to the four Snake River species, including an updated discussion of "latent" and "differential delayed" mortality. The geographic area addressed in the 2008 Hydro Module and the 2017 Supplemental Hydro Module extends from the accessible mainstem habitat in the Snake River (i.e., to the tailrace of Hells Canyon Dam) downstream to the tailrace of Bonneville Dam (see Figure 1 below).[2]

This 2017 Supplemental Hydro Module, together with the 2008 Hydro Module, will comprise an appendix to the ESA Snake River "roll-up" Recovery Plan. The 2008 and 2017 Supplemental Hydro Modules provide consistent information on the general effects of Columbia River mainstem hydropower and water storage projects.

This 2017 Supplemental Hydro Module incorporates new scientific data that assesses the implementation of the Reasonable and Prudent Alternative (RPA) described in the 2008 Federal Columbia River Power System (FCRPS) Biological Opinion (NMFS 2008a) and the 2009 Adaptive Management Implementation Plan, which we incorporated into the 2010 and 2014 FCRPS Supplemental Biological Opinions (NMFS 2010, 2014). This new information includes post-2007 configuration changes at FCRPS mainstem dams and recent data on survival rates for inriver downstream migrants, juvenile fish transportation and latent mortality, and adult upstream survival including that of steelhead kelts.

We will continue to update this module in the future as emerging monitoring and research findings change our understanding of the ways that hydropower facilities in the Columbia basin affect the recovery of ESA-listed salmon and steelhead.

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[1] This 2017 module is a supplement to the September 24, 2008 Hydro Module (*Recovery Plan Module, Mainstem Columbia River Hydropower Projects*; NMFS 2008b) in the sense that it updates the information in the 2008 module. The 2008 module and this supplement together serve as guidance for the recovery of the four Snake River salmon and steelhead species and the remaining nine listed salmonid species in the Columbia River.

[2] The *Columbia River Estuary ESA Recovery Plan Module for Salmon and Steelhead* (NMFS 2011) provides guidance for the recovery of all 13 listed species of salmon and steelhead in the Columbia basin based on limiting factors and threats in the lower Columbia River below Bonneville Dam.

2. Hydropower System Overview

Historically, the Snake River species traveled through a free-flowing river system as they migrated from their freshwater natal streams to the Pacific Ocean, and again as they returned as adults to spawn. Many large dams were constructed by the Corps of Engineers, Bureau of Reclamation, and Idaho Power Company in the Snake River basin during the 20th century beginning with the construction of Swan Falls Dam and its hydroelectric plant in 1901. The reservoirs behind these dams inundated habitat, blocked access to upstream spawning and rearing areas, altered the natural hydrograph, and affected water quality (temperature, turbidity, etc.) and sediment transport processes. The construction of these water storage and hydro generating projects affected the ecological functions necessary for fish growth and survival. In the following paragraphs we describe the past and continuing effects of these dams and their operations on the four listed Snake River species and their designated critical habitat.

2.1 Limiting Factors & Threats

The reasons for a species' decline are generally described in terms of limiting factors and threats. Limiting factors are the biological, physical or chemical conditions and associated ecological processes and interactions that limit a species' viability. Threats are human activities or natural events, such as floodplain development or drought that cause or contribute to limiting factors.[3] The most dramatic effect of dams is blocked access to important historical production areas for salmon and steelhead. For example, prior to dam development the great majority of Snake River fall Chinook spawned primarily in the Thousand Springs and Marsing reaches of the Snake River, near Hagerman and Marsing, Idaho. Today, fall Chinook occupy the mainstem Snake River downstream of the tailrace of Hells Canyon Dam, which represents approximately 18 percent of the historical range of this ESU (Groves and Chandler 2005, Williams et al. 2008), and the lower reaches of the Grande Ronde, Imnaha, Clearwater, and Tucannon rivers.

Those projects on the mainstem Snake and Columbia rivers where fish passage has been provided affect Snake River salmon and steelhead in the following ways (Williams et al. 2005; Ferguson et al. 2005):

- Inundated mainstem spawning and shallow-water rearing areas (loss of spawning gravels and access to spawning and rearing habitat);
- Altered riparian vegetation;
- Altered water quality (reduced spring turbidity levels);

[3] The term "threats" carries a negative connotation; however, they are often legitimate and necessary activities that at times may have unintended negative consequences on fish populations. These activities can be managed to minimize or eliminate the negative impacts.

- Altered water quantity (seasonal changes in flows and consumptive losses resulting from use of stored water for agricultural, industrial, or municipal purposes);
- Influenced natural regulation of water temperature (including generally warmer minimum winter temperatures, cooler temperatures later in the spring, and warmer temperatures later in the fall);
- Altered water velocity (reduced spring flows, decreased channel gradient, and increased cross-sectional areas of the river channel);
- Altered habitat for predators in the reservoirs and in the tailrace of each mainstem dam
- Changed food webs (including the type and abundance of prey species [both native and non-native]); and
- Reduced or delayed juvenile and adult passage.

Together these factors affect all of the listed Snake River species as they migrate through the Columbia and Snake River systems. The effects on fall Chinook salmon include changes in their spawning and rearing habitat because they use the mainstem river environment for these functions as well. In addition to access, important features of spawning and rearing habitat include spawning gravel, water quality, water quantity, water temperature, food, and riparian vegetation.

Detailed descriptions of the effects of the Columbia basin hydropower system on salmon and steelhead are provided in Williams et al. (2005) and Ferguson et al. (2005) and summarized in the 2008 Hydro Module and in Section 5.1 of NMFS (2008a).

In the following sections we provide new information on configuration and operational changes at the eight mainstem FCRPS projects; the five FCRPS reservoir storage projects; and Idaho Power Company's three-project Hells Canyon Complex on the Snake River.

2.2 Federal Columbia River Power System

The FCRPS has been the subject of two supplemental biological opinions since 2008:

- 2010 FCRPS Supplemental Biological Opinion (NMFS 2010), which amended the RPA to incorporate the 2009 Adaptive Management Implementation Plan (BPA et al. 2009)
- 2014 FCRPS Supplemental Biological Opinion (NMFS 2014), which made some modifications to the RPA

On May 4, 2016, U.S. District Court Judge Michael Simon issued the most recent court ruling on the FCRPS Biological Opinion. Judge Simon's order did not vacate the 2008 Biological Opinion or its supplements, but it does require NMFS to issue a new biological opinion. It also requires the FCRPS agencies to issue a new, comprehensive environmental impact statement under the

National Environmental Policy Act. In a subsequent order, on July 6, 2016, Judge Simon provided deadlines for these tasks. The federal Action Agencies (U.S. Army Corps of Engineers, Bonneville Power Administration, and U.S. Bureau of Reclamation) are to complete a final EIS no later than March 26, 2021. NMFS must complete a biological opinion correcting the deficiencies identified in the court's May 4, 2016, opinion on or before December 31, 2018. To integrate the long-term decision that will result from the NEPA process with ESA section 7, NMFS expects to complete a longer-term biological opinion following the selection of a preferred alternative in the final EIS. Prior to completion of the December 2018 Biological Opinion, the Action Agencies will continue to implement the actions required by the 2008 FCRPS Biological Opinion. As described in more detail below, these actions have contributed, and will continue to contribute, to improving the status of ESA-listed Snake River salmon and steelhead.

The following descriptions of recent hydrosystem improvements (and monitoring data on juvenile and adult survival rates) include the measures described in the 2008 RPA (and the 2010 and 2014 Supplemental Biological Opinions) and some developing measures resulting from adaptive management or in response to information learned through inseason management and RME during the last few years.

2.2.1 Recent Changes to FCRPS Project Configurations and Operations

Most of the mainstem project configuration and operational improvements required by the 2008 FCRPS RPA (as amended in the 2010 Supplemental Biological Opinion) were in place by 2012. All eight run-of-river dams on the lower Snake and lower Columbia rivers now have a surface oriented passage route (spillway weirs at six dams, a corner collector at Bonneville Dam, and an ice and trash sluiceway at The Dalles Dam). These facilities were designed to improve passage conditions for juvenile and adult salmon and steelhead. The most significant changes made during 2008 to 2013 were:

- In 2008, the U.S. Army Corps of Engineers (Corps) installed a spillway weir at Lower Monumental Dam and two spillway weirs at John Day Dam to provide surface oriented passage routes for downstream migrants.
- In 2009, the Corps installed a spillway weir at Little Goose Dam and increased summer spill levels at McNary Dam to 50 percent of total river flow, following several years of testing alternative operations.[4]
- In 2010, the Corps rebuilt the John Day Dam north adult fish ladder's flow control section, installing redesigned weirs to improve passage conditions for adult salmon and steelhead.
- In 2010, the Corps completed construction of a spillway wall at The Dalles Dam. This structure, along with improved avian predator deterrents (wire arrays), has substantially

[4] Before 2005, no spill was provided after June 30. A determination of when to begin transporting juvenile fish reaching this project was made by the Technical Management Team based on their assessment of in-river migration conditions. Spring migrants have not been transported from McNary Dam since 1994.

increased the survival of juvenile salmon passing the dam by about 2 to 4 percent. Wire arrays were also installed in the tailrace of John Day Dam. The Corps discontinued the use of the temporary spillway weirs (TSW) at McNary Dam during the summer migration period because survival rates for subyearling fall Chinook were lower than through standard spillbays at this dam.

- In 2012, the Corps relocated the juvenile bypass outfalls at Lower Monumental and McNary dams. In both cases, the old outfalls released fish into the slower-moving water close to the shoreline, exposing them to concentrations of predatory fish and birds. The new outfalls are further downstream and further from shore, where higher velocities prevent predatory fishes from maintaining their positions. This has increased the survival of juvenile salmon and steelhead passing each dam via the turbine bypass system.
- In 2013, the Corps installed adult PIT tag detectors in the ladders at The Dalles Dam, which will help fisheries managers identify adult losses or passage delays in the lower Columbia River.
- The Corps installed adult PIT tag detectors in the ladders at Lower Monumental and Little Goose dams in 2014 and at John Day Dam in 2017, which will help fisheries managers identify adult losses or passage delays in the lower Snake River.
- New turbine units with features developed to improve fish survival will be installed at Ice Harbor Dam starting in 2017. A turbine with a fixed blade design will replace the older adjustable blade design in unit 2. A newer adjustable blade design will replace the existing units 1 and 3 during the following years. The newer turbines feature stay vanes, turbine runners, and draft tubes that reduce fish strike, shear, pressure differential, and passage time relative to the existing units.

In addition to the actions already implemented, the following actions are expected to be completed within the next few years:

- Completion of a new juvenile bypass system at Lower Granite Dam will include the 10-inch with 14-inch diameter orifices. This will reduce delay for smolts leaving the gatewell as well as debris blockages that injure both juvenile and adult salmonids. The outfall will be relocated so that bypassed fish are routed into the thalwag and an area of rapid spillway flow, making it much more difficult for predators to capture bypassed fish. Excess water from the primary dewaterer will be routed to the adult trap, creating cooler trapping conditions during the summer months.
- Installation of a spillway PIT tag detection system for the spillway weir at Lower Granite Dam which should substantially increase the number of juvenile migrant detections and provide directly comparable survival estimates (fish detected passing via the spillway vs those detected in the juvenile bypass system). It will also detect adult salmon and steelhead which pass downstream through this route.

2.2.2 Adult Management Actions & Conversion Rate (Minimum Survival) Estimates

Except during recent years with high summer water temperatures (see Section 2.2.2.1 below), the migration rates of adults through the mainstem FCRPS projects has been similar to that before the dams were built (Ferguson et al. 2005). Any delay that adults experience as they search for and navigate through fish ladder entrances is balanced by the faster rate of migration through the lower velocity reservoir environments.

Water management operations at large upstream flood control storage projects in the United States and Canada and the mainstem run-of-river reservoirs have combined with changing climate patterns to alter the thermal regime of the Snake and Columbia rivers compared to the predevelopment period. In general, the mainstem Snake and Columbia now have higher minimum winter temperatures and are cooler later in the spring and warmer later in the fall (Perkins and Richmond 2001). The combined effects of these changes appear to benefit spring and summer Chinook salmon and early migrating sockeye salmon and steelhead, which migrate during the spring and much of the summer. However, late summer and fall migrating sockeye salmon and steelhead are exposed to elevated temperatures compared to the predevelopment period. The Corps operates Dworshak Dam on the North Fork Clearwater River during July, August, and September to maintain cooler summer temperatures in the lower Snake River in an effort to mitigate these effects of reservoir operations and warmer climate conditions.

Adult salmon and steelhead can pass each of the eight mainstem dams in the lower Snake and Columbia rivers volitionally at fish ladders (also called “fishways”). In general, we consider these adult passage facilities to be highly effective. For example, the current estimate of average adult Snake River spring/summer Chinook salmon survival (conversion rate estimates using known-origin adult fish after accounting for “natural straying” and mainstem harvest) between Bonneville and Lower Granite dams (2012-2016) is approximately 87.3 percent, or 73.7 percent when harvest and straying are included (Tables 1a and 1b, respectively). Prior to 2010 there were not enough detections of PIT tagged adult SR sockeye in the system for assessing conversion rates for this species. We therefore used PIT tag detections from upper Columbia River sockeye stocks as surrogates to assess survival rates in the lower Columbia River reach and extrapolated these to assess likely survival rates for the entire Bonneville to Lower Granite Dam migration corridor. As the captive broodstock program is beginning to increase the number of adults returning to Bonneville Dam, we are now able to make direct estimates of survival to Lower Granite Dam. The average for the 2012-2016 migration years was 49.7 percent (46.7 percent when harvest and straying are included (Tables 1a, and b).

Table 1a. Adult salmon and steelhead survival estimates after correction for harvest and straying based on PIT tag conversion rate analysis for SR salmon ESUs and steelhead DPSs from Bonneville (BON) to McNary (MCN) dams, McNary to Lower Granite (LGR) dams, and Bonneville to Lower Granite dams. Source: http://PTAGIS.org. Note: 2016 Harvest estimate unavailable, so 2011-2015 average harvest rate was used to correct the 2016 survival estimate.

Species	Years	BON to MCN	MCN to LGR	BON to LGR
SR Fall Chinook	2012-2016 Avg	95.8%	94.9%	91.0%
SR Spr/Sum Chinook	2012-2016 Avg	93.1%	94.0%	87.3%
SR Sockeye	2012-2016 Avg	59.9%	74.2%	49.7%
SR Steelhead	2012-2016 Avg	93.2%	94.3%	87.9%

Table 1b. Adult salmon and steelhead base survival estimates (with no corrections for harvest or straying) based on PIT tag conversion rate analysis for SR salmon ESUs and the steelhead DPS from Bonneville (BON) to McNary (MCN) dams, McNary to Lower Granite (LGR) dams, and Bonneville to Lower Granite dams. Source: http://www.PTAGIS.org.

Species	Years	BON to MCN	MCN to LGR	BON to LGR
SR Fall Chinook	2012-2016 Avg	70.5%	94.1%	59.3%
SR Spr/Sum Chinook	2012-2016 Avg	78.2%	93.5%	73.7%
SR Sockeye	2012-2016 Avg	56.3%	74.2%	46.7%
SR Steelhead	2012-2016 Avg	77.8%	94.1%	73.2%

The Northwest Fisheries Science Center conducted a review of PIT tag records and analyzed factors affecting the upstream survival of Snake River sockeye salmon (2008-2013; Crozier et al. 2014) and spring/summer Chinook salmon (2004-2015; Crozier et al. 2017) in recent years.[5] Crozier et al. (2014) evaluated sockeye salmon survival from Bonneville Dam to McNary Dam, McNary to Ice Harbor Dam, Ice Harbor to Lower Granite Dam, and Lower Granite Dam to the Sawtooth Valley, Idaho. Survival rates were compared to other metrics such as stock of origin, downstream migration history, adult migration timing and fallback, and river conditions (Crozier et al. 2014). Most of the upstream mortality within the hydrosystem occurred within the Bonneville to McNary reach. The timing of losses within this reach was consistent with the weekly pattern of reported sockeye salmon catch, the strongest predictor of survival. Mainstem temperature was also very important, as borne out by the extremely high mortality rates of sockeye salmon during the high temperature event of 2015, which occurred after the publication of Crozier et al. (2014).

The following factors influenced survival in the other three reaches:

- McNary to Ice Harbor Dam—juvenile history was the primary predictor of survival (survival rates were lower for hatchery origin fish or those transported as juveniles than their wild/inriver counterparts, possibly due to issues with homing.

[5] Analyses for Snake River steelhead and fall Chinook salmon have not been completed.

- Ice Harbor to Lower Granite Dam—the most significant factors were total dissolved gas concentrations at Lower Granite Dam, the cumulative temperature exposure after passing Bonneville Dam, and travel times between Bonneville and McNary dams.
- Lower Granite Dam to the Sawtooth Valley—elevated water temperatures (>18°C) was the most significant environmental factor associated with upstream survival.

Crozier et al. (2017) performed a similar analysis for Snake River spring and summer and Upper Columbia River spring Chinook salmon over two hydrosystem reaches: the lower Columbia River (Bonneville to McNary Dam; all three stocks) and the lower Snake River (Ice Harbor to Lower Granite Dam; the Snake River stocks only). Temperature had the most consistent influence on survival across all three stocks and through both reaches. Survival from Bonneville to McNary also responded negatively to high spill. Annual and seasonal variation in harvest significantly affected the survival of all three stocks. The authors found a significant interaction between catch and run, such that summer-run populations appeared to experience more indirect effects of catch as well as higher catch rates in some years.

Survival through the Snake River reach (Ice Harbor to Lower Granite Dam) was closely related to temperature and previous travel time in the hydrosystem (Bonneville to Ice Harbor Dam). Fallback rates were highest and most variable at Lower Granite Dam, followed by McNary and Bonneville dams. Temperature was important at all dams, although the shape of the relationship varied. Cumulative temperature, which is a combination of travel time and temperature, consistently had a positive correlation with fallback. Cumulative temperature was a better predictor of fallback rate than travel time alone at three dams. Flow, spill and prior travel time were also important at several dams.

2.2.2.1 Adult passage blockages in the Lower Snake River in 2013 and 2015

Elevated river temperature and low summer flows, combined with high air temperature and little wind, created thermally stratified conditions in the forebay of Lower Granite Dam during July, 2013. The warm forebay surface water entered the upper end (exit) of the adult ladder, which raised the temperature in this section several degrees above that in the ladder entrance from the tailrace and this temperature differential was enough to impede adult passage. In response, the Corps pumped cooler water from deeper in the forebay into the top of the ladder, preventing the temperature block and improving migration conditions. The modified turbine operations, combined with cooler weather, allowed Snake River sockeye and summer-run Chinook salmon to resume passing the dam. However, uncorrected (for harvest and straying) PIT tag based conversion rates from Ice Harbor to Lower Granite Dam indicated that about 30 percent of the migrating sockeye salmon failed to pass Lower Granite Dam and most likely died without spawning. Fewer (about 15 percent) of the summer-run Chinook were affected, but this was still a substantial effect.

A similar event occurred for about a week in September 2013, blocking passage for fall Chinook salmon and for steelhead. The same combination of pumping cooler water from deeper in the forebay and modified turbine operations combined with more favorable weather conditions allowed adults to resume their migration. However, an estimated 7 percent of fall Chinook salmon and 12 percent of steelhead failed to pass Lower Granite Dam during this event.

In 2015, low snow pack coupled with extremely high air temperatures throughout the interior Columbia basin resulted in unusually warm water in major tributaries to the lower Snake and Columbia rivers. Flow from these tributaries into the mainstem, combined with heat gain in the run-of-river reservoirs resulted in record high temperatures from roughly mid-June to mid-July. Sockeye salmon began to arrive at Bonneville Dam in early June and passage peaked near the last week of June, ending in July, a pattern similar to previous years. However, water temperatures at Bonneville Dam were as much as 4°C warmer than average (Figure 2 in NMFS 2016) and these high temperatures took a toll on adult sockeye survival. Fish that passed Bonneville Dam while water temperatures were less than 18°C had the highest survival, approaching 90 percent for upper Columbia sockeye and 70 percent for Snake River fish. Survival rates declined substantially once water temperatures exceeded 20°C. Only 1 percent of the PIT-tagged population that passed Bonneville Dam in 2015 reached Idaho's Sawtooth Valley; another 0.5 percent were collected at Lower Granite Dam and transported directly to Eagle Fish Hatchery. Some Snake River sockeye were apparently able to survive for several months in Little Goose Reservoir, a thermal refuge resulting from cold water releases at Dworshak Dam on the North Fork Clearwater River, because they were detected migrating past Lower Granite Dam in late September or October. However, none of these fish are known to have survived to the Sawtooth Valley.

The proportional return of transported fish to Bonneville Dam is typically higher than that of inriver migrating juvenile Snake River sockeye salmon (Smith et al. 2017). However, those fish that were transported as juveniles generally have lower survival rates upstream to McNary and Lower Granite Dams. Taken together, smolt to adult returns of transported sockeye salmon back to Lower Granite Dam is higher than for inriver migrants in most years. An exception was observed in 2015 when the estimated survival of adult sockeye salmon between Bonneville and Lower Granite dams was much lower for fish that were transported as juveniles (0 percent survival) versus those that migrated inriver (8 percent). Overall, NMFS' analysis suggests that at present, transportation is usually, but not always, beneficial, resulting in more adult sockeye salmon reaching Lower Granite Dam in most years.

Management Measures

As described above, since 2013 the USACE began using a combination of auxiliary and emergency pumps to draw deep, cool water from the forebay at Lower Granite Dam to cool and reduce the thermal temperature gradient within the fish ladder. The USACE installed permanent intake structures and pumps in February 2016: two permanent pumps or "intake chimneys," one on either side of the upstream end of the fish ladder where adults move into the forebay. Both draw water from about 70 feet.

In addition, a semi-circular pipe extends from the intake chimney and sprays cold water into the forebay at the ladder exit, keeping temperatures at or below 68°F (Anchor QEA 2017). This serves two purposes: (1) ensuring that cooler forebay water enters the ladder and (2) inducing adults to continue upstream away from the exit, reducing the risk of fallback. The Corps is building similar structures to cool the fish ladders at Little Goose Dam. Temporary pumps will be used as needed until the permanent chimneys are built in winter 2017/2018 and a spray curtain extension is planned for 2018.

NMFS also recommended that the Corps improve the monitoring and reporting of temperatures in all mainstem fish ladders. During the in-water work period of 2016 and 2017, the Corps installed thermometers in the entrances and exits to all the adult fish ladders at FCRPS dams. The thermometers accurately monitor the entrance and exit water temperatures fish experience and be used to monitor differentials greater than 1.0°C. If the Corps observes temperatures or temperature differentials in the ladders at more projects that are high enough to cause delay, steps may be taken to install the types of cooling pumps already used at Lower Granite and Little Goose dams. To prepare for this type of action, the Corps is monitoring temperatures in the forebay of John Day Dam in 2017 to determine if temperatures are stratified during the summer months. If so, it may be possible to pump the colder water into the upper (exit) sections of the fish ladders.

The Corps is also developing a water temperature model to assess the effect of different project operations on forebay and tailrace temperatures. There is uncertainty regarding the effects of surface (via removable and temporary spillway weirs) and deep spill, as well as powerhouse flow on forebay and downstream temperatures at Lower Granite and Little Goose dams. The modeling tool should reasonably predict temperature and thermocline conditions in the forebay and tailrace from changes in project operations. If these correlate well with empirical data, the model could be used to inform management decisions to improve passage conditions. A tool that looks at the effects of various levels of flow augmentation and operations to meet temperature targets at the tailrace of the Snake River projects could be useful in predicting the best ways to use outflow from Dworshak Dam to meet in-season management goals in the Snake River.

Potential for Effects of Delayed Migration on Spawning Success

Bowerman et al. (2017) examined the reproductive energy expenditure of Snake River spring/summer Chinook salmon returning to the South Fork Salmon River, Idaho. These fish travel more than 600 miles from the ocean and gain almost a mile in elevation while passing all eight FCRPS hydroprojects. The fish evaluated in this study initiated migration with large stores of readily mobilized somatic energy, primarily in the form of muscle lipid. Individuals that took longer to travel through the hydrosystem portion of the migration route, potentially due to fallback or other factors, arrived at the spawning grounds with less energy than faster migrants. However, travel times were not significantly different between successful spawners and those that died before spawning. The authors note that the single year of data used in this study (2002, augmented with observations during 2014) may not have been sufficient to observe the effects of energetic constraints on survival, because pre-spawning mortality rates can vary substantially among years.

2.2.3 Snake River Steelhead Kelt Survival Rates

Unlike other Pacific salmonids, a large fraction of the adult steelhead do not die after spawning. Instead, these fish, termed “kelts,” migrate back to the ocean and then return in subsequent years as repeat spawners. Estimates of FCRPS kelt passage survival in the FCRPS have ranged from 4.1 to 6.0 percent in the low flow year 2001 to 15.6 percent in 2002 and 34 percent in 2003 (Boggs and Peery 2004; Wertheimer and Evans 2005). Although some portion of these losses would occur in a free-flowing river, fisheries managers expect that survival is low because turbine bypass systems were not designed to safely pass adult fish. In addition to causing injury and mortality, the mainstem hydro projects delay kelt downstream migrations (Wertheimer and Evans 2005). Boggs and Peery (2004) and Wertheimer and Evans (2005) estimated that 17 to 25 percent of the steelhead that pass Lower Granite Dam return downstream as kelts. Thus, while there may be a relatively large number of kelts in Snake River, survival through the FCRPS may limit their contribution to the productivity of their respective populations.

BPA and the Corps have developed a Kelt Management Plan (BPA and USACE 2012) to improve the productivity of B-run Snake River steelhead populations by about 6 percent as required by the 2008 FCRPS Biological Opinion (RPA 33). BPA and the Corps are pursuing three strategies for attaining the remaining survival improvements necessary to achieve this goal: implement measures to improve inriver survival of migrating kelts, collect and transport kelts to areas below Bonneville Dam to improve adult return rates, and long-term reconditioning to increase the number of viable females on the spawning grounds.

The Kelt Management Plan includes using surface passage routes at lower Columbia dams outside of the juvenile migration season to increase the survival of kelts moving back downstream. Researchers used hydroacoustic monitoring to evaluate the behavior of adult steelhead passing McNary Dam during winter 2011, 2012, and 2014 to determine whether modified operations could protect downstream migrants (Ham et al. 2012a, 2012b, and 2015). Spillway surface flow weirs were used in a weir-on/weir-off block design in 2011 and 2014, but involuntary spill often confounded the study design. These studies did indicate that kelt passage increased when the spillway weirs were “on” (and turbine passage was lower during those periods). Passage through the turbines appeared to increase with total river flow and to decline during periods of involuntary spill.

Studies conducted at Bonneville and The Dalles Dams in 2012 (Rayamajhi et al. 2013) estimated dam passage survival rates of 89.9 percent and 89.5 percent, respectively. Route-specific survival Bonneville Dam were 92.5 percent for the spillway and 94.2 percent at the surface collector; at The Dalles were 93.9 percent for the spillway and 93.3 percent at the sluiceway. However, survival through the turbines was much lower at both dams: 73.9 percent at Bonneville and 53.3 percent at The Dalles and survival through the juvenile bypass system at Bonneville was about

60.0 percent. Thus, the relatively high dam passage survival rates indicate that most kelts are passing these two dams via the spillway or other surface routes. If these are not available during their migration, overall rates of dam passage survival probably would be lower.

Colotelo et al. (2014) show a median travel rate of 30 mi/day for tagged kelts that migrated from the Lower Granite tailrace (RM 430) to below Bonneville Dam (RM 145) in 2013 and 32 mi/day in 2012 (Colotelo et al. 2013). These rates are faster than those reported in Wertheimer and Evans (2005) in 2001 and 2002 (12 and 17 mi/day, respectively). However, both sets of studies found that river discharge was positively associated with the travel rates of kelts. Colotelo et al. (2013) estimated that about 40 percent of the kelts released at or above Lower Granite Dam survived to river mile 97 (downstream of Bonneville Dam); compared to about 4 to 16 percent in 2001 and 2002. The median travel time from Lower Granite to Bonneville Dam in 2012 was nine days compared with 27 days in 2001 and 19 days in 2002 (Wertheimer and Evans 2005). Although average Snake River flows were much higher in 2012 than in 2001 or 2002, which would be expected to reduce travel time, the scale of the improvement strongly suggests that improved surface passage routes were also a factor. Shorter travel times are likely to indirectly affect survival through the lower estuary and nearshore ocean environment by reducing stress and the amount of energy expended during the downstream migration. The installation of the surface weir PIT tag detections system at Lower Granite Dam in 2019 could allow managers to estimate steelhead kelt travel times and survival rates annually.

The returns of transported kelts averaged 1.17 percent, compared to 0.68 percent for inriver migrating kelts over a 5-year period (BPA and USACE 2012). However, until more good condition kelts are available, transportation will occur only after the capacity of the rehabilitation research facility at Dworshak Hatchery is exceeded.

Long-term reconditioning at the Dworshak Hatchery rehabilitation research facility continues to have potential for increasing kelt survival in the short term. To date, success rates have been somewhat inconsistent, but recent improvements to the facility should substantially increase the success rate of this program (BPA and USACE 2013). About 38 percent (10-year average) of the kelts in a similar Yakima Basin program are being rehabilitated and released to spawn again (Hatch et al. 2013).

2.2.4 Juvenile Dam Passage Survival

Snake River juvenile migrants pass eight federal mainstem dams on their way to the ocean. They pass these mainstem dams via three potential routes: through turbines, by way of the spillway, or through the juvenile bypass system. Empirical studies indicate survival typically is highest through spillways, followed by bypass systems and then turbines (Muir et al. 2001). These studies have shown that juvenile salmon experience about an 11 percent mortality rate per mainstem dam when they pass by way of turbines (Whitney et al. 1997). Mortality can be caused by striking the turbine runners, exposure to rapid and severe pressure changes that occur in the turbine environment, predation of fish emerging from the turbine tube into the project tailrace in a disoriented state, or other factors. The Corps has constructed juvenile bypass systems at the mainstem FCRPS dams to reduce the number of fish that pass through turbines. Large underwater screens partially cover the turbine intakes, creating a hydraulic field that guides the juvenile migrants into the bypass system. The juvenile fish then pass horizontally through the dam's interior through a series of galleries then through an outfall pipe to the tailrace. At some dams (Lower Granite, Little Goose, Lower Monumental, and McNary dams) the bypassed fish can be collected for barge or truck transport to below Bonneville Dam, but at the other four facilities they can only be discharged downstream into the river.

Fish can also pass the mainstem dams via spillways. All of the mainstem dams are equipped with spillways, which were designed to allow the controlled release of water from behind the dam when flow in the river would exceed the power house capacity or when there is no market for the energy that would otherwise be produced. Flow over the spillway is controlled by large gates, which must be raised to allow water to pass at a depth of 40 feet or more. Water spilled to provide a safer passage route for juvenile fish even when flows are below powerhouse capacity (rather than running the water through turbines to produce electricity) is called "voluntary" spill. Whether or not it is voluntary, as spill levels increase, the proportion of smolts passing through turbines (and bypass systems) generally decreases. The Corps has voluntarily spilled water as a means to increase the survival of smolts passing dams on the Snake and Columbia rivers since 1994, although the proportion of flow spilled for fish has increased over time.

Although spillways generally provide the highest survival rates for migrating juveniles, spillways were not designed for this purpose. Most yearling Chinook salmon migrate in the upper 10 to 20 feet of the water column (and steelhead are even shallower) and must dive 40 to 60 feet to take advantage of the spillway passage route. In addition, water plunging over the spillway increases the amount of total dissolved gas (TDG) in the water below the dams to levels that can injure or even kill fish. At present, spill levels that result in TDG levels in excess of the national water quality standard of 110 percent of saturation are allowed during the juvenile fish migration period (April through August) through "waivers" issued by the Oregon Department of Environmental Quality and Washington Department of Ecology. Because the effects of total dissolved gas on aquatic organisms are moderated by hydrostatic pressure—each meter of depth compensates for 10 percent of gas supersaturation as measured at the water surface—NOAA Fisheries has determined that as long as the water is deep enough for fish to migrate 2 meters below the surface, they will not be harmed. Thus, the waivers allow managers the ability to increase spill levels (beyond those that could occur without a waiver) to provide effective passage for juvenile migrants at the mainstem Columbia and Snake River dams.

During the early 2000s, hydrosystem biologists and engineers designed surface spillway weirs to capitalize on the natural tendency of juvenile salmonids to migrate at shallow depths (Beeman et al. 2006). Each spillway weir design is based on the concept of providing an overflow weir with a depth similar to the natural migration depths of juvenile Chinook and steelhead (Beeman et al. 2010). Empirical studies have shown that surface spillway weirs have guided enough fish away from the turbine and bypass system passage routes that total dam passage survival rates (for all routes combined) have increased (Beeman et al. 2010).

Fish passage operations including voluntary spill levels at lower Snake and Columbia River dams have been relatively stable since 2010 and the Corps of Engineers have made substantial progress during the past five years in implementing the structural improvements anticipated in the 2008 Biological Opinion. Survival studies show that with few exceptions, these measures are performing as expected and are very close to achieving, or are already achieving, the juvenile dam passage survival objectives of 96 percent for yearling Chinook salmon and steelhead and 93 percent for subyearling Chinook salmon (in NMFS 2014). We expect the Action Agencies to complete the remaining configuration and operational improvements and any necessary juvenile performance standard testing by 2018.

2.2.4.1 Juvenile Inriver Reach Survival Estimates

Inriver reach survival estimates allow us to assess the combined effects of background environmental conditions, actions at the run-of-river projects within the lower Snake and Columbia River migration corridor, and water management operations at upstream storage projects on juvenile migrants. Because they estimate survival over distances of hundreds of miles and time periods of days to weeks, they are influenced by factors such as the condition and health of these fish when they first reach the mainstem and interactions between run timing and environmental conditions. To derive these estimates, thousands of juvenile salmon and steelhead are PIT tagged at or above Lower Granite Dam each year. Detections at mainstem dams (in juvenile bypass systems or the corner collector at Bonneville Dam) and in the estuary allow NMFS to estimate survival rates through the Lower Granite to Bonneville reach.

The 2008 Hydro Module presented Base Period (1980-2001 migrations) survival estimates for wild steelhead and yearling Chinook salmon smolts for the purpose of comparing to average "Current" and "Prospective" survival estimates in the 2008 FCRPS Biological Opinion (NMFS 2008a and 2008b). This 2017 Supplemental Hydro Module recognizes that nearly all of the actions required by that biological opinion (and its 2010 and 2014 supplements) that were designed to affect juvenile survival now have been implemented. We compare the average of annual survival rates for the past 10 years (2007-2016) to the average for the Base Period (NMFS 2008c, Faulkner et al. 2017, and FPC 2016a) to illustrate how improvements in smolt survival are contributing to the productivity of Snake River salmon and steelhead. We display this information for wild Snake River steelhead (Figure 1), wild yearling spring/summer Chinook salmon (Figure 2), wild and hatchery origin sockeye salmon (Figure 3), and hatchery-origin subyearling fall Chinook salmon (Figure 4).

The recent 10-year average inriver survival rates for wild Snake River steelhead smolts from Lower Granite to Bonneville Dam is 46.5 percent compared to the estimated Base Period estimate of 26.5 percent (Figure 1). This represents a 75 percent [(.465-.265)/.265] increase compared to the 1980-2001 Base Period.

The recent 10-year average survival rates for wild yearling Snake River spring/summer Chinook salmon is 51.0 percent compared to the Base Period estimate of 33.4 percent (Figure 2). This represents about a 53 percent [(.510-.334)/.334] increase compared to the 1980-2001 Base Period.

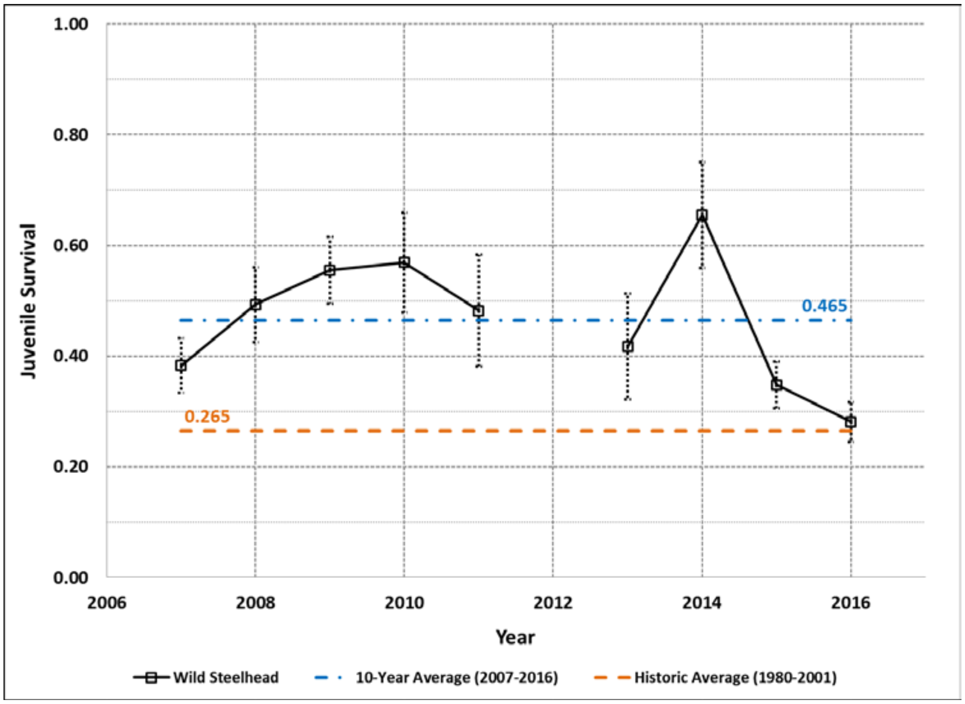


Figure 1. Lower Granite to Bonneville Dam average annual survival estimates (± 1 standard error) for wild SR steelhead smolts (2007–2016) compared to the 10-year average for that period (blue horizontal dot-dash line) and the 1980-2001 Base Period (orange horizontal dashed line). Note: Too few PIT tagged fish were detected at Bonneville Dam in 2012 to make a credible survival estimate.

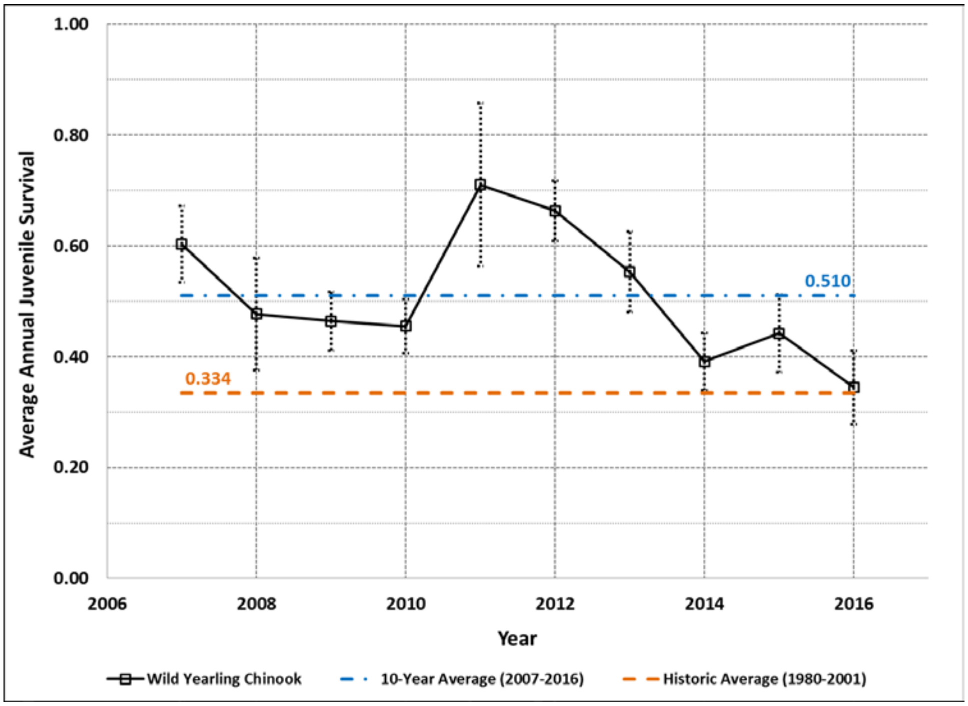


Figure 2. Lower Granite to Bonneville Dam average annual survival estimates (± 1 standard error) for wild SR yearling spring/summer Chinook salmon smolts (2007–2016) compared to the 10-year average for that period (blue horizontal dot-dash line) and the 1980-2001 Base Period (orange horizontal dashed line).

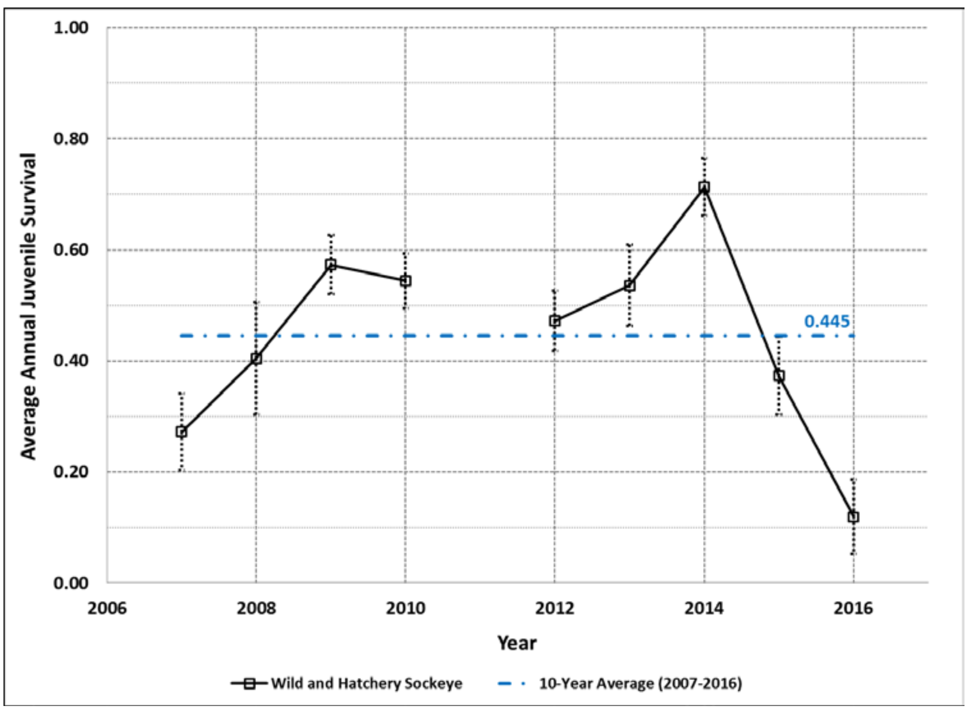


Figure 3. Lower Granite to Bonneville Dam average annual survival estimates (± 1 standard error) for wild and hatchery origin SR sockeye smolts (2007–2016) compared to the 10-year average for that period (blue horizontal dot-dash line). No data are available for estimating survival during the 1980-2001 Base Period. Note: Too few PIT tagged fish were detected at Bonneville Dam in 2011 to make a credible survival estimate.

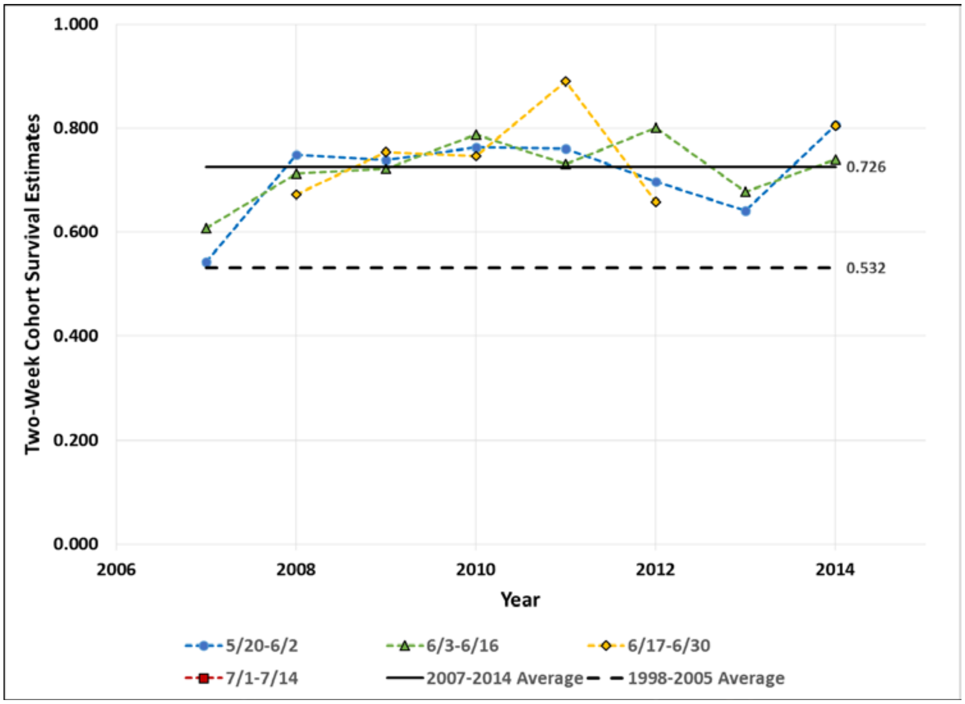


Figure 4. Estimated average survival rates for two-week cohorts of hatchery-origin subyearling SR fall Chinook salmon in the reach between Lower Granite and McNary Dams (2007 to 2014). The horizontal solid line is the average annual survival across that eight-year period; the dashed line is the average annual survival during 1998-2005, an earlier period representing limited summer spill and before the installation of surface passage routes.

The recent 10-year inriver survival rates for wild and hatchery-origin (combined) Snake River sockeye salmon smolts is 44.5 percent (Figure 3).[6] There are no available estimates of the survival rates of these fish during the 1980-2001 Base Period. However, given the generally improved conditions and survival rates observed for spring migrating steelhead and spring/summer Chinook smolts, similar increases in average smolt survival rates (50 to 75 percent) between the two periods are likely.

Base Period survival estimates are also unavailable for subyearling fall Chinook salmon smolts. Furthermore, survival rates cannot be reliably estimated all the way to Bonneville Dam each year because too few fish are tagged for adequate numbers of detections in the lower river. The Fish Passage Center has estimated survival for up to four two-week cohorts of subyearling hatchery smolts in the reach between Lower Granite and McNary dams for 1998-2014. Comparing these estimates for the recent (2007-2014)[7] and an earlier (1998-2005) period indicates that the installation of surface passage routes (completed in 2008) and 24-hour spill (2005-2017) have substantially improved subyearling survival in the Lower Granite to McNary reach. Potential mechanisms for this improvement include faster travel times, which reduce the exposure of late June and July migrants to adverse environmental conditions during years characterized by low

[6] Too few PIT tagged sockeye smolts were detected at Bonneville Dam and the estuary trawl provide a credible survival estimate in 2011.

[7] 2007-2014 was chosen to be consistent with reporting for other Snake River species.

flow and increased mainstem temperatures. The latter is associated with increased predator metabolic and feeding rates as well as the increased risk of disease. In general, survival rates during the recent period have been higher than those before 2005 (i.e., before the 24-hour summer spill operation was fully implemented).

The 2007-2014 estimated average Lower Granite to McNary Dam survival rates for two-week cohorts of subyearling hatchery Snake River fall Chinook salmon smolts is 72.6 percent (Figure 4). The average for the earlier (1998-2005) period was 53.2 percent. This represents about a 36 percent [(.726-.532)/.532] increase in the inriver survival of hatchery origin subyearling Snake River fall Chinook smolts. Based on the availability of surface passage routes and 24-hour summer spill in the lower Columbia River it is reasonable that a similar increase in survival has occurred for subyearling fall Chinook salmon migrants between McNary and Bonneville dams. In addition, the survival of natural origin smolts has likely increased at a rate similar to that of hatchery origin fish.

In summary, recent average annual reach survival estimates for migrating smolts have improved substantially compared to the 1980-2001 Base Period for Snake River steelhead, yearling spring/summer Chinook salmon, and sockeye salmon (by roughly 50-75 percent) and compared to the 1998-2005 earlier period for subyearling hatchery fall Chinook salmon (about 35 percent). As noted in the 2010 Supplemental Biological Opinion (NMFS 2010; see also Section 2.2.2.2), on a per-kilometer basis, these survival rates are approaching those estimated for several free-flowing river systems. Controlling for other factors affecting adult returns such as poor ocean conditions, these increased average survival rates for inriver migrating smolts have resulted in higher adult returns in recent years compared to the Base Period.

Direct survival

Many juvenile salmon and steelhead do not survive their journey through the Columbia River to the ocean. Direct estimates of survival can be measured at a dam, through a reservoir, or past a series of dams and reservoirs using either passive (e.g., passive integrated transponder or “PIT”) or active (e.g., radio or acoustic) tags. In most studies, direct survival is measured from an upstream point to a location immediately below a dam or below a series of dams. The mortality rate can be calculated as 1 minus the observed survival rate (e.g., 1.00 – 0.98 survival rate = 0.02 or 2 percent mortality).

Latent Mortality

More complex is the concept of latent, or indirect, mortality. In terms of the Columbia River hydrosystem, it is defined as the mortality that occurs after a juvenile fish passes Bonneville Dam that would not occur in a free-flowing system of equal length (Williams et al. 2005). The concept assumes that juveniles passing through the FCRPS experience a certain degree of harm, which reduces the likelihood of that some proportion will survive to return as spawning adults. Potential causes of latent mortality include:

- Delayed arrival timing in the estuary and ocean (the series of dams and reservoirs increases juvenile travel time through the migration corridor);
- Sublethal injuries or stress incurred during migration through juvenile bypass systems, turbines, or spillways;
- Disease transmission or stress resulting from the artificial concentration of fish in bypass systems;
- Depletion of energy reserves from prolonged migrations;
- Altered conditions in the estuary and plume as a result of water management operations; and
- Disrupted homing ability in fish transported as juveniles.

Most researchers agree that some level of latent mortality exists. However, there are many opinions regarding what mechanisms are important and by extension, what managers can do to minimize or mitigate for these effects in the future. For example, Williams et al. (2005) posited that a major component of latent mortality was the disrupted migration timing of transported fish and inriver migrants and that the effect of interactions between latent mortality and ocean conditions was likely to vary seasonally. Schaller and Petrosky (2007) found that Snake River Chinook salmon adult return rates were substantially lower after construction of the four lower Snake River dams than during the years preceding their existence. More recently, DeHart (2010) conducted a literature review and concluded that passage through turbines and bypass systems at the mainstem dams results in significant latent and differential delayed mortality of juvenile salmonids, which in turn reduces adult returns. Similarly, Buchanan et al. (2011) reviewed the effects of juvenile bypass systems and found that for some species, adult return rates were consistently lower for individuals that experienced bypass systems than for smolts that used turbines or spillways. They further noted that some pairs of dams had synergistic effects – where the experience of using two or more bypasses had a greater statistical effect on adult returns than the sum of the effect of each bypass individually.

The Independent Scientific Advisory Board (ISAB) reviewed a number of hypotheses relating causative factors for latent mortality. The panel noted that researchers have made estimates of latent mortality that range from 0.01 to 64 percent (ISAB 2007). The management implications of these vastly different estimates are substantial. If the 64 percent figure is accurate, then the adverse effects of FCRPS passage would be greater than currently known requiring consideration of commensurate reconfiguration actions to support recovery objectives. Conversely, if the 0.01 percent estimate is correct, mainstem passage would not play a significant role in post-Bonneville survival rates. The ISAB (2007) strongly advised against continuing efforts to measure absolute latent mortality because it requires a reference condition that does not exist: the Columbia and Snake River system with no dams. Instead, "the focus should be on the total mortality [direct and indirect] of in-river migrants and transported fish, which is the critical issue for recovery of listed salmonids," and "research and monitoring [should] be used to further quantify biological factors[8] that contribute to variability in estimated post-Bonneville mortality" (ISAB 2007).

More recently, the ISAB (2011, 2012) was asked to review several Fish Passage Center documents relating to latent mortality of in-river migrants due to route of dam passage (spill passed fish versus bypassed fish). They concluded that "[b]ased, on our review, the studies and analyses cited in these technical memos do not provide an adequate base of reliable information to support a 'weight of evidence' conclusion on the strength of a relationship between multiple bypass passage and latent mortality of juvenile Chinook and steelhead. That is, the relationships observed between latent mortality and bypass passage are confounded with other factors that obscure unambiguous interpretation."

In summary, the experience of hydrosystem passage in the lower Snake and Columbia Rivers is likely to result in some latent mortality, but the specific mechanisms (e.g., altered migration timing, passage through bypass systems, etc.) and how these factors might interact with factors such as ocean productivity are poorly understood. Hopefully, continued monitoring of Smolt to Adult returns relating to hydrosystem improvements (juvenile bypass system outfall relocations, reduced travel times due to increased access to surface passage routes) and other ongoing research will shed additional light on this issue.

2.2.4.2 Juvenile Transportation

The Action Agencies, in cooperation with NMFS and other regional fish management agencies, developed the juvenile fish transportation system to mitigate for juvenile mortality incurred when passing through the mainstem Federal dams. Fish are collected at the uppermost mainstem dams and transported in barges (or trucks when numbers are very low) to a release point below Bonneville Dam. This is intended to eliminate the mortality juveniles would otherwise experience by passing multiple dams. Three of the four lower Snake River dams are equipped with juvenile fish collection and transportation facilities that obtain fish from the bypass system discussed above. Collection and transportation at McNary Dam on the Columbia River was terminated in the 2014 Biological Opinion (NMFS 2014) because the recent, available data did

[8] Identifiable factors that contribute to variability in post-Bonneville mortality may include: predation by birds; predation by fishes; increased vulnerability to predators because of size, stress, or disease; timing of ocean entry; ocean conditions; ocean interceptions and harvest of returning adults; and in-river adult pre-spawn mortalities. Source: ISAB (2007)

not demonstrate a consistent or substantial benefit to fish transported from this location compared to inriver migrants.

NMFS continuously evaluates transportation as a strategy to improve juvenile survival. Studies have consistently shown that transportation results in a higher adult return rate for steelhead compared to in-river migrants (Marsh et al. 2005, 2006, 2007; Williams et al. 2005; Schaller et al. 2007). However, this is not true for wild (i.e., natural-origin) spring Chinook when measured as an annual average rate of return (Schaller et al. 2007). Williams et al. (2005) and Marmorek et al. (2004) have demonstrated a seasonal benefit from transport, generally beginning in early May. In addition, adult steelhead and to a lesser extent spring Chinook that were transported as juveniles tend to stray into non-natal spawning areas at higher rates than adults that out-migrated inriver as juveniles (NMFS 2008c and ISAB 2008).

Seasonal trends in the effectiveness of juvenile transport were reflected in the COMPASS model, which was used to evaluate proposed spill and transport operations and their likely effect on steelhead and spring/summer Chinook adult returns for the 2008 Biological Opinion. As a result of this modeling effort, the 2008 Biological Opinion called for two transportation operations, depending on the runoff volume forecast. In years when the Snake River spring flow was forecast to average less than 65 kcfs, no spill was to be provided at the three Snake River collector dams and all fish collected were to be transported beginning April 3. In years when the Snake River spring flow was forecast to exceed 65 kcfs, spill was to be provided and juvenile fish would be collected for transportation beginning April 21. The 2008 Biological Opinion specified a spill cessation period from May 7 to May 20, with spill resuming May 21, to maximize transportation and to spread the risk between transport and inriver migration routes. However, the ISAB (2008) did not endorse NMFS' proposal to maximize transport even for the discreet periods proposed, citing a list of uncertainties with respect to this action including:

- The effects of recent configuration improvements (e.g., surface spillway weirs) at the dams
- Effects of transport on lamprey and sockeye
- Relative amounts of adult straying, and potential effects on genetic and life history diversity, for transported versus inriver fish.

Based on the COMPASS model, the 2008 Biological Opinion had anticipated that the percentage of spring Chinook transported would range from about 40 to 96 percent (averaging 64 percent over the range of flow conditions analyzed). We expected a somewhat higher percentage of steelhead to be transported – from about 50 to 98 percent (averaging 74 percent). However, the actual percentage of spring yearlings transported has generally been less than 50 percent since 2008 (roughly 23 to 40 percent for natural-origin spring/summer Chinook salmon and 28 to 46 percent for natural-origin steelhead) because, based on the ISAB's advice, spill has been throughout the migration season and across all flow conditions. In addition, with the advice of regional fisheries managers, the Action Agencies have delayed the start of collection for transport until May 1 each year at the lower Snake River dams. Reduced transport rates should substantially reduce straying by SR spring/summer Chinook and steelhead into other basins. Transport rates ranged from 11 to 36 percent for wild yearling Chinook salmon and 12 to 40 percent for wild steelhead in 2012-2016 (Faulkner et al. 2017) and from 8 to 61 percent for sockeye salmon in 2012-2015 (FPC 2016b).

Subyearling SR fall Chinook salmon begin to pass Lower Granite Dam in late May and June. Transportation operations begin in early May at the three Snake River collector dams and continue through October (between 33 and 61 percent of wild subyearling fall Chinook salmon were transported during 2012-2015 [FPC 2016b]). The Corps conducted a 6-year (2006 and 2008-2012) study to compare the adult returns of SR fall Chinook salmon that passed the mainstem dams via spillways, turbines, or routes that divert juveniles to an area where they can be collected for transportation. The data suggest that adult returns were higher if fish collected before July 1st were returned to the river ("bypassed") and only those collected later in the summer were transported (Smith et al. 2017).

McCann et al. (2016) also assessed the likelihood of adult returns for transported subyearling fall Chinook salmon as part of the Cumulative Survival Study (CSS). Adult returns were significantly higher for 18 of 48 bypassed groups and five of the transported groups; the remaining 25 transport-inriver rations (TIRs) were not significantly different from one. In all, 31 of 48 adult return cohorts showed a benefit to in-river migration (ln TIRs < 0) while 17 showed a transport benefit.

In the 2008 Biological Opinion, we estimated that 52 percent of subyearling juvenile SR fall Chinook would be transported; the actual average during 2012-2015 for wild fish was 44 percent (FPC 2016b).

Differential Delayed Mortality

"D" or differential delayed mortality is a specific type of latent mortality that is used to measure the relative effectiveness of transporting juvenile fish past the FCRPS dams compared to inriver migration. The direct survival rate of transported juveniles to below Bonneville Dam is estimated to be about 98 percent. However, average adult return rates are usually lower for transported fish than for fish that migrated through the hydrosystem in-river. "D" is defined as the ratio of post-Bonneville Dam survival for transported fish to that of in-river migrants.[9] When D = 1, the post-BON survival rates for transported and inriver migrating juveniles is equivalent, and when D is not equal to 1, there is a difference. Whether D is greater than or less than 1 indicates which type of hydrosystem passage results in higher relative post-BON survival rates. When D is greater than 1, transported fish survive at a higher rate post-BON, and when D is less than 1 inriver migrants survive at a higher rate. Transportation is beneficial when D exceeds the inriver

[9] $D = (T: I) * S_{inriver}$ where D is differential delayed mortality, T is the SAR of transported juveniles and I is the SAR of inriver migrating juveniles (from Lower Granite Dam to the ocean and back to Lower Granite Dam for Snake River species), and $S_{inriver}$ is the estimated survival of inriver migrants from Lower Granite Dam to the Bonneville tailrace. Thus, unlike the TIR ratios discussed under "Effectiveness of Transport Operations," D takes into account the survival of inriver migrants to the tailrace of Bonneville Dam.

survival rate. Differential delayed mortality is a ratio and not an absolute measure of survival (Anderson et al. 2012). Although there is regional consensus on the need to track “D” for Snake River salmon and steelhead, the mechanisms that produce the relative differences in post-Bonneville mortality are uncertain at this time. Candidates include:

- Arrival timing in the hydrosystem (i.e., from the spawning and rearing areas)
- Travel time through the hydrosystem (to below Bonneville)
- Fish size, physiological condition, and health
- Dam operations
- Barging conditions
- Environmental conditions and predators in the lower Columbia River
- Environmental conditions and predators (especially terns and cormorants) below Bonneville Dam
- Straying
- Survival estimation techniques

Calculated values of “D” vary by species and between years. The authors of the Comparative Survival Study (CSS, which is a collaborative effort by the U.S. Fish and Wildlife Service; the states of Washington, Oregon, and Idaho; and the Columbia River Intertribal Fish Commission) report average “D” values for spring Chinook and steelhead each year (Table 2; McCann et al. 2016).

Annual estimates of “D” remain one of the metrics that regional managers consider in evaluating trends in the effectiveness of transportation and its appropriate use as a mitigation strategy.

Table 2. Date at which transport started at Lower Granite Dam and D values reported by the CSS for natural origin SR spring Chinook and steelhead. Source: McCann et al. 2016.

Year	Transport Start Date at LGR	Spring Chinook D	Steelhead D
2006	April 20	0.47	0.52
2007	May 1	0.80	1.20
2008	May 1	0.82	0.60
2009	May 1	0.65	0.94
2010[1]	April 24	0.72	0.92
2011	May 1	0.44	0.93
2012	May 1	0.44	0.54
2013	May 1	0.79	1.35[1]
2014	May 1	0.85[2]	

[1] Incomplete steelhead adult returns until 3-salt returns (if any) occur after September 16, 2016, at LGR.

[2] Incomplete adult return (only returning 2-salts as of September 16, 2016.

Note: "n-salt" refers to the number of years an adult has spent in the ocean prior to returning to freshwater to spawn. Most Chinook salmon return to freshwater after spending 1 to 3 years in the ocean (e.g., 1- to 3-salt returns).

Effectiveness of Transport Operations

We consider the smolt-to-adult return rates (SAR) of the juveniles that were transported (SAR_T), and the fish that migrated inriver (SAR_I) to assess the effectiveness of transportation. We use the ratio of SAR_T to SAR_I, referred to as the transport-to-inriver (TIR) ratio, to compare the two rates. A TIR greater than 1 indicates that transported fish survived to return as adults at a higher rate than inriver migrants. A TIR less than 1 indicates that inriver fish survived to return as adults at a higher rate than transported fish. The data used to calculate the inriver SARs are based on juveniles that were not detected at any of the Snake River collector projects (McCann et al. 2016). The TIRs for adults returning to Lower Granite Dam are available for the years 2006-2014 for spring Chinook and 2006-2013 for steelhead (Table 3; McCann et al. 2016). The TIRs greater than 1 in Table 3.3-5 indicate that transport has returned more natural origin adult steelhead and spring Chinook for most years. The TIR for both steelhead and spring Chinook was less than 1 in 2006, which had an early transport start date at Lower Granite Dam (April 20) compared to April 24 to May 1 in subsequent years. The earlier transport start date in 2006 may have contributed to the low TIR for that year.

Table 3. Initial date of transport for natural origin spring Chinook and steelhead at Lower Granite Dam. TIRs (Transport to Inriver ratios) from McCann et al. 2016.

Year	Transport Start Date at Lower Granite Dam	Spring Chinook TIR	Steelhead TIR
2006	April 20	0.78	0.85
2007	May 1	1.27	2.89
2008	May 1	1.19	1.16
2009	May 1	1.11	1.31
2010	April 24	1.21	1.45
2011	May 1	0.68	1.18
2012	May 1	0.71	0.88
2013	May 1	1.42	2.15[1]
2014	May 1	1.82[2]	

[1]Incomplete adult returns for steelhead until 3-salt returns (if any) occur after September 16, 2016, at Lower Granite Dam.

[2]Incomplete adult return (only returning 2-salts as of September 16, 2016)

Note: “n-salt” refers to the number of years an adult has spent in the ocean prior to returning to freshwater to spawn. Most Chinook salmon return to freshwater after spending 1 to 3 years in the ocean (e.g., 1- to 3-salt returns).

As mentioned above, the NWFSC conducts a similar analysis of juvenile transportation effects, but focuses on within-season patterns in SARs relative to juvenile migration timing and changing environmental conditions. The metric used to report these results is the T:B ratio because the comparison is between transported (T) and bypassed (B) fish (i.e., bypassed, but returned to the river below the dam rather than transported). The average annual T:B ratios for juveniles that were PIT tagged upstream from Lower Granite Dam during 2006–2013 have ranged from 0.54 to 1.87 across the season for natural origin spring Chinook and 1.22 to 2.49 for steelhead (USACE 2016a). The seasonal benefit from transport is most prominent for natural origin spring Chinook; before May 1, there is almost no benefit from transport, but after May 1 transport is generally beneficial during the month of May (Williams et al. 2005; Smith et al. 2013). Steelhead typically show a benefit from transport during April and continuing through May.

To summarize, several different metrics have been developed to evaluate how juvenile fish transport affects adult returns: Transport to Inriver (TIR), Transport to Bypass (T:B), and Differential delayed mortality (“D”). “TIR” compares the relative success in terms of producing adult returns of juvenile fish that were transported versus those that migrated downstream “inriver” (i.e., fish that were never detected in a juvenile bypass system at any of the four dams on the Snake River or at McNary Dam on the Columbia River). Calculating this metric allows fish managers to assess of how the transport of juvenile fish affects adult returns in a given year. “T:B” compares the relative success in terms of adult returns of juveniles that were transported versus those that migrated inriver and were detected in one or more of the juvenile bypass systems on the Snake River or at McNary Dam. This metric, calculated daily, allows us to assess how transporting juveniles affects adult returns relative to juveniles that migrate inriver on the same day. "D" compares the relative success in terms of adult returns between fish that were either transported to below Bonneville Dam as juveniles or migrated inriver and survived to below Bonneville Dam.

2.2.5 Smolt-to-Adult Returns

Smolt-to-adult return ratios (SARs) represent the survival of salmon from the smolt stage at a particular location in the freshwater environment through adults returning to the same location (or to another useful location in the migration corridor). These estimates typically represent aggregate survival through a portion of the juvenile freshwater migration corridor, the estuary, the ocean, and a portion of the adult freshwater migration corridor. SARs therefore provide useful information to assess survival through the mainstem migration corridors and ocean-rearing environment. This section focuses on the SARs of all migrants (inriver and transported fish combined) rather than on the comparisons of these groups (see Section 2.2.4).

Estimated SARs (Lower Granite dam back to Lower Granite dam) for Snake River spring/summer Chinook and steelhead from the mid-1960s to mid-2000s are shown in Figures 5 and 6. The older (1960s to early 1990s) data were derived using run reconstruction techniques; the more recent data were generated using PIT tagged fish. In general, SARs for both Chinook salmon and steelhead have declined since the 1960s; but continue to be highly variable; ranging from about 0.5 to 4 percent in recent years. The exact causes are unknown, but several factors likely contributed including the construction of four dams in the late 1960s and early 1970s (John Day Dam on the Columbia River, and Lower Monumental, Little Goose, and Lower Granite dams on the Snake River); and a shift to generally less productive conditions in the northern Pacific Ocean (Mantua et al. 1997; Peterson and Schwing 2003; Scheuerell and Williams 2005; Petrosky and Schaller 2010; Haeseker et al. 2012; Burke et al. 2013). Other human factors, including increased hatchery production, and land use management activities (e.g., agriculture, forestry, and mining) could potentially affect the relative fitness (condition, size, or competiveness) of juvenile fish and so may also have contributed to a downward trend in SARs.

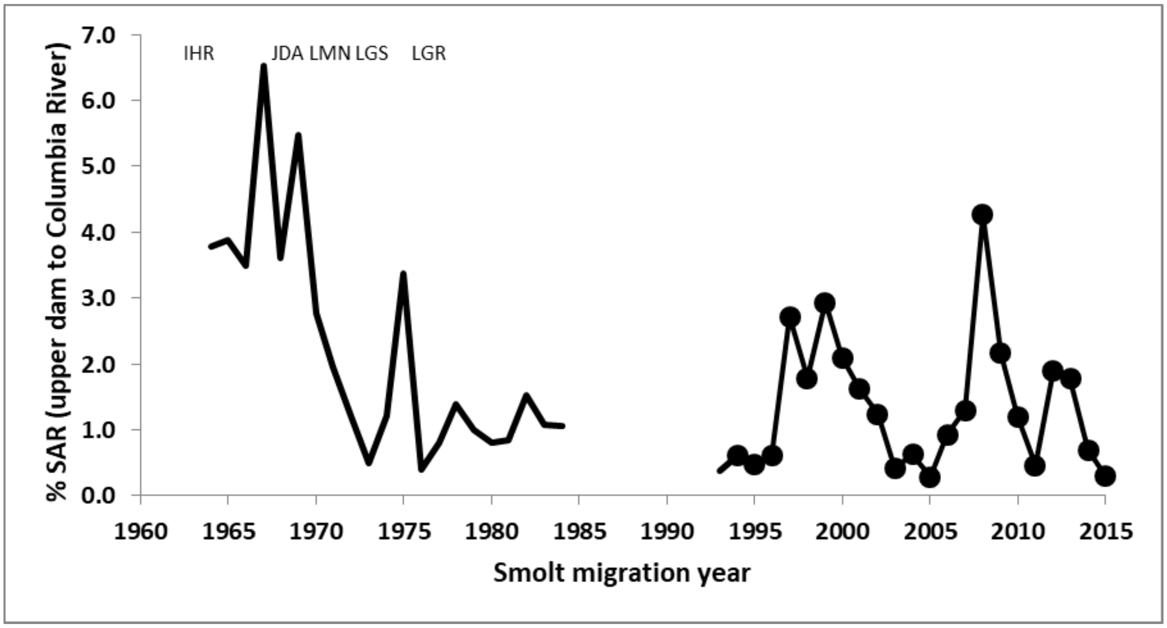


Figure 5. SARs from smolts at uppermost Snake River dam to Columbia River returns (including jacks) for wild Snake River spring/summer Chinook, 1964–2015. Dam construction sequence was: 1961-IHR, 1968-JDA, 1969-LMN, 1970-LGS, 1975-LGR. SARs are based on run reconstructions (1964-1984 and 1993, solid line) and CSS PIT tags (1994-2013, dots and solid line). Smolt migration years are (brood year+2). The 2010 and 2011 estimates are derived from incomplete returns; estimate of SAR for the 2015 outmigration year is complete through 2-salt returns only. Source: McCann et al. 2016.

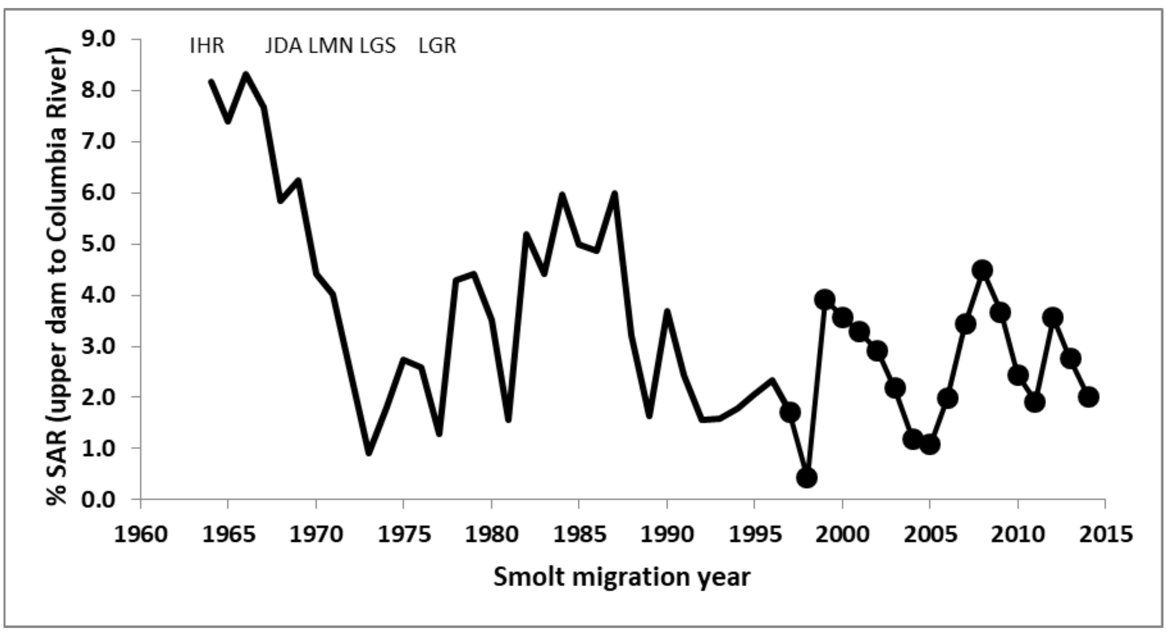
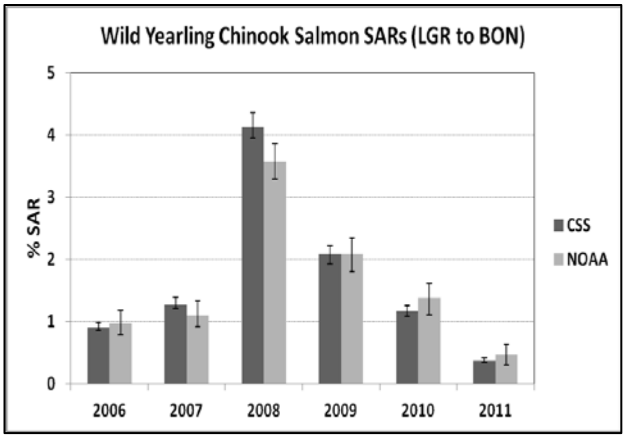


Figure 6. SARs for wild Snake River steelhead from and returning to the uppermost Snake River dam in place each year, 1964-2014. Dam construction sequence was: 1961-IHR, 1968-JDA, 1969-LMN, 1970-LGS, 1975-LGR. SARs based on run reconstructions (1964-1996, solid line) and CSS PIT tags (1997-2013, dots and solid line). Source: McCann et al. 2016.

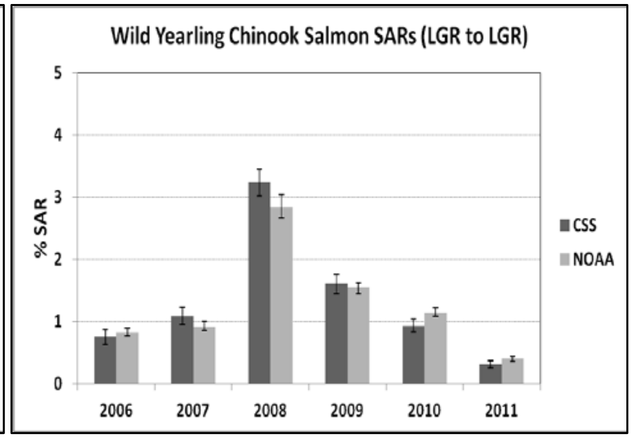
This remainder of this section summarizes recent SAR estimates for PIT tagged migrating smolts[10] that passed Lower Granite Dam from 2006 to 2014 (inriver and transported migrants combined). Figure 7 depicts SAR estimates (with 90% confidence intervals) for wild yearling Chinook salmon (including jacks) and steelhead smolts detected at Lower Granite and returning to either Bonneville (Figures 7a,c) or Lower Granite Dam (Figures 7b,d). The differences between the paired estimates represents adult losses from Bonneville Dam to Lower Granite Dam from all sources (e.g., hydropower, harvest, injuries due to pinniped predation, and other natural factors). These graphics include estimates from the Comparative Survival Study (McCann et al. 2016) as well as the NOAA Fisheries' Northwest Fisheries Science Center (unpublished data) for juveniles tagged upstream of Lower Granite Dam.

There is substantial agreement in the SAR estimates made by CSS and NOAA. As expected, SAR estimates to Lower Granite Dam were consistently lower than SAR estimates to Bonneville Dam. Recent SARs peaked for both yearling Chinook salmon and steelhead smolts that outmigrated in 2008 with steelhead SARs exceeding 4 percent and yearling Chinook salmon SARs exceeding 3.5% back to Bonneville Dam. SAR estimates declined substantially to less than 0.55% in 2011 for spring/summer Chinook salmon.

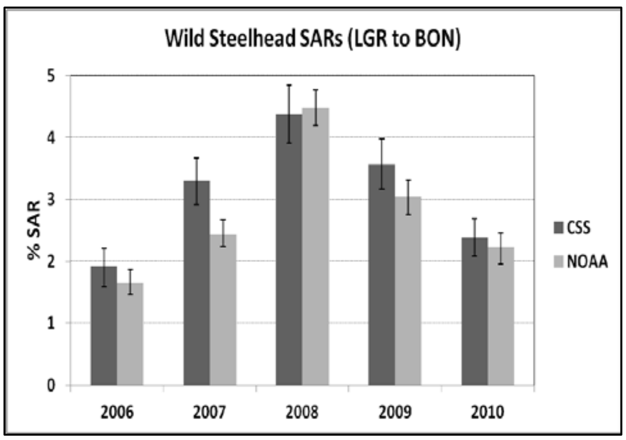
[10] There is evidence suggesting that PIT tagged juveniles return at lower rates (Knudsen et al. 2009) than untagged fish, although the magnitude and variability of this "handling effect" are poorly understood. Thus, PIT tag derived estimates should be interpreted as "minimum" SAR estimates for the run as a whole because they are likely lower (to an unknown degree) than those of untagged fish.



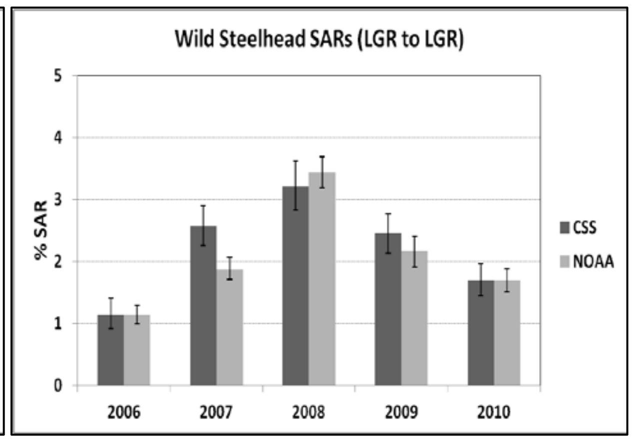
a.



b.



c.



d.

Figure 7a-d. Smolt-to-Adult Return estimates (with 90% confidence intervals) for juvenile Chinook salmon and steelhead tagged upstream of Lower Granite Dam: a.) wild yearling Chinook salmon returning as adults to Bonneville Dam; b.) wild yearling Chinook salmon returning as adults to Lower Granite Dam; c.) wild steelhead returning as adults to Bonneville Dam; and d.) wild steelhead returning as adults to Lower Granite Dam. Sources: Tuomikoski et al. 2013 and NOAA Fisheries' Northwest Fisheries Science Center (Smith 2014).

2.2.6 Key Uncertainties

Annual estimates of direct survival rates of both juvenile and adult salmon and steelhead migrating through the mainstem Snake and Columbia Rivers are well documented (Faulkner et al 2017; McCann et al. 2016; NMFS 2014). The degree to which mortality in the estuary and ocean is caused by the prior experience of juveniles passing through the FCRPS (i.e., delayed or latent mortality) is unknown and hypotheses regarding the magnitude of this effect vary greatly (ISAB 2007; ISAB 2012). The relative magnitude of delayed or latent effects, the specific mechanisms causing these effects, and the potential for interactions with other factors (ocean conditions, toxics, etc.) remain key uncertainties. Addressing these key uncertainties would give hydrosystem managers information that could be used to improve survival (and SARs) through additional structural improvements or operational modifications at the mainstem dams (see for example Section 2.2.6.2, Proposed Spill Experiment).

2.2.6.1 Latent Mortality of In-River Migrants Due to Route of Dam Passage

As previously discussed, juvenile migrants can pass through dams via spillways (either conventional or surface oriented), screened bypass systems, or turbine units. Although estimates of direct survival through spillways and bypass systems tend to be high, there is evidence that fish bypass systems are associated with some latent mortality. The ISAB (2012) summarized the two competing hypotheses explaining this association and noted that the hypotheses have very different implications for hydrosystem operations:

> *The significant association between fish bypass and latent mortality might only reflect a non-random sampling of smolts at the bypass collectors (the selection hypothesis) rather than injury or stress caused by the bypass event (the damage hypothesis).*

Simply put, if sick, distressed, or injured fish are substantially more likely to pass a dam through the screened bypass systems (selection hypothesis), then actions to move these fish to spillway routes of passage will have little bearing on the long-term survival of these already compromised fish or their likelihood of returning as adults. However, if the fish are randomly entering the screened bypass systems and being injured or otherwise impacted by these systems, then actions to move these fish to spillway routes would be expected to increase long-term survival and likelihood of returning as adults.

Some of the fish losses included in latent mortality estimates undoubtedly include mortalities stemming from fish being injured within the bypass systems or from predation in the vicinity of the bypass system outfall. Many modifications were made during the early 2000s to improve survival rates through these systems, i.e., screens and debris management improvements, use of “full flow” systems, and outfall relocations (USACE et al. 2007, Appendix A: Overhaul of the System; BPA et al. 2013; and BPA et al. 2014). Most recently, the outfalls of several juvenile bypass systems have been relocated to areas that better protect juvenile migrants from predators (Little Goose Dam in 2010, McNary Dam in 2011, and Lower Monumental Dam in 2012). Improvements are also planned for completion at Lower Granite Dam prior to 2018 (BPA et al. 2014).

Assuming that the “damage hypothesis” is correct, these improvements should result in some reduction in rates of latent mortality for bypassed juveniles. Detections of adult fish that were both PIT tagged and bypassed as juveniles should provide evidence, over time, to support or refute this hypothesis.

The Corps of Engineers, with the assistance of NMFS and other regional parties, is designing a PIT tag detector to be installed in a spillway bay at Lower Granite Dam before 2019 (BPA et al. 2014). This system would, for the first time, allow a direct comparison of the survival rates and downstream detection probabilities of juveniles passing this dam via the spillway and bypass system. However, this tool, by itself, would not allow for a comparison of the condition and health of these fish, information that is needed to support either the “selection” or “damage” hypotheses. This would require a study that either 1) captured smolts in the forebay of a dam and then compared their condition and health to that of juveniles collected from the bypass system on the same day or 2) captured smolts passing through the spillways into the tailrace to compare with those taken from the bypass system.

2.2.6.2 Proposed Spill Experiment

Consistent with the "damage" hypothesis noted above, in recent annual reports for the Comparative Survival Study, Tuomikoski et al. (2011, 2012, 2013) hypothesized that substantially increasing spill levels (to reduce exposure of juveniles to juvenile bypass systems and turbines) would substantially increase both inriver smolt survival and SAR rates (inriver plus ocean survival). The CSS reports present prospective modeling results for four scenarios, ranging from current levels of spill at the eight mainstem dams to spill that creates total dissolved gas levels up to 125 percent of saturation in each tailrace. The CSS participants recommended that the region design and implement a large-scale operational study to evaluate this hypothesis (Haeseker 2013; CSS Oversight Committee 2017).

NMFS considered the proposed spill test in the 2014 Supplemental FCRPS Biological Opinion (NMFS 2014):

> *NOAA will continue to monitor the effects of project operations on juvenile survival and adult returns as reported by CSS and the NWFSC. We note the adult returns from the year 2011, a year that had high levels of spill and flow, has produced below average adult return rates. Results such as this reinforce our current management approach to hydrosystem operations. Substantial progress has been made toward improving survival of juvenile anadromous fish in the hydrosystem. Models of the system effects will continue to improve through 2018 as more data from current operations is added, and NOAA Fisheries will continue to consider opportunities to make further improvements to hydrosystem operations or configurations.*

NMFS also identified several technical issues and other factors to be addressed in consideration of a spill test and ultimately did not determine that such a test was necessary to avoid jeopardy within the time frame of the 2014 Supplemental Biological Opinion (i.e., through 2018). The proposed spill test was also reviewed by the Independent Scientific Advisory Board (ISAB 2014), which identified several weaknesses in the proposal and advised additional scrutiny of the available data. However, the ISAB also indicated that a spill test or experiment with appropriate controls and adequate monitoring would increase the region's base of knowledge "regarding spill, juvenile salmonid dam passage survival, impacts on adult fish passage and other species, and total dissolved gas effects."

Proposals for large, multi-year operational experiments must be based on the best available science, have a high potential to improve fish survival, and possess a sound study design. A study must also be consistent with state and federal laws, deemed operationally and economically feasible by the operating agencies and be subject to independent scientific reviews. Assuming these and other necessary conditions are met, such experiments could be used to inform future management decisions regarding configuration and operational improvements at mainstem dams.

In an Order dated March 27, 2017, Judge Michael H. Simon granted, in part, motions for injunctive relief requested by plaintiffs, directing NMFS and the Action Agencies to evaluate spill operations at the eight mainstem dams up to the State of Washington's water quality limits for total dissolved gas (120 percent in the tailrace; 115 percent in the forebay). The plaintiffs requested these spill levels as a means of increasing juvenile survival through the hydrosystem with the expectation of substantial increases in smolt-to-adult returns as hypothesized by the CSS modeling study.

As a result, NMFS, the Action Agencies, and regional stakeholders including the states and tribes have been developing spill operations for each of the eight mainstem hydroelectric projects to begin in 2018; identifying the potential for negative consequences (e.g., to adult passage), which could inform requests for spill limits; and considering what monitoring will be needed to evaluate the effects of increased spill.

NMFS expects that experimentally increasing spill levels at the eight mainstem projects will reduce the proportion of fish passing mainstem projects via the juvenile bypass systems or turbine units. The CSS hypothesis predicts increasing juvenile survival rates (direct and indirect) and substantially improved smolt-to-adult returns (including reductions in latent mortality). Results from an evaluation of increased spill starting in 2018 would provide information to support or refute elements of the CSS hypothesis and support future management decisions and could contribute somewhat (juvenile survival information is estimated annually, but adult returns would be partial and limited to the 2018 and 2019 outmigrations) to the Action Agencies' evaluation of hydrosystem alternatives in the Columbia River System Operations NEPA process, which is scheduled for completion in 2021.

2.2.6.3 Adult Survival Rates from the Estuary to Lower Granite Dam

In the Estuary and at Bonneville Dam

Numbers of California and Steller sea lions in the Columbia River below Bonneville Dam have increased dramatically in the last decade (Carretta et al. 2013, Sorel et al. 2017). Warm ocean conditions coinciding with recent El Niño years have led more pinnipeds to travel further north to find food. Counts of pinnipeds hauled out in the estuary have increased in recent years and may be correlated with relatively low adult Chinook survival below Bonneville Dam. In the most recent survival estimates available (2010-2016), adult spring Chinook salmon survival from Rkm 45 to Bonneville dam (Rkm 235) has ranged from 58 to 91 percent (average = 77 percent) (Table 4).

Table 4. Weighted mean survival estimates in the lower Columbia River for PIT-tagged adult Chinook salmon destined for tributaries above Bonneville Dam. Survival adjusted to account for potential mortality due to harvest (assumed equal to 5 percent) and due to handling (13 percent). Source: Rub 2017.

Year	# Adults	Dates	Adj Survival	95% CI
2010	172	4/14-5/11	91%	83-99
2011	381	4/1-5/16	87%	82-92
2012	372	3/23-5/31	86%	80-92
2013	73	4/19-6/14	74%	57-91
2014	297	3/20-5/13	58%	49-67
2015	205	3/19-5/8	67%	56-79

The earliest migrating spring Chinook populations are at highest risk to pinniped predation their run timing below Bonneville Dam coincides with peak sea lion abundance in the estuary. Sorel et al. (2017) estimated population specific survival rates and found consistently lower survival in the estuary for early migrants relative to the later migrating populations. Early migrating populations that show this trend in reduced survival include the Lemhi River, Marsh Creek, Upper Grande Ronde, Catherine Creek, Tucannon River, and Methow River (Figure 8).

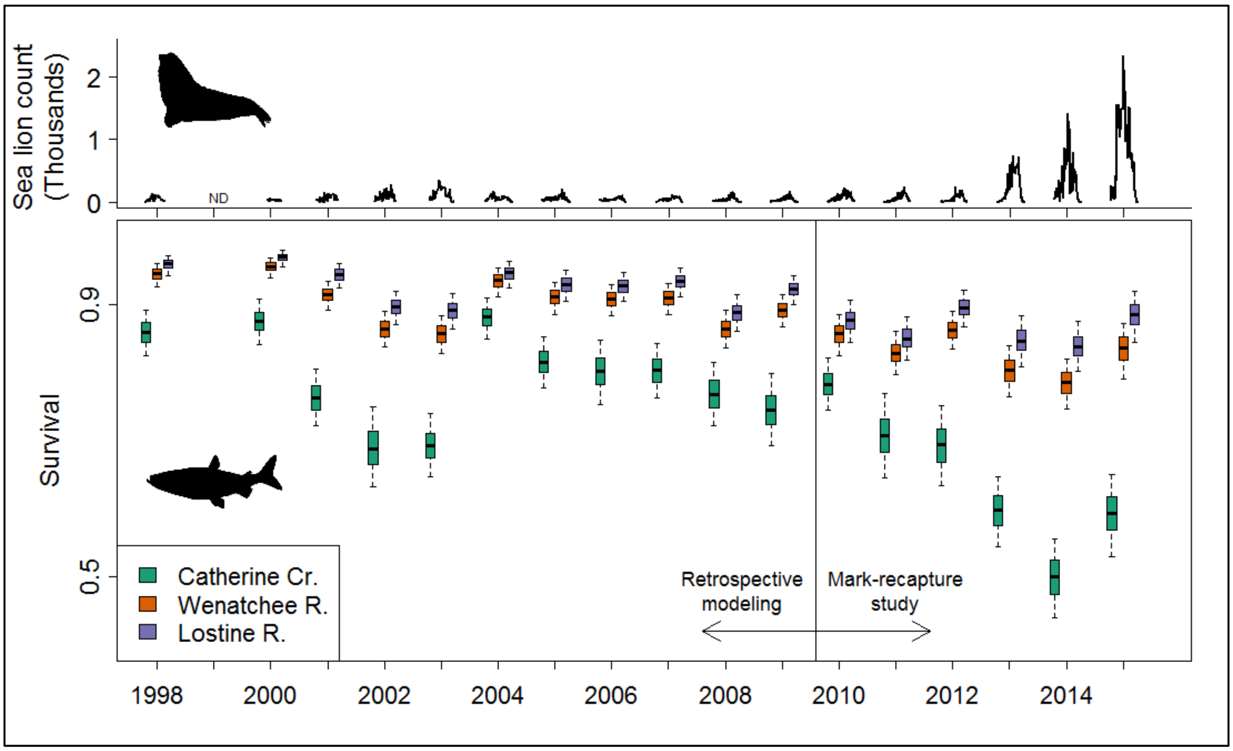


Figure 8. Top panel: daily counts of California sea lions hauled out at the East Moring Basin in Astoria, Oregon, January 1 to June 30, 1998–2015. Sea lion counts are not available for 1999. Bottom panel: modeled population- and year-specific survival rates of adult spring-summer Chinook salmon during their migration from the mouth of the Columbia River (near Astoria) to Bonneville Dam. The boxplots show the median, interquartile ranges, and 5^{th} and 95^{th} percentiles of the survival rate estimates. Source: Sorel et al. 2017.

The Corps has monitored the seasonal presence, abundance, and predation activities of pinnipeds in the tailrace and forebay of Bonneville Dam since 2002. They documented the largest number of pinnipeds and estimated the highest rate of spring Chinook salmon predation in the 14-year observation period during 2015 (9,780 fish or 3.3 percent of the spring Chinook salmon passing

Bonneville between January 1st and June 15th) (Madsen et al. 2017). The predation estimate for 2016 was the second highest, an estimated 8,709 spring Chinook salmon or 4.5 percent of the run. Pinnipeds consumed 162 winter steelhead in 2015 and 143 in 2016, 5.2 and 4.9 percent of the runs, respectively (USACE 2016b, Madsen et al. 2017). The adjusted estimate of summer steelhead consumption was 159 fish (6.3 percent of the steelhead passing from April 1 through May 31, 2016). In addition, the mean daily numbers of Steller sea lions in the Bonneville tailrace have been increasing, from 3 per day in October 2011 to 22 per day in 2015, and this species is now present for 10 months of the year (Madsen et al. 2017).[11] Beginning with the 2017 fall Chinook salmon migration, the Corps Fish Field Unit initiated an evaluation to estimate Steller Sea lion consumption of fall Chinook and summer steelhead in the tailrace of Bonneville Dam.

Active hazing from the face of the dam and by boat crews using acoustic and tactile deterrents appear to have only short-term effectiveness. Since 2008, the Oregon Department of Fish and Wildlife and the Washington Department of Fish and Wildlife (the States) have branded and removed individual California sea lions (59 in 2016) that were regularly observed eating salmon near Bonneville Dam.[12] The Corps has installed sea lion exclusion gates at the fish ladder entrances and other barriers to keep Steller sea lions from climbing into the adult fish channel at Powerhouse Two through the floating orifice gates.

Adult Salmonid Survival through the FCRPS Reach

Recent (2012-2016) average conversion rates for adult Snake River salmonids from Bonneville to Lower Granite Dam (see Section 2.2.2 and Tables 1a, b) are about 2 percent (Snake River steelhead), 4 percent (Snake River spring/summer Chinook salmon), and 31 percent lower (Snake River sockeye salmon) or in the case of Snake River fall Chinook salmon, 10 percent higher than we expected in the 2008 FCRPS Biological Opinion (see Table 3.3-1 in NMFS 2014). As described in Section 2.2.2, most of these losses appear to occur between Bonneville and McNary dams. The factors most closely associated with observed conversion rates vary by species, but include harvest rates, mainstem temperatures, and spill operations (Crozier et al. 2014, 2017).

If annual estimates of adult reach survival were extended to the Columbia River below Bonneville Dam, managers could assess whether pinniped predation, which increased in recent years, was causing adult conversion rates to the spawning areas to decline or whether any losses to pinnipeds are compensated by lower density dependent effects further upstream. NMFS is therefore exploring the feasibility of installing PIT tag detection systems below Bonneville Dam. As of 2017, PIT tag detectors are present in the fish ladders at all eight mainstem dams and have been installed in the lower reaches of many tributaries to the mainstem Snake and Columbia rivers. Recent and future improvements to the network of PIT tag detection systems, augmented by occasional adult radio-telemetry studies and efforts to evaluate the role of environmental factors and management choices affect conversions rates should substantially improve the ability of mangers to identify issues within their control and implement corrective measures, when warranted.

[11] California sea lions have occasionally been observed at Bonneville Dam in the fall, but unlike SSL their numbers have remained low, averaging less than one per day (USACE 2017).

[12] The States have not applied to the National Marine Fisheries Service for permits to remove Steller sea lions under Section 120 of the Marine Mammal Protection Act.

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