Endangered Species Act
Federal Columbia River Power System
2016 Comprehensive Evaluation: Section 2

Detailed Description of Reasonable and Prudent Alternative (RPA) Action Implementation

Under Reasonable and Prudent Alternative (RPA) Action 3, the Bonneville Power Administration (BPA), United States Army Corps of Engineers (Corps), and the Bureau of Reclamation (Reclamation), collectively referred to as the Action Agencies, submit a comprehensive RPA evaluation that reviews all implementation activities through the end of the previous calendar year and compares them to scheduled completion dates as identified in the RPA or as modified in the Implementation Plans in 2009 or 2013. Section 2 describes the implementation progress and Research, Monitoring, and Evaluation (RME) project information.

Contents

Appendix C – Impacts of Climate Change on Columbia River Salmon: A Review of the Scientific Literature Published in 2015

Tables

Figures

This page intentionally left blank

Hydropower Implementation Reports, RPA Actions 4–33

The Hydropower RPA actions are intended to be implemented over the term of the National Oceanic and Atmospheric Administration's National Marine Fisheries Service (NMFS) (*hereafter* NOAA Fisheries) 2014 Federal Columbia River Power System (FCRPS) Supplemental Biological Opinion[1] (hereafter, NOAA Fisheries 2014 FCRPS Supplemental BiOp). For hydropower system (hydro) operations, actions are reported by water year (October through September) and through calendar year 2015 because this is consistent with the actual approach for project operations. Operations for earlier years were reported in the Annual Progress Report for each year and the 2013 Comprehensive Evaluation.

Table 1. Hydropower strategy reporting.

RPA Action No.	Action	Comprehensive Evaluation Reporting
		Hydropower Strategy 1
4	Storage Project Operations	Comprehensive Evaluation Report will summarize storage project operations for the fish season. There is no other physical or biological monitoring or reporting.
5	Lower Columbia and Snake River Operations	Comprehensive Evaluation Report will summarize MOP operations at the Lower Snake River projects and John Day elevations for the fish passage season. There is no other physical or biological monitoring or reporting.
6	In-Season Water Management	Comprehensive Evaluation Report will summarize FCRPS operations for the fish passage season. There is no other physical or biological monitoring or reporting.
7	Forecasting and Climate Change/Variability	Comprehensive Evaluation Report will summarize annual forecast reviews and identify any new procedures that become available. The report will also summarize any new, pertinent climate change research and the potential impacts to listed salmon and steelhead.
8	Operational Emergencies	Comprehensive Evaluation Report will summarize any emergency situations and actions taken. There is no other physical or biological monitoring or reporting.
9	Fish Emergencies	Comprehensive Evaluation Report will summarize any emergency situations and actions taken. There is no other physical or biological monitoring or reporting.
10	Columbia River Treaty Storage	Comprehensive Evaluation Report will summarize actions taken to provide 1 Maf of storage in Treaty space. There is no other physical or biological monitoring or reporting.
11	Non-Treaty Storage (NTS)	Comprehensive Evaluation Report will summarize actions taken to refill the remaining non-Treaty storage space by June 30, 2011. There is no other physical or biological monitoring or reporting.
12	Non-Treaty Long-Term Agreement	Comprehensive Evaluation Report will summarize actions taken to refill the remaining non-Treaty storage space by June 30, 2011. There is no other physical or biological monitoring or reporting.
13	Non-Treaty Coordination with Federal Agencies, States, and Tribes	Comprehensive Evaluation Report will summarize actions to coordinate non-Treaty storage agreements. There is no other physical or biological monitoring or reporting.

[1] *The NOAA Fisheries 2014 FCRPS Supplemental BiOp incorporates, in whole, the NOAA Fisheries 2008 Biological Opinion, the 2009 FCRPS Adaptive Management Implementation Plan, and the 2010 Biological Opinion.*

RPA Action No.	Action	Comprehensive Evaluation Reporting
14	Dry Water Year Operations	Comprehensive Evaluation Report will summarize actions taken during dry water years. There is no other physical or biological monitoring or reporting.
15	Water Quality Plan for Total Dissolved Gas and Water Temperature in the Mainstem Columbia and Snake Rivers	Comprehensive Evaluation Report will summarize actions taken to implement actions for ESA commitments. There is no other physical or biological monitoring or reporting
16	Tributary Projects	No specific Comprehensive Evaluation reporting requirement.
17	Chum Spawning Flows	No specific Comprehensive Evaluation reporting requirement.
Hydropower Strategy 2		
18	Configuration and Operational Plan for Bonneville Project	Comprehensive Evaluation Report will summarize actions taken and the results of the associated RME. The Report will also include an analysis of the biological effectiveness of the actions taken to meet the dam passage survival performance standard.
19	Configuration and Operational Plan for The Dalles Project	Comprehensive Evaluation Report will summarize actions taken and the results of the associated RME. The Report will also include an analysis of the biological effectiveness of the actions taken to meet the dam passage survival performance standard.
20	Configuration and Operational Plan for John Day Project	Comprehensive Evaluation Report will summarize actions taken and the results of the associated RME. The Report will also include an analysis of the biological effectiveness of the actions taken to meet the dam passage survival performance standard.
21	Configuration and Operational Plan for McNary Project	Comprehensive Evaluation Report will summarize actions taken and the results of the associated RME. The Report will also include an analysis of the biological effectiveness of the actions taken to meet the dam passage survival performance standard.
22	Configuration and Operational Plan for Ice Harbor Project	Comprehensive Evaluation Report will summarize actions taken and the results of the associated RME. The Report will also include an analysis of the biological effectiveness of the actions taken to meet the dam passage survival performance standard.
23	Configuration and Operational Plan for Lower Monumental Project	Comprehensive Evaluation Report will summarize actions taken and the results of the associated RME. The Report will also include an analysis of the biological effectiveness of the actions taken to meet the dam passage survival performance standard.
24	Configuration and Operational Plan for Little Goose Project	Comprehensive Evaluation Report will summarize actions taken and the results of the associated RME. The Report will also include an analysis of the biological effectiveness of the actions taken to meet the dam passage survival performance standard.
25	Configuration and Operational Plan for Lower Granite Project	Comprehensive Evaluation Report will summarize actions taken and the results of the associated RME. The Report will also include an analysis of the biological effectiveness of the actions taken to meet the dam passage survival performance standard.
26	Chief Joseph Dam Flow Deflector	No specific Comprehensive Evaluation reporting requirement.
27	Turbine Unit Operations	No specific Comprehensive Evaluation reporting requirement.
28	Columbia and Snake River Project Adult Passage Improvements	Comprehensive Evaluation Report will summarize actions taken and the results of the associated RME.
Hydropower Strategy 3		
29	Spill Operations to Improve Juvenile Passage	This information is the same as will be reported for each mainstem dam in Hydro Actions 18-25.
30	Juvenile Fish Transportation in the Columbia and Snake Rivers	Please see Hydro Action 31.
31	Configuration and Operational Plan Transportation Strategy	Annual progress reports will describe the status of the construction and operational actions and associated RME to support the transportation strategy.

RPA Action No.	Action	Comprehensive Evaluation Reporting
		Hydropower Strategy 4
32	Fish Passage Plan	Not applicable.
		Hydropower Strategy 5
33	Snake River Steelhead Kelt Management Plan	Status of project implementation (including project milestones) through December of the previous year for all actions identified in implementation plans.

RPA Action 4 – Storage Project Operations

The Action Agencies will operate the FCRPS storage projects (Libby, Hungry Horse, Albeni Falls, Grand Coulee, and Dworshak projects) for flow management to aid anadromous fish. These storage project operations will be included in the Water Management Plan. These projects are operated for multiple purposes including fish and wildlife, flood control, irrigation, navigation, power, and recreation.

The Action Agencies operated the FCRPS storage projects to provide flows to improve juvenile and adult fish survival consistent with Hydropower Strategy 1 of the BiOp as described in the 2015 Water Management Plan (WMP) (BPA et al. 2014a). In accordance with the adaptive management provisions of the 2008 BiOp, the WMP was developed to meet RPA water management actions identified in the NOAA Fisheries 2008 BiOp, the NOAA Fisheries 2010 Supplemental BiOp, and the NOAA Fisheries 2014 Supplemental BiOp (collectively referred to as NOAA's 2014 Supplemental BiOp) as well as the U.S. Fish & Wildlife Service (USFWS) 2000 and 2006 BiOps. It describes the Action Agencies' annual plan for implementing specific operations. The 2015 WMP was developed in the fall of 2014 with regional coordination.

The dams in the FCRPS were authorized by Congress for multiple purposes, which are implemented in a manner that is consistent with the BiOp RPA actions. Details of how the projects were operated to improve juvenile and adult survival are described in the following sections and shown in Figures 1 through 6. This information is presented from the start of the 2015 water year, October 2014 through December 2015. Real-time operations follow RPA Action 4 specifications as adjusted in-season with recommendations from the Technical Management Team (TMT), an oversight group consisting of regional sovereign biologists and hydrologists. Further discussion of these operations is included in the minutes of the TMT "2015 Year End Review Session" (TMT 2015a; 2015b).

Figure 1 provides a high level summary of the operational constraints (fish operations, flood risk management, power operation) that have been put in place and actions that are taken during the year to provide improved conditions for fish at FCRPS storage projects. Operations for purposes such as power generation occur within the constraints established for flood risk management (FRM) and fish operations shown in this figure.

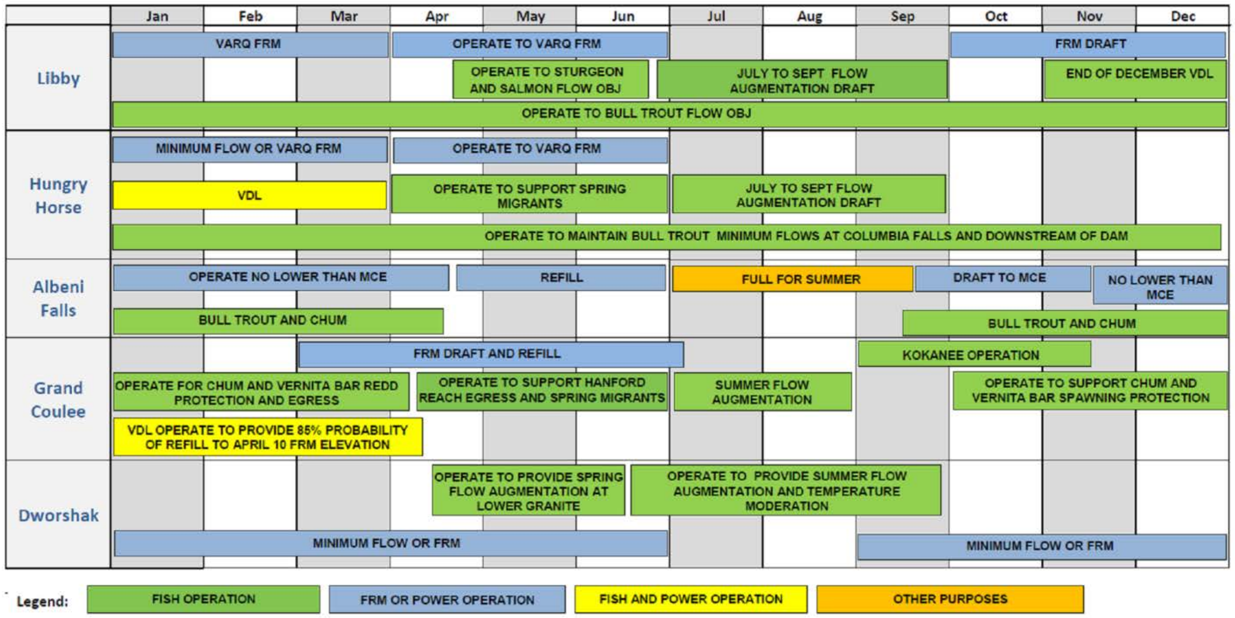


Figure 1. Storage projects operations timeline. VARQ = variable discharge. FRM = Flood Risk Management. VDL = Variable Draft Limit. MCE = Minimum Control Elevation.

Dworshak Dam

From October 2014 until February 10, 2015, the Corps operated Dworshak Dam to release near minimum flows of approximately 1.6 to 1.7 thousand cubic feet per second (kcfs). Dworshak Reservoir began January 2015 at elevation 1534.4 feet, well under the FRM elevation, due to lack of inflows typical of early winter conditions.

In early February, inflows to Dworshak spiked dramatically due to warm and rainy conditions and the project increased outflows beginning February 10. Despite the rain event, the Dworshak water supply forecast (WSF) for February was only 79 percent of average for the April–July runoff period. Lower elevation snow was depleted earlier than normal due to warm conditions. After discussions in the TMT, the Corps' Walla Walla District submitted, and Columbia Basin Water Management approved, a deviation request to allow the project to end the month of February 5.7 feet above its FRM requirement of 1560 feet. The February deviation provided additional conservation of water for potential future fish benefits. To avoid excessive spill during the month of March, the project requested and was approved to end March above its FRM requirement elevation of 1577.7 feet. The project's actual end of March elevation was 1586 feet. Dry spring conditions had set in by late March, and the April WSF was 70 percent of average.

Dworshak operated for refill in April and May and ramped up to powerhouse flows during the weeks of April 19 and May 3 to provide flow augmentation for juvenile fish migration in the lower Snake River. The project was full (1600 feet) by June 7, earlier than the norm of about July 4. The project passed inflow until June 17, after which time the Corps managed Dworshak Dam to regulate outflow temperatures and attempt to maintain water temperatures at the Lower Granite tailwater gauge at or below 68 degrees Fahrenheit. Water temperatures were modeled with CEQUAL-W2, a 2-dimensionial hydrodynamic and water quality model. Model results, weather forecasts, and input from the TMT were used to shape releases from Dworshak on a daily basis. Temperature control operations continued through August. During this time, the hourly tailwater temperature at Lower Granite Dam exceeded 68 degrees from July 6 through July 13 and again on August 12 and 13 due to a combination of high air temperatures, lack of cloud cover, low wind, and low natural streamflow. During the ten days that tailwater water temperature exceeded 68 degrees, water temperature ranged from a low of 68.1 degrees on July 6 to a high of 70.5 degrees on July 10.

During August, the project coordinated with the Nez Perce tribe in order to draft about 1.5 feet deeper than the 1535 foot end-of-August elevation called for by the BiOp. This water volume was accounted for as fulfilling a portion of the 200 thousand acre-feet (kaf) of Nez Perce water (Dworshak Board Operational Plan) for fish migration that was due to be released by September 20. The target elevation of 1520 feet for the Nez Perce operation was actually achieved on September 19. After reaching its target elevation of 1520 feet in September, the project ramped down to minimum outflows of about 1.6–1.7 kcfs and remained in that range for the remainder of 2015, with pool elevation on December 31, 2015 at 1522.7 feet, well below the FRM requirement. Figure 2 shows inflows, outflows and forebay elevations through the water year at Dworshak Dam.

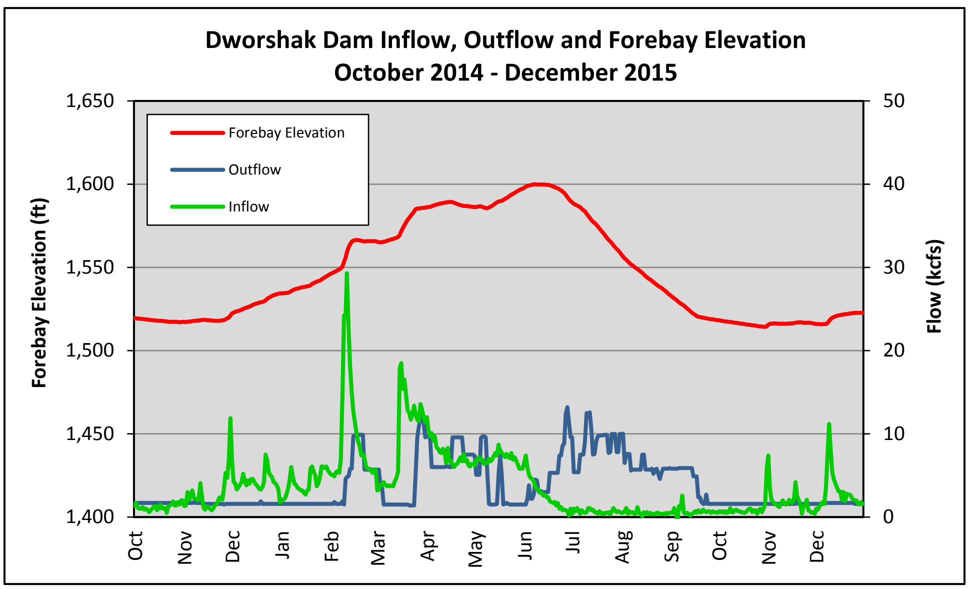


Figure 2. Dworshak Dam inflow, outflow, and forebay elevation from October 1, 2014, through December 31, 2015.

Libby Dam

Libby Dam started October 2014 at a pool elevation of 2447.45 feet. From October 04 through November 3, the Corps operated the project at its minimum release of 4 thousand cubic feet per second (4 kcfs). The project then began its fall drawdown, with variable outflow shaped by load demands. The reservoir was drafted to just above its November intermediate requirement of 2435 feet and end December slightly below its end of month FRM elevation of 2411.0 feet. Discharges from the project averaged 21.1 kcfs during the month of December.

Libby Dam operated on minimum releases of 4 kcfs during the first three months of 2015 while meeting its FRM goals. Inflows from January to March were 160 percent of average due to high precipitation and warmer than normal temperatures, allowing the project to slowly fill to 2418 feet by the end of March, well below the FRM elevation of 2433.8 feet. The 4 kcfs outflow during the months January through March were intended to try to reach the April 10 upper rule curve as called for in the NOAA BiOp. The January WSF for Libby was 6.3 million acre-feet (Maf) (107 percent of average) and in February, the WSF decreased to 5.5 Maf (94 percent of average). In March, the forecast nudged up slightly to 5.7 Maf (97 percent of average). The project increased outflows on 12 April in response to storm activity and warm temperatures. Average outflows during April were 8.5 kcfs, and the project ended the month at 2420.9 feet, 7.7 feet below the FRM elevation for April. From late April through the first three weeks of May, Libby Dam continued to fill slowly while following VARQ flows. As in other parts of the Columbia Basin, spring conditions were much drier than average.

The 2015 Kootenai River white sturgeon (sturgeon) pulse operation began on 22 May and consisted of a single pulse, applying a Tier II sturgeon volume of about 800 kaf. Following prescribed ramp rates, outflows were increased to full powerhouse flows of about 26.5 kcfs and held at that level for seven days. The sturgeon volume was exhausted on 17 June, after which time project flows were gradually ramped down until they reached near minimum bull trout flows of 7 kcfs on about August 3. Lake Kookanusa reached its maximum elevation of 2444.1 feet on July 15, which is 14.9 feet below full pool.

Pursuant to a request for assistance (low flows) with the Kootenai River Habitat Restoration Project (System Operation Request (SOR) 2015-02 from the Kootenai Tribe of Idaho), the project operated to the minimum bull trout flows of 6 kcfs for most of September and then ramped down to an outflow of 4 kcfs on October 3 and held these minimum flows through 16 November. This operation was also coordinated with members of the TMT. Libby Dam then began its fall drawdown, increasing outflows in order to reach the elevation target of about 2437 feet by the end of November.

The project continued to slowly decrease outflows through August and reached the minimum September bull trout flow of 6 kcfs on September 4. The 6 kcfs was coordinated through the TMT through the spring and summer. The 2015 September drawdown to approximately 2439 feet by the end of the month was coordinated by TMT members. The project's actual end of September elevation was slightly higher at 2440.2 feet. The elevation came in higher than 2439 feet but also had been coordinated through TMT in the summer time to not increase releases in September about 6 kcfs for the habitat work if the elevation target was going to be missed due to increased precipitation.

Based on the Libby December 2015 WSF of 5.8 Maf (98 percent of average), the project had a slightly relaxed end of December elevation target of 2415.3 feet, in accordance with VARQ FRM. The full VARQ draft target elevation for the end of December is 2411 feet. Average Libby outflow in December was 18.5 kcfs and its actual ending elevation was 2415 feet. Figure 3 shows inflows, outflows and forebay elevations through the water year at Libby Dam.

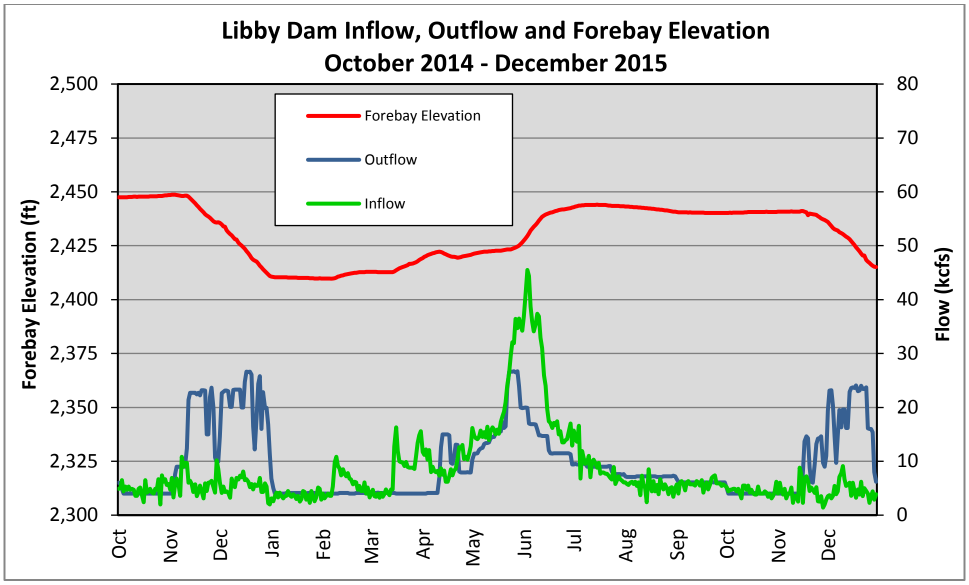


Figure 3. Libby Dam inflow, outflow, and forebay elevation from October 1, 2014, through December 31, 2015.

Grand Coulee Dam

In 2015, Reclamation operated Grand Coulee Dam consistent with the WMP and adjusted in-season to meet real-time considerations such as changing water conditions. The Project supported flows during the juvenile salmonid migration season (e.g., managing reservoir elevations and drafting Banks Lake), and helped support flows for chum salmon.

Lake Roosevelt drafted slightly in November 2014 for power due to a cold snap over the region. Tailwater elevations for chum spawning below Bonneville Dam were not adversely impacted by this draft for power. Lake Roosevelt elevations remained within the top 5 feet of the reservoir during the month of December. Precipitation and moderate temperatures in the mid- and lower Columbia Basin tributaries helped to maintain adequate tailwater elevations below Bonneville Dam.

The 2015 water year started warmer than normal with near normal precipitation from October through December 2014. As a result volume forecasts were near average on January 1. Much above average temperatures occurred in January through March while precipitation during this period measured in the normal to below normal levels. In April temperatures were near normal while precipitation remained well below normal. May precipitation rebounded in the southern basins with above normal precipitation while the northern basins remained dry. Warm and dry conditions prevailed during June.

The water supply outlook which was near average in January eroded through the spring with the below average precipitation and above average temperatures.

The National Weather Service's Northwest River Forecast Center (NWRFC) in Portland, Oregon, provided the April—August volume forecast for Grand Coulee and The Dalles. The April through August WSFs decreased through the season with a high of 100 percent of average in January to a low of 67 percent of average in July. Table 2 shows the WSFs for The Dalles and Grand Coulee Dam, and the April 30 FRM upper rule curve elevation at Grand Coulee Dam.

Table 2. The Dalles and Grand Coulee water supply forecasts and Grand Coulee April 30 flood risk management elevations.

	Jan	Feb	Mar	Apr	May	Jun	Jul
The Dalles Apr-Aug forecast (percent of average)	100	95	82	83	71	70	67
Grand Coulee Apr-Sep forecast (percent of average)	100	98	88	91	81	79	74
Grand Coulee Apr 30 FRM elevation (feet)	1243.1	1282.7	1282.9	1281.8	N/A	N/A	N/A

Late winter and spring operations during water year 2015 were impacted by drum gate maintenance at Grand Coulee Dam. Since maintenance had been deferred in the previous two years, maintenance was required in 2015. Lake Roosevelt had to be drafted to 1255 feet by March 15 and the lake remained in the 1250 to 1255 foot elevation range through May 10 for the full 8-week maintenance cycle. Since the February through April volume forecasts were below average, the FRM requirements for April 30 did not require drafting below 1255 feet. Lake Roosevelt drafted slightly below 1250 feet during May to help maintain flows in the lower river. The maximum draft was 1248.3 feet on May 23.

The April 10 elevation from the volume forecast was 1283.3 feet. Due to drum gate maintenance the actual elevation on April 10 was 1253.4 feet.

Operators began refilling Lake Roosevelt after the May 23 maximum draft with discharges ranging from 80 to 120 kcfs. Grand Coulee Dam was operated to refill Lake Roosevelt by early July to provide summer flow augmentation. Figure 4 shows inflows, outflows and reservoir operations through the water year at Grand Coulee Dam.

No spill was required at Grand Coulee Dam during the spring of the water year.

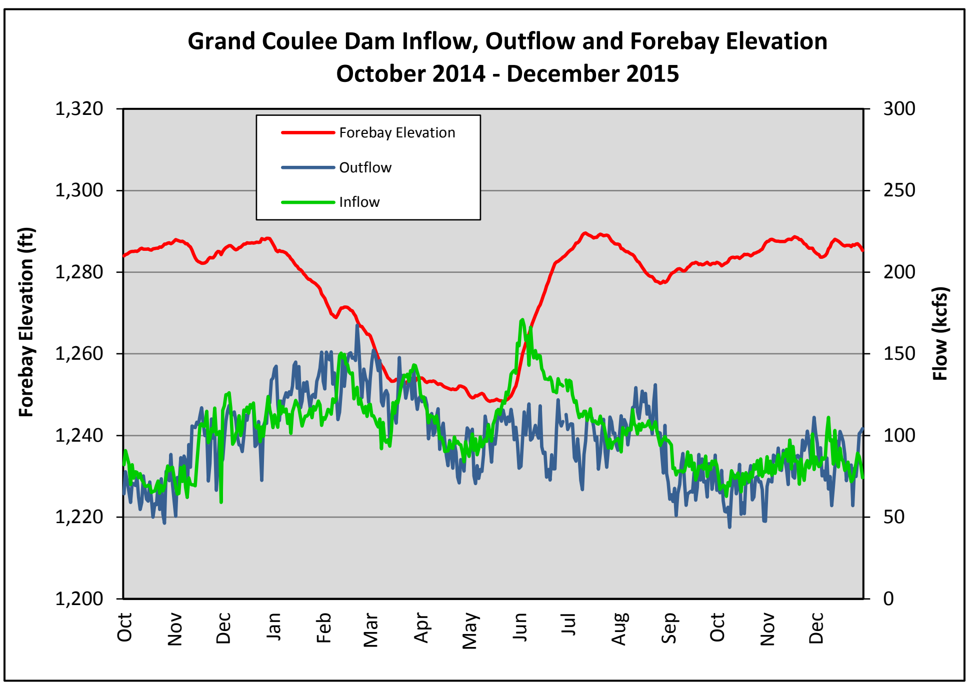


Figure 4. Grand Coulee Dam inflow, outflow, and forebay elevation from October 1, 2014, through December 31, 2015.

In order to demonstrate that water was released from Grand Coulee Dam under the Lake Roosevelt Incremental Storage Release Program (LRISRP), operations staff targeted a refill elevation and end of August draft following a recommendation from the Fish Flow Releases Advisory Group. The refill target elevation was 1289.7 feet which is 0.3 feet below the full pool elevation. Lake Roosevelt was refilled to 1289.8 feet on July 13, which was a week after July 4; the summer draft began shortly after. The summer draft for flow augmentation is set by the NWRFC's July Final April-August WSF at The Dalles Dam. The Final April-August WSF at The Dalles was 58.4 Maf, less than 92 Maf threshold, which set the draft for flow augmentation to 1278 feet. The end of August draft for the LRISRP was 0.3 feet, combining with the flow augmentation draft for an end of August target of 1277.7 feet. Lake Roosevelt was drafted to elevation 1277.5 feet on August 31.

Banks Lake is drafted to elevation 1565 feet by August 31 to provide water for summer flow augmentation. In 2015, pumping to Banks Lake was reduced and irrigation for the Columbia Basin Project was met by drafting the reservoir 5 feet from full (elevation 1565 feet) by August 31. Operators drafted Banks Lake to elevation 1564.97 feet on August 31.

Hungry Horse Dam

Reclamation operated Hungry Horse Dam during the fall of 2014 and throughout 2015 to maintain minimum flows in the Flathead River at Columbia Falls and in the South Fork Flathead River below the dam. Minimum flows are for bull trout, which are listed under the Endangered Species Act (ESA), and were calculated from a sliding scale based on the Hungry Horse Dam inflow volume forecast. The calculated minimum flows from October 2014 to December 2014 are listed in Table 3. Fall 2014 minimum flows were based on the March 2014 final WSF. Minimum flows for 2015 were based on the WSF for January through March, with the March final WSF setting the minimum flows from March to December 2015. The March 2015 final WSF for April to August was 1,916 kaf (99 percent of average) which set the minimum flow requirements on the South Fork Flathead River below Hungry Horse and on the mainstem Flathead River at Columbia Falls at 900 cfs and 3,500 cfs, respectively.

Table 3. Minimum flow requirements from October 2014 to December 2015.

Period	Hungry Horse Minimum Flow (cfs)	Columbia Falls Minimum Flow (cfs)
October-December 2014	900	3,500
January 2015	900	3,500
February 2015	900	3,500
March-December 2015	900	3,500

Operators followed VARQ FRM procedures in 2015. In January, the May-to-September WSF for Hungry Horse Dam was at 117 percent of average and decreased to 99 percent of average by the March forecast. The target April 10 elevation based on the March final forecast was 3539.5 feet and the April 30 FRM elevation based on the April final forecast was 3548.4 feet. Hungry Horse was drafted to 3540 on April 10 and 3538.5 feet by April 30. Because of the dry conditions Hungry Horse did not need to spill during the spring of 2015.

The end of September draft at Hungry Horse is based on the May final WSF at The Dalles. The May final WSF at The Dalles for 2015 was in the lowest 20 percentile, causing the end of September draft for flow augmentation to be 20 feet. Hungry Horse Dam operators targeted a September 30 elevation of 3540 feet but actual operations required discharges to maintain instream flow requirements at Columbia Falls on the main Flathead River. Due to low flows in the mainstem Flathead River at Columbia Falls Hungry Horse had to draft deeper than 3540 feet and was at 3536 feet on September 30. Figure 5 shows inflows, outflows and forebay elevations through the water year at Hungry Horse Dam.

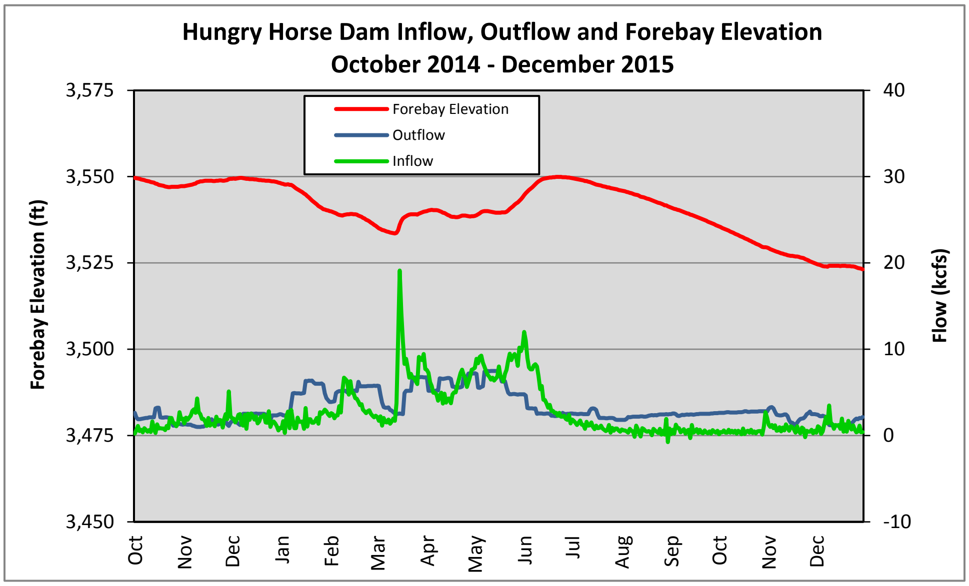


Figure 5. Hungry Horse Dam inflow, outflow, and forebay elevation from October 1, 2014, through December 31, 2015.

Albeni Falls Dam

During October 2014, the Albeni Falls project continued its fall draft to the year's minimum control elevation (MCE) for kokanee spawning of 2051.0 feet as measured at the Hope gauge. The project ended the month at 2051.8 feet, well below the FRM elevation of 2056 feet. Average outflow from the project during October was about 26.2 kcfs. The project spilled from October 1 through October 24 in order to maintain progress towards the MCE target.

After reaching its MCE on November 5, Albeni Falls was operated to control the elevation at Lake Pend Oreille to within a half-foot band between 2051.0 and 2051.5 feet to support spawning activity. Although the half-foot band is normally expanded to one foot when kokanee spawning is declared over in late December, environmental restoration work being conducted on a portion of the upstream delta limited lake operation to the half-foot band through early March 2015.

The project was able to operate within the half-foot elevation band during December and January. In February and March, however, two rain and snow melt events occurred which temporarily induced project storage due to limited channel capacity. Albeni Falls generated at full powerhouse capacity and spilled for the majority of this period. The project was not able to accommodate the restricted operating band for the restoration work for most of the construction window. Ending elevations at Hope gauge for February and March were 2052.3 feet and 2053.7 feet, respectively.

Refill of the Albeni Falls project began on April 13, 2015. Objectives for the operation were to fill the project to 2060 feet or slightly higher by the end of May and to achieve the summer operating range of 2062.0 to 2062.5 feet by mid-June. Both objectives were reached successfully; the May ending elevation was 2060.9 feet, and the summer operating range was attained on June 11. Lake Pend Oreille filled earlier than normal due to extremely dry precipitation in May and June and no significant forecasted precipitation through the rest of the month of June. After filling to summer level, the project continued to operate in the summer range of 2062.0 to 2062.5 feet, as measured at the Hope gauge, until the third week of September.

During the third week of September, the project began its fall draft to the MCE of 2051.0 feet for kokanee spawning. The project reached MCE on November 11 and operated within the 2051.0-2051.5 feet range, with one exception, for the remainder of 2015. Due to high inflows about December 10, the project was forced to operate slightly outside of the aforementioned range. Kokanee spawning was deemed over shortly before Christmas, after which time the lake could be operated between elevations 2051.0-2056.0 feet (flexible winter power operations). December's ending elevation as measured at the Hope gauge was 2051.6 feet. Figure 6 shows inflows, outflows and forebay elevations through the water year at Albeni Falls Dam.

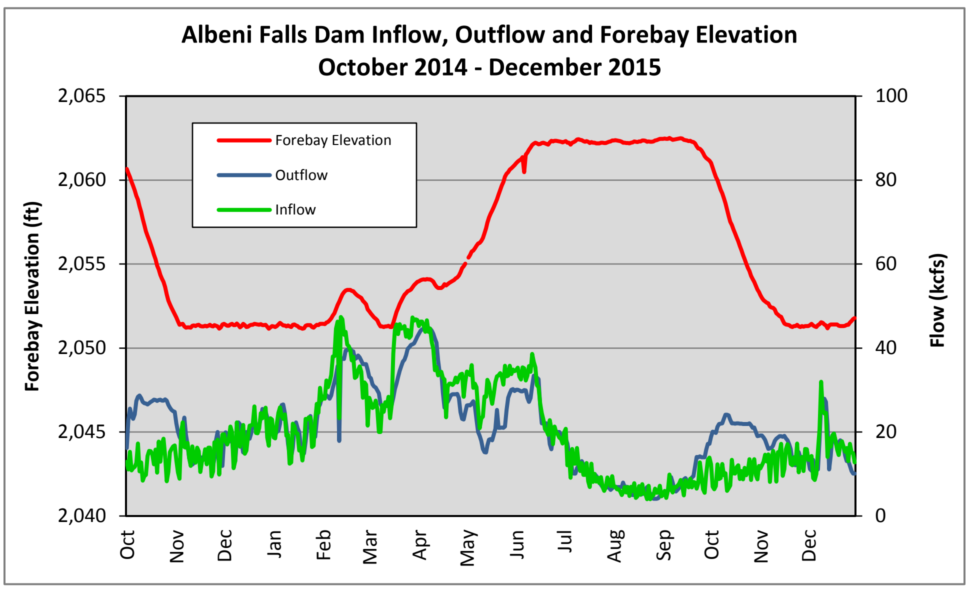


Figure 6. Albeni Falls Dam inflow, outflow, and forebay elevation from October 1, 2014 through December 31, 2015.

RPA Action 5 – Lower Columbia and Snake River Operations

The Action Agencies will operate the FCRPS run-of-river mainstem lower Columbia River and Snake River projects (Bonneville, The Dalles, John Day, McNary, Ice Harbor, Lower Monumental, Little Goose and Lower Granite projects) to minimize water travel time through the lower Columbia and Snake rivers to aid in juvenile fish passage. These run-of-river operations will be included in the annual WMP (see RPA Action 6).

The 2015 WMP included operations for these run-of-river projects. The projects were operated consistent with the WMP and the 2015 Fish Operations Plan (FOP) which were consistent with the NOAA Fisheries and USFWS Biological Opinions to guide spill operations for juvenile fish passage and to also minimize water travel time through the Lower Columbia and Snake rivers to aid in juvenile fish passage and water temperature management. Specific operating rules are used at individual reservoirs to provide salmon flows, protect resident fish, control floods, and operate for navigation and other authorized purposes. These operations are discussed further in the minutes of the TMT "2015 Year End Review Session" (TMT 2015a; 2015b). At Lower Monumental, Ice Harbor, Little Goose, and Lower Granite Projects, the plan was to operate at MOP from April 3 through August 31.

The storage projects in the Columbia and Snake River systems, which are described under RPA Action 4 above, have limited ability to shape natural runoff. This limited storage capability can be managed to make modest adjustments in river flows for fish but cannot improve a low-water year or store water from an above-average water year for use in future below-average water years. As a result, flow objectives for juvenile fish are goals that cannot be physically achieved under some conditions. The flow objectives were used for pre-season planning and in-season water management to guide decision making. Figures 7, 8, and 9 show the observed outflow at McNary, Lower Granite, and Priest Rapids dams relative to the flow objectives.

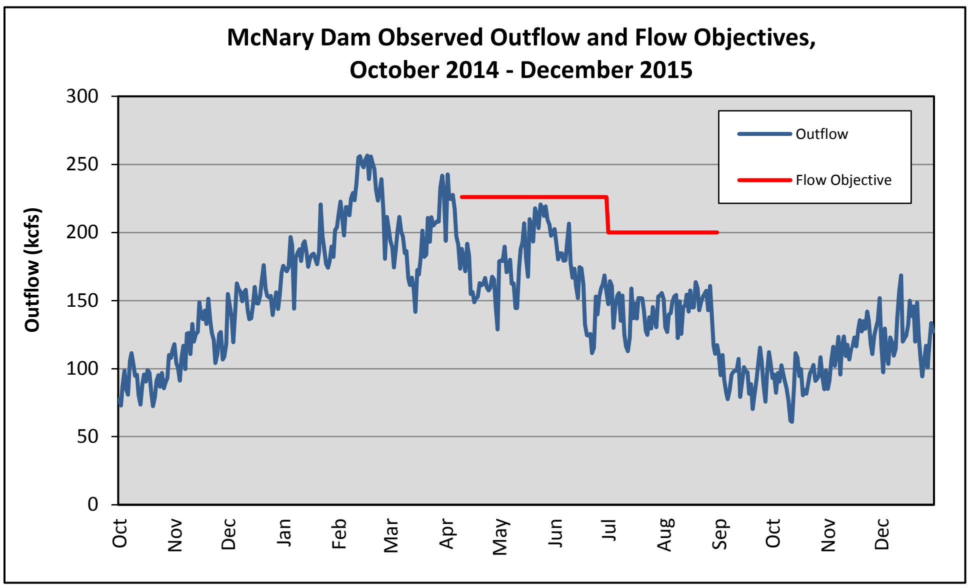


Figure 7. McNary Dam, observed outflow and flow objectives, October 1, 2014, through December 31, 2015. April 10, 2015, to June 30, 2015, actual mean flow 172.9 kcfs, flow objective 220 kcfs. July 01, 2015, to August 31, 2015 actual mean flow 142.6 kcfs, flow objective 200 kcfs. The flow objectives are not achievable in all water conditions; rather they are used for pre-season planning and in-season water management to guide decision making.

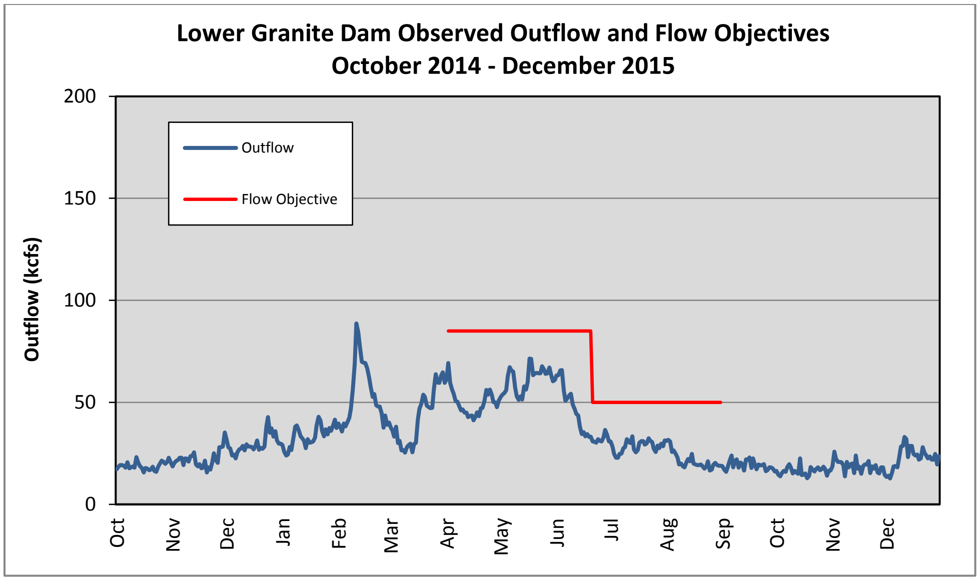


Figure 8. Lower Granite Dam, observed outflow and flow objectives, October 1, 2014, through December 31, 2015. April 3, 2015, to June 20, 2015, actual mean flow 53.3 kcfs, flow objective 85 kcfs. June 21, 2015, to August 31, 2015, actual mean flow 25.9 kcfs, flow objective 50 kcfs. The flow objectives are not achievable in all water conditions; rather, they are used for pre-season planning and in-season water management to guide decision making.

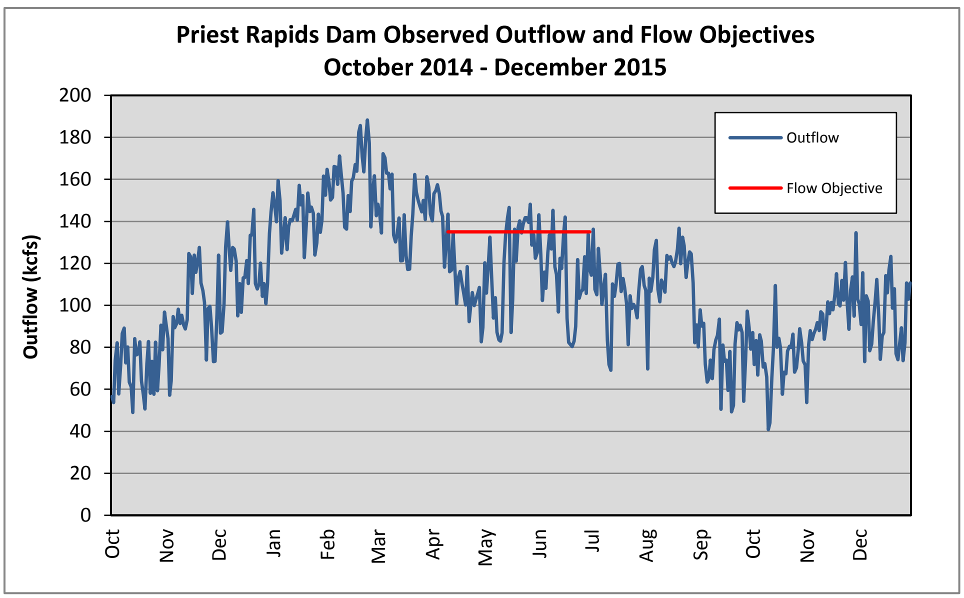


Figure 9. Priest Rapids Dam, observed outflow and flow objectives, October 1, 2014 through December 31, 2015. April 10, 2015, to June 30, 2016 actual mean flow 114.9 kcfs, flow objective 135 kcfs. The flow objectives are not achievable in all water conditions; rather, they are used for pre-season planning and in-season water management to guide decision making.

In 2015, the Columbia River had a below average water year according to NWRFC. The January to July volume as measured at The Dalles Dam (83.7 Maf) was 83 percent of normal (101.3 Maf for period rankings 1981–2010). The Snake River volume from April to July, as measured at Lower Granite (10.6 Maf), was 54 percent of normal (19.8 Maf for period rankings 1981–2010).

RPA Action 6 – In Season Water Management

Prioritization of the use of flow augmentation water is done through in-season management by the Regional Forum. Each fall, the Action Agencies will prepare an annual Water Management Plan (WMP) and seasonal updates that describe planned hydrosystem fish operations for the upcoming fall and winter, and for the spring, and summer passage seasons. The annual WMP strives to achieve the best possible mainstem passage conditions, recognizing the priorities established in the FCRPS BA and the need to balance the limited water and storage resources available in the region. Fall/winter and spring/summer updates are prepared as more data is available on the water conditions for that year. A draft update of the WMP will be prepared by October 1 each year, with a final plan completed by January 1. The fall/winter update to the WMP will be drafted by November 1 and finalized by January 1. A draft of the spring/summer update to the WMP will be prepared by March 1 and finalized by May 15.

The annual WMP for the 2015 operating season (October 1, 2014, through September 30, 2015) was developed collaboratively with the region in accordance with the NOAA Fisheries' 2008 Biological Opinion and their 2010 and 2014 Supplemental Biological Opinions. A draft of the WMP for the 2015 operating season was released on October 2, 2014. The final WMP was released on December 31, 2014.

Prior to 2011, the Action Agencies provided a fall/winter and spring/summer update to the WMP. The TMT indicated that these bi-annual updates were not providing updated information frequently enough to assist in making informed recommendations to the Action Agencies. In an effort to increase the frequency of updates to the WMP, the TMT recommended discontinuing the semi-annual WMP updates and changing to a “seasonal update” format. At minimum, the seasonal update would be posted two times per year with a goal of posting at a greater frequency. During the 2015 operating season the Action Agencies posted four seasonal updates. Changes to the updating mechanism to the WMP were coordinated with the TMT.

RPA Action 7 – Forecasting and Climate Change/Variability

The Action Agencies will hold annual forecast performance reviews looking at in-place tools for seasonal volume forecasts and to report on the effectiveness of experimental or developing/emerging technologies and procedures. As new procedures and techniques become available and are identified to have significant potential to reduce forecast error and improve the reliability of a forecast, the Action Agencies will discuss the implementation possibilities with regional interests. The purpose is to improve upon achieving upper rule curve elevations by reducing forecasts errors and thereby providing for improved spring flows. The Action Agencies will work collaboratively with other agencies and research institutions to investigate the impacts of possible climate change scenarios to the Pacific Northwest and listed salmon and steelhead. Focus areas will cover (1) modeling the hydrology and operations of the Columbia River system using possible future climate change scenarios, (2) investigating possible adaptation strategies for the system, (3) monitoring the hydrologic system for trends, cycles, and changes, and (4) staying abreast of research and studies that address climate cycles, trends, and modeling.

Columbia River Forecast Group

The Columbia River Forecast Group (CRFG) continues to work collaboratively to assist the Action Agencies in implementing this RPA action. The CRFG annual reports are available at http://www.salmonrecovery.gov/Hydro/Operations.aspx.

In 2015, CRFG examined ongoing and experimental forecasting techniques. Water year 2015 posed a challenge to most forecasters as near-normal winter precipitation was offset by near-record warmth, followed by a warm and dry spring. Thus, while winter precipitation was near normal, early spring snowpack conditions were near historic lows across the majority of the basin, and the snowpack ran off much earlier than usual.

Traditional statistical forecasts started near normal, but these forecasts did not respond as quickly as the Ensemble streamflow prediction (ESP) approaches to the warm condition in late winter and spring. ESP forecasts also started near normal, but then diminished rapidly as the winter progressed in response to the lagging snowpack, early runoff, and dry spring. These forecasts capture the decreasing water supply trend and accounted for some of the early runoff. Because ESPs can be prepared and issued much more frequently than statistical forecasts, decision makers have gained considerable advance notice when conditions are changing rapidly in the basin – either wetter or drier. The CRFG is still learning how to use these forecasts, though, since they have their own shortcomings (i.e. under-dispersion of potential range of outcomes, longer range/lower skill precipitation forecasts occasionally cause sharp swings in forecasts).

Several experimental forecast improvements were presented to CRFG in 2015. These techniques included a partnership between Reclamation and U.S. Department of Agriculture (USDA) Agricultural Research Service that tested the use of a spatially-distributed, physically-based snowmelt model to provide more accurate water supply and runoff conditions. These techniques show promise to be resilient to non-normal years but may be impractical for large basins. Another technique presented by the NWRFC was the Hydrologic Ensemble Forecast Service, an ensemble forecast procedure that has the potential to improve forecasts by accounting for uncertainty and removing bias while presenting probabilistic future flows and volumes. Finally, BPA has begun to experiment with reweighting ESPs based on climate indices which demonstrate some skill in long-range Columbia Basin weather prediction (i.e. El Nino-Southern Oscillation, Quasi-Biennial Oscillation, and Pacific Decadal Oscillation).

In addition to examining forecasting techniques some agencies improved accessibility and utility of current information. For example the NRCS launched an updated webpage that allows station queries and comparisons of current snowpack conditions to the historic record. Both the NWRFC and BPA updated temperature and precipitation time series records for the Columbia through 2015 for its runoff and seasonal WSFs. This update increased the number of ESP traces in use from 54 to 66. In addition, this record extension method jointly developed by NWRFC and BPA will allow the agencies to update their ESPs annually and include the most recent information.

In review the group found that statistical WSFs remain powerful tools to guide decision-making at headwater projects, especially when statistical variables used in the equations have solid reasoning and meteorological backing. However, statistical forecasts are susceptible to conditions well outside of the historical norm. ESP forecasts showed promise by identifying changing trends in the forecasts. The experimental methods presented, especially the Hydrologic Ensemble Forecast Service, may provide similar benefits as current ESPs but with the added benefit of accounting for uncertainty and bias. Both the statistical and ESP approaches continue to be challenged by mid- to long-term weather forecast uncertainty. With a changing climate it is anticipated that there will be more variability in weather and less reliable snowpack development for many basins, which could add uncertainty to water supply and runoff forecasting.

Climate Change Studies

The River Management Joint Operating Committee (RMJOC) and its research partners at the University of Washington and Oregon State University continued the RMJOC-II Climate Change Study Project and related research. The CRFG continues to function as the main technical body to review project progress, and sponsored regional workshops in February and October 2015 to discuss progress and recommend research improvements. The unregulated streamflow portion of the project is on track to allow hydroregulation studies likely in 2017.

The overall objective is to use the latest data from the Global Climate Models, published as part of the Coupled Model Intercomparison Project Phase 5 (CMIP-5) and generate a new temperature, precipitation and streamflow dataset for use in future planning studies. Initial evaluations of the new climate modes indicate a warmer and slightly wetter trend for the Pacific Northwest through the 2040s compared to the CMIP-3 dataset. However, the new global climate models show a slightly larger range in possible future temperatures in the Pacific Northwest, and a continued large spread in future basin precipitation.

Future flows at over 300 locations Columbia River basin-wide will be generated for use in the Action Agencies water resource models to evaluate the impact of future climate change on reservoir operations, power, and flooding.

RPA Action 8 – Operational Emergencies

The Action Agencies will manage interruptions or adjustments in water management actions, which may occur due to unforeseen power system, flood control, navigation, dam safety, or other emergencies. Such emergency actions will be viewed by the Action Agencies as a last resort and will not be used in place of operations outlined in the annual WMP. Emergency operations will be managed in accordance with TMT Emergency Protocols, the Fish Passage Plan (FPP) and other appropriate Action Agencies emergency procedures. The Action Agencies will take all reasonable steps to limit the duration of any emergency impacting fish.

There were no operational emergencies in 2015.

RPA Action 9 – Fish Emergencies

The Action Agencies will manage operations for fish passage and protection at FCRPS facilities. They may be modified for brief periods of time due to unexpected equipment failures or other conditions. These events can result in short periods when projects are operating outside normal specifications due to unexpected or emergency events. Where there are significant biological effects of more than short duration resulting from emergencies impacting fish, the Action Agencies will develop (in coordination with the in-season management Regional Forum) and implement appropriate adaptive management actions to address the situation. The Action Agencies will take all reasonable steps to limit the duration of any fish emergency.

Lower Granite Dam: Beginning at 1210 hours on July 8, the Corps implemented the operation recommended by the Fish Passage Operation and Maintenance (FPOM) workgroup, intended to improve tailrace hydraulics and temperature conditions for the benefit of adult sockeye passage. The spillway weir was closed and spill was distributed uniformly across the spillway as described in the 2015 Fish Passage Plan (FPP), Table LWG-9. This operation did not alter FOP spill levels. The operation was coordinated to continue through 2400 hours on August 31.

Additionally, from 1500 hours on July 13 through 0500 hours on August 3, the Corps implemented the FPOM recommendation to change from operating Unit 2 to operating Unit 1 as the priority turbine unit to improve passage conditions for adult sockeye during emergency trap and haul operations implemented by the Idaho Department of Fish and Game. The operation of Unit 1 provides optimum attraction flow near the adult fish ladder, improves tailrace hydraulics near the ladder entrance by minimizing the eddy created by spill, and improves downstream temperature conditions by passing more cool water from deeper in the forebay to the tailrace. However, Unit 1 has fixed blades (non-adjustable) and operates at approximately 18.4 kcfs, compared to Unit 2 which can be adjusted as flow decreases down to minimum generation of approximately 12.4 kcfs. Consequently, during minimum generation operations, Unit 1 results in less spill (approximately 6 kcfs) than Unit 2.

The operations to improve Snake River sockeye passage conditions were discussed and coordinated with FPOM on several conference calls on July 6, 8, 9, 10, 13, 17, 20, 24, and 27; and coordinated with TMT at meetings on July 8, 15, 22, 27, 29, and 30. FPOM and TMT members either supported or did not object to the implementation of these operations.

Little Goose Dam: From 0400 hours on July 23 through 0400 hours on July 25, and again at 0400 hours on July 28 through 0400 hours on July 30, the Corps implemented experimental emergency operations at Little Goose Dam as recommended by NOAA Fisheries and other regional sovereigns to improve passage conditions for adult sockeye. In conjunction with the Lower Granite operations described above, the goal was to assess whether these actions could improve temperature and hydraulic conditions at the two projects as a means of facilitating adult sockeye passage at both dams during the Idaho Department of Fish and Game’s emergency trap and haul operations.

The two 2-day experimental emergency operations at Little Goose consisted of a period of no spill during daytime hours (0400-2000) and the operation of one unit at minimum generation and spilling the remainder of project outflow during nighttime hours (2000-0400). As a result, hourly average spill during these operations ranged from 0–16.9 kcfs, as compared to the 2015 FOP low flow spill operation that would have resulted in fixed spill of 9 or 11 kcfs as determined by the previous day’s average outflow.

These operations were coordinated with FPOM during conference calls on July 21, 24, and 27, and with TMT at meetings on July 22, 27, 29, and 30. Consensus at TMT on the 2-day experimental operation was not reached. After conferring with NOAA Fisheries and reviewing their recommendation and supporting documents, the Corps proceeded with implementation of the 2-day experimental operation. Oregon’s representative for the Regional Implementation Oversight Group (RIOG) requested a meeting to further discuss the operation. The RIOG was convened on July 28, and after discussing these experimental emergency operations, no further objections were raised by sovereign representatives.

RPA Action 10 – Describe Actions Taken to Provide 1 Maf of Treaty Storage

BPA and the Corps will pursue negotiations with Canada of annual agreements to provide 1 Maf of storage in Treaty space by April 15 consistent with:

1. *Providing the greatest flexibility possible for releasing water to benefit U.S. fisheries May through July.*

2. *Giving preference to meeting April 10 upper rule curve elevation or achieving refill at Grand Coulee Dam over flow augmentation storage in Canada in lower water supply conditions.*

3. *Releasing flow augmentation storage to avoid causing damaging flow or excessive TDG in the United States or Canada.*

BPA and the Corps will coordinate with Federal agencies, States and Tribes on Treaty operating plans.

Under authority detailed in the 2014-2015 Detailed Operating Plan, the Columbia River Treaty Operating Committee signed and executed a Non-power Uses agreement to provide mutual advantageous non-power benefits for both Entities. This *Agreement on Operation of Canadian Storage for Non-power Uses for December 1, 2014, through July 31, 2015*, was signed on November 6, 2014. Under terms of this agreement, 1 Maf of flow augmentation water was stored in Canadian reservoirs in January 2015 and fully released by July 31, 2015, for U.S. fisheries benefits.

A new Non-power Uses agreement for 2016 was signed on November 13, 2015, which provided for 1 Maf of flow augmentation water storage and release under the same terms as the prior agreement. Under the 2016 agreement, 1 Maf of water had been stored in Treaty space in Canada by the end of January 2016.

BPA and the Corps held meetings with federal agencies, states and tribes in spring 2015, fall of 2015 and spring of 2016 to discuss the Treaty and non-Treaty storage operations and Treaty operating plans.

RPA Action 11 – Non-Treaty Storage

BPA, in concert with BC Hydro, will refill the remaining non-Treaty storage space by June 30, 2011, as required under the 1990 non-Treaty storage agreement. Refill will be accomplished with minimal adverse impact to fisheries operations.

In January 2011, BPA and the Corps completed the return of non-Treaty storage water called for under the 1990 Non-Treaty Storage Agreement (NTSA). Refill was accomplished outside of fish passage season to minimize adverse impact to fisheries.

RPA Action 12 – Non-Treaty Long-Term Agreement

BPA will seek to negotiate a new long-term agreement on use of non-Treaty space in Canada so long as such an agreement provides both power and non-power benefits for BC Hydro, BPA, and Canadian and U.S. interests. As part of these negotiations, BPA will seek opportunities to provide benefits to ESA-listed fish, consistent with the Treaty. If a new long-term, non-Treaty agreement is not in place, or does not address flows for fisheries purposes, BPA will approach BC Hydro about possibly negotiating an annual/seasonal agreement to provide U.S. fisheries benefits, consistent with the Treaty.

BPA entered into a new long-term Columbia River NTSA with BC Hydro on April 10, 2012, (2012 NTSA) which expires in 2024. The 2012 NTSA allows for coordinated use of non-Treaty storage in Canada to shape flows within the year for benefits, and provides up to an additional 0.5 Maf of water to benefit fish in dry period water conditions, if not requested in the previous year. 0.5 Maf was released flat over May and June of 2015 under the BPA dry-year provisions of the 2012 NTSA.

BPA coordinated with federal agencies, states and tribes throughout the spring and summer of 2015 on Canadian project operations, including Non-Treaty storage operations in addition to the regular twice-yearly meetings (spring and fall) described above. Coordination on NTS operations in 2016 began in May 2016.

RPA Action 13 – Non-Treaty Coordination with Federal Agencies, States, and Tribes

Prior to negotiations of new long-term or annual non-Treaty storage agreements, BPA will coordinate with Federal agencies, States, and Tribes to obtain ideas and information on possible points of negotiation, and will report on major developments during negotiations.

As explained in RPA Action 12, BPA entered into the new 2012 NTSA with BC Hydro. The 2012 NTSA allows for coordinated use of non-Treaty storage in Canada to shape flows within the year for fisheries benefits, and provides up to an additional 0.5 Maf of water to benefit fish in the lowest water conditions. This action continued to be implemented in 2015.

RPA Action 14 – Dry Water Year Operations

Flow management during dry years is often critical to maintaining and improving habitat conditions for ESA-listed species. A dry water year is defined as the lowest 20th percentile years based on the NWRFC averages for their statistical period of record (currently 1971 to 2000) using the May final water supply forecast for the April to August period as measured at The Dalles. The Action Agencies will complete the following activities to further the continuing efforts to address the dry flow years:

1. *Within the defined "buckets" of available water (reservoir draft limits identified in RPA Action 4), flexibility will be exercised in a dry water year to distribute available water across the expected migration season to optimize biological benefits and anadromous fish survival. The Action Agencies will coordinate use of this flexibility in the Regional Forum TMT.*

2. *In dry water years, operating plans developed under the Treaty may result in Treaty reservoirs being operated below their normal refill levels in the late spring and summer, therefore, increasing flows during that period relative to a standard refill operation.*

3. *Annual agreements between the U.S. and Canadian entities to provide flow augmentation storage in Canada for U.S. fisheries needs will include provisions that allow flexibility for the release of any stored water to provide U.S. fisheries benefits in dry water years, to the extent possible.*

4. *BPA will explore opportunities in future long-term NTS storage agreements to develop mutually beneficial in-season agreements with BC Hydro to shape water releases using NTS space within the year and between years to improve flows in the lowest 20th percentile water years to the benefit of ESA-listed ESUs, considering their status.*

5. *Upon issuance of the FCRPS Biological Opinion, the Action Agencies will convene a technical workgroup to scope and initiate investigations of alternative dry water year flow strategies to enhance flows in dry years for the benefit of ESA–listed ESUs.*

6. *In very dry years, the Action Agencies will maximize transport for Snake River migrants in early spring, and will continue transport through May 31.*

7. *BPA will implement, as appropriate, its Guide to Tools and Principles for a Dry Year Strategy to reduce the effect energy requirements may pose to fish.*

The BiOp defines a dry year as a year when the NWRFC May final forecast for April-to-August runoff at The Dalles Dam is below the 20th percentile for the NWRFC statistical period of record. The statistical period of record is now 1981 to 2010, for which the 20th percentile value is 72.5 Maf. The 2015 water year was a dry year, with the May forecast coming in at 62.1 Maf or 71 percent of average for the April–August period. The actual runoff volume was 58.4 Maf, or 67 percent of average.

The dry year actions as outlined in RPA Action 14 were implemented in water year 2015 as follows:

1. *RPA Action 4 Reservoir Draft Limits.* The Action Agencies, in consultation with the TMT, operated in accordance with the reservoir draft limits identified in RPA Action 4.

   A. *Dworshak Dam.* Due to dry conditions FRM space was shifted from Dworshak Dam to Grand Coulee Dam allowing Dworshak to be 9 feet above its March 31 Upper Rule Curve. As a result of this action and additional coordinated operational changes Dworshak Dam was filled nearly 1 month early. This action improved the effectiveness of the flow augmentation delivery and the timing of temperature augmentation.

   B. *Libby Dam.* In accordance with the RPA Action 4 Libby Dam was drafted to 20 feet from full by September 30.

   C. *Grand Coulee Dam.* In accordance with the RPA Action 4 provision regarding the variable draft limit based on the WSF, the August 31 forebay elevation was 1277.5 feet.

   Pumping was reduced into Banks Lake allowing Banks Lake draft to 5 feet from full pool by August 31st to help meet salmon flow objectives when needed.

   D. *Hungry Horse.* In accordance with RPA Action 4, Hungry Horse Dam was drafted to 20 feet from full by September 30. Due to low flows, additional augmentation was provided from storage at Hungry Horse Dam to meet the minimum flow at Columbia Falls. The elevation of the reservoir on September 30 was 24 feet from full.

2. *Treaty Operations.* During May through September treaty operations drafted Canadian reservoirs 5.8 Maf below their normal refill levels.

3. *Annual Agreements Between U.S. and Canadian Entities to Provide Flow Augmentation.* The annual Non-Power Uses agreement to store 1 Maf of flow augmentation in Treaty storage was signed in December of 2014. This volume was stored in treaty storage during the month of January and released May – August in coordination with regional Salmon Managers.

4. *Non-Treaty Storage.* In accordance with the 2012 NTSA, 0.5 Maf of non-Treaty storage was released during the salmon migration season as coordinated with Regional Salmon Managers.

5. *Technical Work Group to Investigate Alternative Dry Water Year Flow Strategies.* The Action Agencies convened a technical workgroup, which scoped and initiated investigations of alternative dry water year flow strategies to enhance flows in dry years for the benefit of ESA-listed fish. The group's analysis contributed to the development of a dry water year's provision of the 2012 NTSA (see RPA Action 12).

6. *Maximize Transport for Snake River Migrants in Early Spring.* Based on Regional Salmon Managers annual recommendation, this operation has not been implemented since the issuance of this BiOp.

7. *BPA Will Implement its Guide to Tools and Principles for a Dry Year Strategy.* These tools were designed to meet regional power load while minimizing the impact to fish protection measures during dry years. In 2015, these tools were not needed as BPA was able to meet regional power demand without impact to fish protection measures.

RPA Action 15 – Water Quality Plan for Total Dissolved Gas and Water Temperature in the Mainstem Columbia and Snake Rivers

The Action Agencies will continue to update the Water Quality Plan for Total Dissolved Gas and Water Temperature in the Mainstem Columbia and Snake Rivers (WQP) and implement water quality measures to enhance ESA-listed juvenile and adult fish survival and mainstem spawning and rearing habitat. The WQP is a comprehensive document which contains water quality measures needed to meet both ESA and Clean Water Act responsibilities. For purposes of this RPA, the WQP will include the following measures to address TDG and water temperature to meet ESA responsibilities:

1. *Real-time monitoring and reporting of TDG and temperatures measured at fixed monitoring sites,*

2. *Continued development of fish passage strategies with less production of TDG, and*

3. *Update the SYSTDG model to reflect modifications to spillways or spill operations,*

4. *Continued development and use of SYSTDG model for estimating TDG production to assist in real-time decision making, including improved wind forecasting capabilities as appropriate,*

5. *Continued development of the CEQUAL-W2 model for estimating river temperatures from Dworshak Dam on the Clearwater and Upper Snake River near the confluence with the Grand Ronde River (USGS Anatone gauge) through the lower Snake River (all four Corps lower Snake River projects) to assist in real-time decision making for Dworshak Dam operations, and*

6. *Expand water temperature modeling capabilities to include Columbia River from Grand Coulee to Bonneville dams to better assess the effect of operations or flow depletions on summer temperatures, and*

7. *Investigate alternatives to reduce total mass loading of TDG at Bonneville Dam while maintaining juvenile survival performance, and*

8. *Continued operation of the Lower Snake River projects at MOP.*

Real-time total dissolved gas (TDG) and temperature values are reported hourly on the water quality pages of the TMT website at http://www.nwd-wc.usace.army.mil/ftppub/water_quality/tdg/.

The 2015 final WQP provides the overall framework for addressing water quality measures needed to meet both the ESA and Clean Water Act responsibilities. In 2015, spill at the projects was managed consistent with the Total Dissolved Gas Management Plan, which is Appendix 4 of the 2015 Water Management Plan (BPA et al. 2014a). Real-time monitoring was conducted consistent with the 2015-2018 TDG Monitoring Plan (ACOE 2014).

The System Total Dissolved Gas (SYSTDG) model was used as a real-time decision support tool to manage spill at Lower Columbia and Snake rivers projects. A statistical evaluation of SYSTDG's performance was conducted to assess how well the model estimated percent TDG. The predictive errors that SYSTDG computed in 2015 compared favorably with the predictive errors from previous years, for most gauges and showing similar trends as seen in previous statistical analyses.

The following improvements were made to the SYSTDG model in 2015:

1. A multi-year contract was established with Pacific Northwest National Laboratory (PNNL) to maintain and further develop the SYSTDG model.

2. The SYSTDG's programming code was changed to a more conventional style and was used to aid maintenance and updates. Changes made so that all workbooks were consistently similar. This included changing the programming of how the Nbay equations are calculated, how the spill patterns are recognized in the Nbay equations, and how the modeler can designate which spill pattern should be used in the Nbay equations.

3. PNNL provided recommendations on how to improve the SYSTDG statistical analysis after they reviewed several past years' SYSTDG statistical analyses and the methodology of how they are performed.

4. The pathnames used in the new SYSTDG downloading application were modified to ensure that a complete set of the current year's data was received when the model is run.

5. The pathnames the new SYSTDG downloading application uses to pull the 2005-2013 data were modified and the data for those pathnames were requested to be migrated from CDB or CWMS1.5 into CMWS2.1. This is in preparation of improving SYSTDG run simulations of back years.

The developer's manual and the user's manual were updated prior to giving them to PNNL for their use and update.

The CEQUAL-W2 model was used from May through September 2015 to support decisions regarding operation of Dworshak Dam for flow augmentation and temperature management on the lower Snake River. The results were presented and discussed routinely with TMT members and Action Agencies to develop best management strategies. A series of upgrades to the individual lower Snake River CEQUAL-W2 reservoir models began in 2015 and are ongoing through 2016.

Development and calibration of the water quality model for Grand Coulee reservoir has been completed. The model spans the extent of Lake Roosevelt from the international border with Canada down to and including Grand Coulee Dam. The model incorporates the Kettle, Colville, Spokane, and Sanpoil River reaches via U.S. Geological Survey (USGS) gauging stations. The model also uses Reclamation AgriMet weather station data as the forcing variables for meteorological conditions. The model was built using CEQUAL-W2 and is currently calibrated to model Grand Coulee Dam outflow temperatures using recent historical data. Model calibration was limited by the amount of available meteorological data and was only performed for calendar years 2000, 2006, and 2011. The calibration report, authored by Portland State University, is currently in draft format with final reviews in progress.

Work included the development and calibration of a RiverWare model to supplement the CEQUAL-W2 model for Grand Coulee Dam. The RiverWare model contains modeling assumptions and rules that simulate operations at Grand Coulee Dam with regard to powerhouse operations as well as Banks Lake pumping and generation. Given projected inflows and operational assumptions, the RiverWare model is used to route Grand Coulee Dam outflows to the left, right, or third powerhouses, Banks Lake, or spill. RiverWare outputs are used as inputs for CEQUAL-W2 to determine outflow temperatures at each outlet and the weighted average temperature for the total outflow. The RiverWare model was completed and calibrated.

RPA Action 16 – Tributary Projects

The tributary projects that have not yet completed ESA Section 7 consultation are located in the Yakima, Okanogan, and Tualatin river basins. Reclamation will, as appropriate, work with NOAA Fisheries in a timely manner to complete supplemental, project-specific consultations for these tributary projects. These supplemental consultations will address effects on tributary habitat and tributary water quality, as well as direct effects on salmon survival in the tributaries. The supplemental consultations will address effects on mainstem flows only to the extent to which they reveal additional effects on the instream flow regime not considered in the FCRPS and Upper Snake River BA/Comprehensive Analysis.

Reclamation submitted Biological Assessments (BAs) to NOAA Fisheries on the Okanogan, Tualatin, and Yakima projects. Reclamation is currently working with NOAA Fisheries on each of these tributary-specific consultations. The current status on each consultation and the predicted future work schedules for these project consultations are provided below.

Tualatin Project Consultation

NOAA Fisheries issued a final Tualatin Project Biological Opinion to Reclamation on October 1, 2014. This Biological Opinion was a non-jeopardy opinion that included both monitoring and reporting reasonable and prudent measures (RPMs) as part of the Incidental Take Statement. Reclamation began implementing the RPMs that were included in the Tualatin Project Final Biological Opinion.

Okanogan Project Consultation

Reclamation submitted a BA for the future operation and maintenance of the Okanogan Project in 2008. This consultation covers Upper Columbia Steelhead. Since 2009 Reclamation has been collecting data in the Okanogan Basin to determine if the proposed action can be modified to address concerns raised by NOAA Fisheries. Data collection continued into the 2014 to 2018 period. It is anticipated that Reclamation will reinitiate consultation with NOAA Fisheries in the 2015 through 2016 time period. The objective would be to provide an updated proposed action to NOAA Fisheries at the end of 2016 and to conclude Section 7 consultation with NOAA Fisheries in 2017.

Yakima Project Consultation

Reclamation and the NOAA Fisheries re-initiated consultation at the end of 2012 on mid-Columbia Steelhead. Through 2014, Reclamation and the Services (NOAA Fisheries and USFWS) were revising the 2000 BA, the 2009 BA Supplement, and integrating new information obtained from the 2012 Integrated Water Resource Management Planning effort into a new BA. Reclamation and NOAA Fisheries continued to meet on this consultation through 2014 and continued efforts through 2015.

RPA Action 17 – Chum Spawning Flows

1. *Provide adequate conditions for chum spawning in the mainstem Columbia River in the area of the Ives Island complex and/or access to the Hamilton and Hardy Creeks for this spawning population.*

2. *Provide a tailwater elevation below Bonneville Dam of approximately 11.5 feet beginning the first week of November (or when chum arrive) and ending by December 31, if reservoir elevations and climate forecasts indicate this operation can be maintained through incubation and emergence.*

3. *Through TMT, if water supply is deemed insufficient to provide adequate mainstem spawning or continuous tributary access, provide, as appropriate, mainstem flow intermittently to allow fish access to tributary spawning sites if adequate spawning habitat is available in the tributaries.*

4. *Make adjustments to the tailwater elevation through the TMT process consistent with the size of the spawning population and water supply forecasts.*

5. *After the completion of spawning, use the TMT process to establish the tailwater elevation needed to provide protection for mainstem chum redds through incubation and the end of emergence.*

6. *If the emergence period extends beyond April 10th and the decision is made to maintain the tailwater, TMT will discuss the impacts of TDG associated with spill for fish in the gravel.*

7. *Bonneville Dam typically starts its spring spill around April 10, but a delay in the start of spill may be needed.*

8. *Revisit the chum protection level decision at least monthly through the TMT process to assure it is consistent with the need to provide spring flows for listed Columbia and Snake River stocks.*

2014-2015 Operation

All actions below were carried out in coordination with the TMT.

On November 1, 2014, the Action Agencies initiated the chum operation. The Action Agencies issued the following guidance to operators at Bonneville Dam to provide habitat for spawning chum salmon: (1) Operate Bonneville tailwater within a 1 foot range of 11.5 - 12.5 feet elevation during all hours, (2) if necessary to pass additional flows, operate Bonneville tailwater up to 13.0 feet elevation during all hours, returning to 11.5 - 12.5 feet whenever possible, (3) if necessary to pass additional flows, operate Bonneville tailwater up to 16.5 feet elevation during nighttime hours (5 pm-6 am) with the highest tailwater elevations around midnight, (4) if necessary, operate Bonneville tailwater up to 18.5 feet elevation during nighttime hours (5 pm - 6 am) with the highest tailwater elevations around midnight, (5) if necessary, operate Bonneville tailwater at a range of 13.0 - 16.5 feet elevation during daytime hours (6 am - 5 pm) with no upper limit during nighttime hours and the highest tailwater elevations around midnight.

On December 23, 2014, the Action Agencies discontinued the day/night spawning operation and began the 13.0 feet minimum tailwater operation at all hours for chum incubation.

On April 10, 2015, the Action Agencies ended the chum operation with the start of spill for juvenile fish passage.

2015-2016 Operation

All actions below were carried out in coordination with the TMT.

On November 7, 2015, the Action Agencies initiated the chum operation. The Action Agencies issued the following guidance to operators at Bonneville Dam to provide habitat for spawning chum salmon: (1) Operate Bonneville tailwater within a 1 foot range of 11.5-12.5 feet during all hours. (2) If necessary to pass additional flow, operate as necessary up to 13.0 feet during all hours, returning to the range of 11.5-12.5 feet whenever possible. (3) If necessary to pass additional flow, operate Bonneville tailwater up to 16.5 feet during nighttime hours (5 pm-6 am). The highest tailwater elevations will be concentrated around midnight. (4) If necessary to pass additional flow, the Bonneville Dam tailwater will be operated up to 18.5 feet during nighttime hours (5 pm-6 am). The highest tailwater elevations will be concentrated around midnight. (5) If necessary to pass additional flow, operate tailwater between 13.0-16.5 feet during daytime hours (6 am-5 pm) with no upper limit during nighttime hours. The highest tailwater elevations will be concentrated around midnight.

On December 16, 2015, the Action Agencies operated the Bonneville Dam tailwater at a minimum of 13.0 feet while increasing the tailwater elevation up to 16.0 feet for a 4 hour period to rewet any redds. Regional Salmon Managers made the recommendation to implement this operation because of high tailwater elevations that occurred between the dates of December 8-13, which exceeded the tailwater elevations specified in the operation previously coordinated on November 7.

On January 1, 2016, the Action Agencies discontinued the spawning operation and began the 12.2 feet minimum tailwater operation on all hours for chum incubation.

On April 10, 2016, the Action Agencies ended the chum operation with the start of spill for juvenile fish passage.

RPA Action 18 – Configuration and Operation Plan for Bonneville Project

The Corps will consider all relevant biological criteria and prepare, in cooperation with NOAA Fisheries and the co-managing agencies, a Configuration and Operational Plan (COP) for the Bonneville Project (2008). As part of the first phase of modifications, the Corps will investigate, and implement the following reasonable and effective measures to reduce passage delay and increase survival of fish passing through the forebay, dam, and tailrace as warranted. Initial modifications will likely include:

Bonneville Powerhouse I

1. *Sluiceway modifications to optimize surface flow outlet to improve fish passage efficiency and reduce forebay delay (2009).*

Powerhouse I sluiceway improvements, which converted the sluiceway to a surface flow outlet, were completed in 2010.

2. *Minimum-gap turbine runner installation to improve survival of fish passing through turbines (2009).*

Installation of the final minimum-gap turbine runners at Powerhouse I was completed in 2010.

Bonneville Powerhouse II

3. *Screened bypass system modification to improve fish guidance efficiency and reduce gatewell residence time (2008).*

Modifications to the juvenile bypass system to improve fish guidance efficiency (FGE) were completed in 2008. However, after those modifications a fish injury problem was identified. From 2009 through 2014, the Corps evaluated alternatives to remedy the increased injury rates caused by FGE improvements. In 2014, the recommended alternative, a gatewell flow reduction device, was installed in a single Powerhouse II turbine unit gatewell and hydraulic conditions were evaluated. Results indicated that the prototype modifications improved flow conditions within the gatewell. A biological evaluation and additional hydraulic measurements were planned for implementation in 2015 in a fully modified turbine unit.

In 2015, fish condition and survival for tagged fish passing through modified gatewells were compared to fish passing through an unmodified (current condition) gatewell. Tests were conducted at varying flow within the 1 percent peak efficiency range. A hydraulic evaluation followed in the fully modified unit that compared pre- and post-modification conditions. The results from the biological and hydraulic evaluation suggest that the objectives have been met to improve hydraulic conditions and juvenile fish survival in modified gatewells when operating in the upper 1 percent peak efficiency range.

Efforts are underway to fully implement the gatewell modification across all main units at Powerhouse II in late 2016 and early 2017. Unmodified Powerhouse II turbine units continue to be operated at the mid to lower end of the 1 percent peak efficiency range, as coordinated through FPOM. While both the modification and the interim operation reduce flow into the gatewells, thereby reducing the injury to fish passing into the juvenile bypass system, the reduction in FGE is expected to be minimal. Once modifications are complete, Powerhouse II turbine unit operation is expected to return to the full 1 percent range, and the effectiveness of the modification will be evaluated again.

4. *Shallow behavioral guidance screen installation to increase Corner Collector efficiency and reduce forebay delay (prototype 2008).*

Testing of a shallow behavioral guidance structure at Powerhouse II was completed in 2010. Due to minimal benefits and high operation and maintenance costs, the structure was removed prior to the 2011 migration season.

Bonneville Dam Spillway

5. *Spillway operation or structure (e.g., spillway deflectors) modification to reduce injury and improve survival of spillway passed fish; and to improve conditions for upstream migrants (2013).*

   Hydraulic modeling and fish survival studies were completed and spillway operations that increased survival of juvenile salmonids passing through the spillway were implemented in 2008. A study to identify and evaluate structural fish passage improvements to the spillway was completed in 2009.

The COP will be updated periodically and modifications may be made as new biological and engineering information is gathered. The COP and modifications will be coordinated through the Regional Forum. Comments developed by NOAA Fisheries on the draft COPs shall be reconciled by the Corps in writing to NOAA Fisheries' satisfaction before release of the final COP. If Phase I actions fail to meet the intended biological targets, the COP will be updated to identify additional Phase II actions for further implementation.

Performance standard testing was conducted in 2011 for yearling Chinook salmon and juvenile steelhead and in 2012 for subyearling Chinook salmon (Table 4). In 2011, dam passage survival estimates for yearling Chinook were slightly below the 96-percent BiOp performance standard, at 95.7 percent, while juvenile steelhead dam passage survival exceeded the standard at 97.6 percent during the portion of the study period when the target spill level (100 kcfs) was attained (April 30-May 13). The 95 percent confidence intervals of 2011 steelhead survival estimates exceeded the ± 3 percent BiOp requirement by ±0.5 percent. The target spill levels were not met for the full duration of these tests. For example, the spring spill target in 2011 was 100 kcfs spill, however the season-wide estimate in 2011 averaged 181 kcfs spill.

Table 4. Dam passage survival (with standard errors), passage times, and spillway passage efficiency for yearling Chinook salmon, juvenile steelhead, and subyearling Chinook at Bonneville Dam in 2011 and 2012 (Skalski et al. 2012a; 2013a). Spill passage efficiency includes spillway and other surface passage routes.

Species	Dam Passage Survival (Percent with Standard Error)	Median Forebay / Tailrace Passage Time (Hours)	Spill Passage Efficiency (Percent)
100-kcfs Spill (April 30-May 13, 2011)			
Yearling Chinook	95.69 (0.42)	n/a	n/a
Juvenile Steelhead	97.55 (1.80)	n/a	n/a
181-kcfs Season-wide Spill (April 30-May 31, 2011)			
Yearling Chinook	95.97 (1.76)	0.55 / 0.38	59.59
Juvenile Steelhead	96.47 (2.12)	0.85 / 0.39	64.06
149 kcfs Season-wide Spill (June 19 – July 22, 2012)			
Subyearling Chinook	97.39 (0.69)	0.48 / 0.36	57.06

The Corps will work with NOAA Fisheries and other regional partners to determine if the juvenile dam passage survival standards have been met or if additional actions and/or operation adjustments may be necessary to meet the performance standards.

RPA Action 19 – Configuration and Operation Plan for The Dalles Project

The Corps will consider all relevant biological criteria and prepare, in cooperation with NOAA Fisheries and the co-managing agencies, a Configuration and Operational Plan for The Dalles Project (2008). As part of the first phase of modifications, the Corps will investigate, and implement the following reasonable and effective measures to reduce passage delay and increase survival of fish passing through the forebay, dam, and tailrace as warranted. Initial modifications will likely include:

1. *Turbine operation optimization to improve overall dam survival (2011).*

   A model turbine runner was fabricated in 2009 in preparation for future turbine operation improvements. At this time, there are no plans for observational modeling of The Dalles Dam turbine runner.

   A Phase II Turbine Optimization report was completed in 2013. For more details on this report, see RPA Action 27.

2. *Extended tailrace spill wall to increase direct and indirect survival of spillway passed fish (2010).*

   The extended length spillwall was completed in 2010. Additional avian predation deterrent wires were installed over the spillway tailrace in 2011.

The COP will be updated periodically and modifications may be altered as new biological and engineering information is gathered. The COP and modifications will be coordinated through the Regional Forum. Comments developed by NOAA Fisheries on the draft COPs shall be reconciled by the Corps in writing to NOAA Fisheries' satisfaction before release of the final COP. If Phase I actions fail to meet the intended biological targets, Phase II actions, as described in the FCRPS BA – Appendix B.2.1 will be considered for further implementation.

The COP was updated in 2009 and recommended installation of an extended length spillwall as the preferred alternative to improve juvenile fish passage survival. The spillwall construction was completed in 2010 and juvenile fish performance testing conducted in 2010–2012. Current performance testing results are shown in Table 5 below. All juvenile fish survival performance tests have been completed. Dam passage survival standards for all tests were met except for steelhead in 2010 (95.3 percent). Following the 2010 test, avian deterrent wires were installed over the spillway tailrace and the avian predator hazing effort was increased at the project. In 2011, steelhead survival was 99.5 percent. Required precision levels were met for all tests. In addition, all identified survival model assumptions were met in each year (Johnson et al. 2011; Skalski et al. 2012b; 2013b). Observed spill passage efficiency values were within or above the range of Columbia Basin Fish Accord (Accord) values for all species tested. Forebay residence times were estimated over a 1 km distance in the performance standard tests, but only over a 100 meter distance in the Accord metrics. Therefore a direct comparison of the two values is not a useful way to evaluate whether forebay delay has improved or declined from the estimates included in the accords. In general, overall passage times remain relatively short at The Dalles Dam.

Table 5. Dam passage survival (with standard errors), passage time, and spill passage efficiency for yearling Chinook, juvenile steelhead, and subyearling Chinook at The Dalles Dam in 2010, 2011, and 2012 (Johnson et al. 2011; Skalski et al. 2012b; 2013b). Spill passage efficiency includes spillway and other surface passage routes.

Species	Dam Passage Survival (Percent with Standard Error)	Median Forebay / Tailrace Passage Time (Hours)	Spill Passage Efficiency (Percent)
2010 – 40 Percent Spill			
Yearling Chinook	96.41 (0.96)	1.28 /0.39	94.66
Juvenile Steelhead	95.34 (0.97)	1.28 / 0.35	95.36
Subyearling Chinook	94.04 (0.91)	1.20 / 0.32	82.98
2011 – 40 Percent Spill			
Yearling Chinook	96.00 (0.72)	0.97 / 0.24	83.1
Juvenile Steelhead	99.52 (0.83)	0.81 / 0.20	89.1
2012 – 40 Percent Spill			
Subyearling Chinook	94.69 (0.59)	1.08 / 0.24	78.39

RPA Action 20 – Configuration and Operation Plan for John Day Project

The Corps will consider all relevant biological criteria and prepare, in cooperation with NOAA Fisheries and the co-managing agencies, a Configuration and Operational Plan for the John Day Project (2008). As part of the first phase of modifications, the Corps will investigate, and implement the following reasonable and effective measures to reduce passage delay and increase survival of fish passing through the forebay, dam, and tailrace as warranted. Initial modifications will likely include:

1. *Full-flow bypass and PIT Tag detection installation to reduce handing stress of bypassed fish (2007).*

   A full-flow passive integrated transponder (PIT) tag detector was installed in the juvenile bypass system in 2007.

2. *Turbine operation optimization to improve overall dam survival (2011).*

   Hydraulic and numerical model studies of the turbine environment, laboratory studies on fish, and field studies were conducted to develop and verify a turbine operating point for John Day Dam turbines. However, an evaluation of total mortality, which also incorporates pressure effects on fish, was determined to be infeasible at this time.

   A Phase II Turbine Optimization report was completed in 2013. For more details on this report, see RPA Action 27.

3. *Surface flow outlet(s) construction to increase fish passage efficiency, reduce forebay delay and improve direct and indirect survival (prototype 2008 with final installation by 2013), and improve tailrace egress conditions.*

   Spillway weirs were installed in spillbays 18 and 19 in 2010. In 2013, the two prototype spillway weirs and associated handling equipment were modified so they would be suitable for long-term operation and maintenance.

As part of the surface flow outlet system, three tailrace improvements were implemented.

- An extended-length spillway deflector was installed in Bay 20 to improve tailrace egress.
- An expanded avian wire array was installed in 2010. In 2013, the avian wire array was modified to improve reliability and future maintenance. Additional modifications are currently being planned to address remaining design deficiencies and improve maintenance capability of this wire array.
- New spill patterns were implemented to optimize tailrace egress in conjunction with spillway weir flow.

The COP will be updated periodically and modifications may be altered as new biological and engineering information is gathered. The COP and modifications will be coordinated through the Regional Forum. Comments developed by NOAA Fisheries on the draft COPs shall be reconciled by the Corps in writing to NOAA Fisheries' satisfaction before release of the final COP. If Phase I actions fail to meet the intended biological targets, Phase II actions, as described in the FCRPS BA – Appendix B.2.1, will be considered for further implementation.

The COP was completed in 2007 and recommended installing surface flow outlets and tailrace improvements as Phase I actions. All Phase I configuration modifications have been constructed and tested.

Two years of juvenile survival performance tests have been completed for yearling Chinook, steelhead and subyearling Chinook salmon (Table 6). Results for spring migrants indicate John Day Dam is meeting performance standard goals. In 2014, survival estimates for subyearling results fell below the target (93 percent) at both 30 percent and 40 percent spill. Specific spill targets were not met for all tests. The Corps will work with NOAA Fisheries and other regional partners to determine if additional actions and/or operation adjustments may be necessary to meet the performance standards for subyearling Chinook salmon.

Table 6. Dam passage survival (with standard errors), passage time, and spill passage efficiency for yearling Chinook salmon, juvenile steelhead, and subyearling Chinook at John Day Dam in 2011, 2012, and 2014 (Skalski et al. 2012c; 2013c; 2015a).

Species	Dam Passage Survival (Percent with Standard Error)	Median Forebay / Tailrace Passage Time (Hours)	Spill Passage Efficiency (Percent)
2011 – 30-Percent Spill			
Yearling Chinook	96.66 (1.03)	2.0 / n/a	61.2
Juvenile Steelhead	98.36 (0.90)	4.3 / n/a	61.2
2011 – 40-Percent Spill			
Yearling Chinook	97.84 (1.07)	1.5 / n/a	66.4
Juvenile Steelhead	98.97 (0.96)	3.2 / n/a	65.9
2011 – Seasonwide Spill			
Yearling Chinook	96.76 (0.71)	1.42 / 0.57	63.68
Juvenile Steelhead	98.67 (0.61)	2.91 / 0.58	62.78

Species	Dam Passage Survival (Percent with Standard Error)	Median Forebay / Tailrace Passage Time (Hours)	Spill Passage Efficiency (Percent)
2012 – Seasonwide Spill			
Yearling Chinook	96.73 (0.65)	1.15 / 0.50	74.56
Juvenile Steelhead	97.44 (0.28)	2.39 / 0.46	74.52
Subyearling Chinook	94.14 (0.31)	1.02 / 0.48	69.62
2014 – 30-Percent Spill			
Subyearling Chinook	91.96 (0.74)	2.28 / 0.58	55.52
2014 – 40-Percent Spill			
Subyearling Chinook	91.31 (0.77)	1.91 / 0.56	71.26
2014 – Seasonwide Spill			
Subyearling Chinook	91.69 (0.61)	2.12 / 0.57	63.67

RPA Action 21 – Configuration and Operational Plan for McNary Project

The Corps will consider all relevant biological criteria and prepare, in cooperation with NOAA Fisheries and the co-managing agencies, a Configuration and Operational Plan for the McNary Project (2009). As part of the first phase of modifications, the Corps will investigate, and implement the following reasonable and effective measures to reduce passage delay and increase survival of fish passing through the forebay, dam, and tailrace as warranted. Initial modifications will likely include:

1. *Turbine operation optimization to improve survival of fish passing through turbines (2013).*

   Extensive turbine modeling has been conducted for this project. The Phase II Turbine Optimization report was completed in 2013. For more details on this report, see RPA Action 27.

2. *Improve debris management to reduce injury of bypass and turbine passed fish (2011).*

   Screen cleaning data were evaluated in 2009 and 2010, and the frequency of screen cleaning was increased. Beginning in 2010, debris was removed from trash racks a minimum of four times (March, April, May, June) during the passage season. Prior to this, raking occurred initially before watering up the juvenile fish facility (JFF) in late March and on an as-needed basis after that. The Corps acquired a boat in 2015 to assist with moving mats of forebay debris over to the spillway for passage.

3. *Relocate juvenile bypass outfall to improve egress, direct, and indirect survival on bypassed fish (2011).*

   Juvenile bypass outfall relocation was completed in 2012.

4. *Surface flow outlet installation to increase fish passage efficiency, reduce forebay delay, and improve direct and indirect survival (temporary structure testing in 2007 and 2008 to develop a permanent system).*

   Two spillway weirs were installed in 2007, tested in several spillbays, and moved to their expected permanent locations in 2010.

The COP will be updated periodically and modifications may be altered as new biological and engineering information is gathered. The COP and modifications will be coordinated through the Regional Forum. Comments developed by NOAA Fisheries on the draft COPs shall be reconciled by the Corps in writing to NOAA Fisheries' satisfaction before release of the final COP. If Phase I actions fail to meet the intended biological targets, Phase II actions, as described in the FCRPS BA—Appendix B.2.1, will be considered for further implementation.

The McNary COP was completed and distributed in 2013.

In addition, a study evaluating and comparing fish guidance efficiency with turbine unit head gates in the raised and stored positions was completed in 2013 (Ham et al. 2013). The study included two operating points and was split between spring and summer migrants. No significant difference in fish guidance efficiency was found between head gate positions or operations for spring or summer migrants. Head gates were lowered to the design storage position for 7 of the 14 turbine units in 2014. The head gates for the remaining turbines were stored in the raised position due to pending maintenance requirements to facilitate lowering to the design storage position.

Two years of performance standard testing have been completed for both spring and summer migrants at McNary Dam (Table 7). Target spill operations were not met for all tests. Pending the results of additional performance standard testing, the Corps will work with NOAA Fisheries and other regional partners to determine if the juvenile dam passage survival standards have been met or if additional actions and/or operation adjustments may be necessary to meet the performance standards.

Table 7. Dam passage survival (with standard errors), passage time, and spill passage efficiency for yearling and subyearling Chinook salmon and juvenile steelhead at McNary Dam in 2012 and 2014 (Hughes et al. 2013; Skalski et al. 2015b). Target spill was 40 percent spring and 50 percent summer.

Species	Dam Passage Survival (Percent with Standard Error)	Median Forebay / Tailrace Passage Time (Hours)	Spill Passage Efficiency (Percent)
2012			
Yearling Chinook	96.16 (1.40)	1.76 / 0.41	72.46
Juvenile Steelhead	99.08 (1.83)	1.78 / 0.34	83.15
Subyearling Chinook	97.47 (1.11)	1.77 / 0.385	78.32
2014			
Yearling Chinook	96.10 (1.27)	1.73 / 0.44	71.40
Juvenile Steelhead	96.98 (1.36)	2.57 / 0.37	84.33
Subyearling Chinook	92.39 (1.80)	2.22 / 0.54	53.80

RPA Action 22 – Configuration and Operation Plan for Ice Harbor Project

The Corps will consider all relevant biological criteria and prepare, in cooperation with NOAA Fisheries and the co-managing agencies, a Configuration and Operational Plan for the Ice Harbor Project (2008). As part of the first phase of modifications, the Corps will investigate, and implement the following reasonable and effective measures to reduce passage delay and increase survival of fish passing through the forebay, dam, and tailrace as warranted. Initial modifications will likely include:

1. *Guidance screen modification to improve fish guidance efficiency (2010).*

   A regional team evaluated the biological effects of possible FGE improvements to the existing standard length traveling screens and concluded that no significant survival benefit would be gained. Therefore, this action was not recommended in the draft COP and has been indefinitely deferred due to a lack of regional support.

2. *Turbine operation optimization to improve survival of turbine passed fish (2011).*

   A Phase II Turbine Optimization report was completed in 2013. For more details on this report, see RPA Action 27.

3. *Spillway chute and/or deflector modification to reduce injury and improve survival of spillway passed fish through the removable spillway weir (2009).*

   A construction contract for spillway chute and deflector modifications to reduce injury and improve survival of spillway-passed fish through the spillway weir was awarded in 2014 and construction completed during the winter of 2014-2015. During the spring of 2015 a Direct Injury and Sensor Fish evaluation of the new chute and deflector was completed. Results indicated a significantly improved route of passage for the spillway weir bay.

4. *Turbine unit 2 replacement to improve the survival of fish passing through turbines and reduce oil spill potential (2015).*

   The Ice Harbor test turbine project will replace Units 1–3. Turbines were designed for optimal fish passage and reliability with greatly reduced risk of oil leaks. A fixed blade runner will be installed in unit 2 and adjustable blade runners will be installed in units 1 and 3. Manufacturing on the fixed blade runner began in 2013, while in 2014 the contractor began procuring materials for manufacture of the first adjustable blade runner.

The COP will be updated periodically and modifications may be altered as new biological and engineering information is gathered. The COP and modifications will be coordinated through the Regional Forum. Comments developed by NOAA Fisheries on the draft COPs shall be reconciled by the Corps in writing to NOAA Fisheries' satisfaction before release of the final COP. If Phase I actions fail to meet the intended biological targets, Phase II actions, as described in the FCRPS BA—Appendix B.2.1, will be considered for further implementation.

The Action Agencies believe the current project configuration is ready for full performance standard testing.

RPA Action 23 – Configuration and Operation Plan for Lower Monumental Project

The Corps will consider all relevant biological criteria and prepare, in cooperation with NOAA Fisheries and the co-managing agencies, a Configuration and Operational Plan for the Lower Monumental Project (2010). As part of the first phase of modifications, the Corps will investigate, and implement the following reasonable and effective measures to reduce passage delay and increase survival of fish passing through the forebay, dam, and tailrace as warranted. Initial modifications will likely include:

1. *Primary bypass operations with PIT Tag detection installation to reduce handling stress of bypassed fish (2007).*

Installation of PIT tag detection in the juvenile bypass system was completed in 2007.

2. *Juvenile bypass system outfall relocation to improve egress, direct and indirect survival on bypassed fish (2011).*

   Relocation of the juvenile bypass outfall and improvements to the smolt monitoring raceway structures at Lower Monumental Dam were completed in early 2012.

3. *Turbine operation optimization to improve the survival of fish passing through turbines (2013).*

   A Phase II Turbine Optimization report was completed in 2013. For more details on this report, see RPA Action 27.

4. *Removable spillway weir installation to improve fish passage efficiency, reduced forebay delay, and improved direct and indirect survival (2008).*

   Spillway weir installation was completed in 2008.

The COP will be updated periodically and modifications may be altered as new biological and engineering information is gathered. The COP and modifications will be coordinated through the Regional Forum. Comments developed by NOAA Fisheries on the draft COPs shall be reconciled by the Corps in writing to NOAA Fisheries' satisfaction before release of the final COP. If Phase I actions fail to meet the intended biological targets, Phase II actions, as described in the FCRPS BA—Appendix B.2.1, will be considered for further implementation.

The final COP report was distributed to the Region in 2013. Performance standard testing at Lower Monumental Dam was conducted in 2012 and 2013 (Table 8). In 2012, survival estimates for subyearling Chinook salmon met the performance standard requirement of 93 percent survival. In 2013 the performance study evaluated survival at 17 kcfs spill for subyearling Chinook. Pending the results of additional performance standard testing, the Corps will work with NOAA Fisheries and other regional partners to determine if the juvenile dam passage survival standards have been met or if additional actions and/or operation adjustments may be necessary to meet the performance standards.

Table 8. Dam passage survival (with standard errors), passage time, and spill passage efficiency for yearling Chinook, juvenile steelhead, and subyearling Chinook salmon at Lower Monumental Dam in 2012 and 2013 (Skalski et al. 2013d; 2014).

Species	Dam Passage Survival (Percent with Standard Error)	Median Forebay / Tailrace Passage Time (Hours)	Spill Passage Efficiency (Percent)
2012			
Yearling Chinook	98.68 (0.90)	2.35 / 0.40	78.89
Steelhead	98.26 (0.21)	2.17 / 0.40	65.85
Subyearling Chinook	97.89 (0.79)	2.60 / 0.53	83.56
2013			
Subyearling Chinook	92.97 (1.05)	2.99 / 0.67	89.10

RPA Action 24 – Configuration and Operation Plan for the Little Goose Project

The Corps will consider all relevant biological criteria and prepare, in cooperation with NOAA Fisheries and the co-managing agencies, a Configuration and Operational Plan for the Little Goose Project (2009). As part of the first phase of modifications, the Corps will investigate, and implement the following reasonable and effective measures to reduce passage delay and increase survival of fish passing through the forebay, dam, and tailrace as warranted. Initial modifications will likely include:

1. *Turbine operation optimization to improve the survival of fish passing through turbines (2014).*

   Phase II Turbine Optimization report was completed in 2013. For more details on this report, see RPA Action 27.

2. *Primary bypass operations with PIT Tag detection installation to reduce handling stress of bypassed fish (2008).*

   Installation of PIT tag detectors in the Juvenile Bypass System primary bypass pipe was completed in 2010.

3. *Primary bypass outfall relocation to improve egress, direct and indirect survival on bypassed fish (2009).*

   The Juvenile Bypass System primary outfall relocation was completed in 2010.

4. *Surface spillway weir and deflector installation to improve fish passage efficiency, reduce forebay delay and improve direct and indirect survival (2009).*

   Installation of a spillway weir in spillbay 1, along with flow deflectors in spillbays 1 and 8, was completed in 2009.

The COP will be updated periodically and modifications may be altered as new biological and engineering information is gathered. The COP and modifications will be coordinated through the Regional Forum. Comments developed by NOAA Fisheries on the draft COPs shall be reconciled by the Corps in writing to NOAA Fisheries' satisfaction before release of the final COP. If Phase I actions fail to meet the intended biological targets, Phase II actions as described in the FCRPS BA—Appendix B.2.1 will be considered for further implementation.

Performance standard testing at Little Goose Dam was conducted in 2012 and 2013. In 2013 the performance study evaluated survival at 30 percent spill for subyearling Chinook. Survival estimates for subyearling Chinook salmon in 2013 were below the performance standard requirement of 93 percent survival (Table 9). The Corps is working with regional partners to determine what actions may be necessary to meet the performance standard for summer-run migrants during those years when summer flows are lower than 30-50 kcfs and water temperature exceeds 20°C. Focus is on reducing recirculating eddies in the tailrace by rebuilding the north shore entrance jetty that eroded in 2011 and revising spill patterns for low flow events with and without operation of the spillway weir. This will be documented for review in a revised Little Goose COP scheduled for regional review in 2016.

Table 9. Dam passage survival (with standard errors), passage time, and spill passage efficiency for yearling Chinook, juvenile steelhead, and subyearling Chinook salmon at Little Goose Dam in 2012 and 2013 (Skalski et al. 2013e; 2014).

Species	Dam Passage Survival (Percent with Standard Error)	Median Forebay / Tailrace Passage Time (Hours)	Spill Passage Efficiency (Percent)
2012			
Yearling Chinook	98.22 (0.76)	2.58 / 0.60	65.28
Steelhead	99.48 (0.81)	2.67 / 0.69	56.09
Subyearling Chinook	95.08 (0.97)	2.80 / 0.80	72.49
2013			
Subyearling Chinook	90.76 (1.39)	3.66 / 1.23	76.83

RPA Action 25 – Configuration and Operation Plan for Lower Granite Project

The Corps will consider all relevant biological criteria and prepare, in cooperation with NOAA Fisheries and the co-managing agencies, a Configuration and Operational Plan for Lower Granite Project (2009). As part of the first phase of modifications, the Corps will investigate, and implement the following reasonable and effective measures to reduce passage delay and increase survival of fish passing through the forebay, dam, and tailrace as warranted. Initial modifications will likely include:

1. *New juvenile fish facility including orifice configuration changes, primary dewatering, holding for transport, and primary bypass to improve direct and indirect survival for all collected fish (2012).*

   Construction of the improvements to the Juvenile Bypass System (JBS) at Lower Granite Dam began in 2015. These improvements include replacing 10-inch gatewell orifices with 14-inch orifices, widening the collection channel, daylighting the transport channel, adding new primary dewatering structures, and constructing new primary and emergency bypass outfall structures. Contract award for construction of the outfall structures is planned for 2016. The overall JBS upgrade is anticipated to be completed before the juvenile outmigration in 2018.

   A two year contract was awarded for monitoring the effect of sound and vibration of heavy construction activities on adult salmon passage behavior and travel times through the ladder. Additionally, a survival study planned for 2018 will also evaluate the improvements to the JBS upgrades from Phase 1 construction activities.

2. *Turbine operation optimization to improve survival of turbine passed fish (2014).*

   A Phase II Turbine Optimization report was completed in 2013. For more details on this report, see RPA Action 27.

The COP will be updated periodically and modifications may be altered as new biological and engineering information is gathered. The COP and modifications will be coordinated through the Regional Forum. Comments developed by NOAA Fisheries on the draft COPs shall be reconciled by the Corps in writing to NOAA Fisheries' satisfaction before release of the final COP. If Phase I actions fail to meet the intended biological targets, Phase II actions as described in the FCRPS BA—Appendix B.2.1 will be considered for further implementation.

A revised draft Lower Granite COP was developed for Agency review in 2015, while the JFF upgrade was being constructed. The draft COP will be circulated for region review and coordination, with a final draft completed in 2016. Commencement of juvenile migrant dam survival Performance Standard testing will begin in 2018, once JBS improvements (Phases 1a and 1b construction) have been completed.

RPA Action 26 – Chief Joseph Dam Flow Deflectors

The Corps will complete the flow deflector construction at Chief Joseph Dam by 2009.

Construction of flow deflectors on all 19 spillway bays at Chief Joseph Dam was completed in September 2008. This completed the structural component for reduction of TDG downstream of Chief Joseph and Grand Coulee dams. A successful spill test occurred in spring 2009 and no further testing is planned.

RPA Action 27 – Turbine Unit Operations

The Action Agencies will operate turbine units to achieve best fish passage survival (currently within 1 percent of best efficiency at mainstem dams on the Lower Columbia and Lower Snake rivers from April 1–October 31 (hard constraint) and from November 1–March 31 (soft constraint) each year. Continue turbine operations evaluations and apply adaptive management to operate units in their optimum configuration for safe fish passage.

In 2015, turbine units on mainstem dams on the Lower Columbia and lower Snake Rivers were operated within 1 percent of best efficiency from April 1 to October 31 (hard constraint) and from November 1 to March 31 (soft constraint).

Building upon the works of Carlson et al. (2010), the Corps pursued an external tag laboratory and subsequent field study to test a tag for turbine passage that would reduce the potential bias in turbine survival estimates due to the presence of an internal tag. Field testing of the external tag was completed in 2012 (Brown et al. 2013; also see RPA Action 55).

The Phase II Turbine Optimization report (ACOE 2013); referred to as the Biological Index Testing report, was completed with available data by the Turbine Survival Program in 2013 and includes specific appendices for Bonneville, John Day, McNary and Lower Monumental Dams. This report considered past turbine modeling and laboratory and field study data collection to provide project-specific recommendations for turbine operations Best Operating Point that are expected to provide a juvenile fish passage benefit. Future efforts will be made to implement the Best Operating Point at these Projects and collect data for the remaining FCRPS projects while they continue to operate within the 1 percent of peak efficiency range.

Turbine passage survival data collected at Bonneville Powerhouse 1 were analyzed from 2010–12 performance standard testing for operations within and above the 1 percent of peak efficiency range (Weiland et al. 2015). Results indicated high smolt survival (≥95 percent) at operating ranges from the low end of 1 percent efficiency to the generator limit (beyond 1 percent efficiency range), and no difference in survival between operations within and above the 1 percent range. Physical and numerical modeling was conducted to complement this information. As a result of these efforts, operating Bonneville Powerhouse I at the Best Operating Point for fish passage under high flow was included in the 2014 FPP.

A detailed biological study design for testing of the new Ice Harbor runners was completed in 2013 (Trumbo et al. 2013). The study design was used by PNNL in 2014 to develop a draft multi-year implementation plan for biological testing of the new runners post-installation. Preliminary Sensor Fish data were collected in 2014 and 2015.

Three-dimensional JSATS (Juvenile Salmon Acoustic Tag System) data were analyzed to estimate the acclimation depth for turbine-passed fish based on forebay behavior in 2014 (Deng et al. 2014; Li et al. 2015). These data were compared to data collected at the Lyon's Ferry Bridge, located between Little Goose and Lower Monumental dams, as a reference location. Turbine-passed fish were deeper in the forebay than fish that passed via the spillway or the JBS. Mean acclimation depths will be applied to juvenile salmonids directly released into the new Ice Harbor turbines during biological testing to estimate the risk of barotrauma relative to pressure nadirs measured by Sensor Fish.

Turbine operations were investigated at the Corps' Engineering Research and Development center in 2015 for Bonneville Powerhouse II. Physical model observations identified increased turbulence and unsafe passage conditions at the lower ±1 percent of peak efficiency for juvenile salmonids. An FPP change form was coordinated through the FPOM to implement a soft constraint limit to operating below the 1 percent mid-range (below 13 kcfs), April 10 – June 15, beginning in 2016.

RPA Action 28 – Columbia and Snake River Project Adult Passage Improvements

The Corps will implement the following structural improvements to adult passage at the mainstem Columbia and Snake river projects:

Bonneville Dam

1. *Improve the Bradford Island ladder system to reduce stress and improve reliability of upstream adult passage (2013).*

   In 2012, the second phase of a two-phase project was completed to assess the fishway condition and recommend feature repairs/replacement for the Bradford Island fishway. The results of the study will be used by the Corps to establish priorities and budget funds for repairs/replacement.

   In addition, the Corps accomplished the following repairs and improvements during 2008-2015:

Bradford Island Ladder:
- repaired A-branch diffusers
- repaired fish valve FV4-3
- refurbished the count station crowder
- repaired a hole in the fish ladder floor at FG3-12
- removed a wooden bulkhead in the south collection channel
- repaired the south end gate in the ice and trash sluiceway (ITS)
- repaired erosion hole under the B-branch of the adult ladder

Cascades Island Ladder:
-repaired FV5-3
-repaired FV5-4
-installed variable width entrance weir to aid in lamprey passage
-installed bollards in floor of fishway entrance to aid in lamprey passage
-installed fully volitional LPS from tailrace to forebay
-reduced picket lead spacing to occlude lamprey from the auxiliary water system

In 2014, a new Project Delivery Team was organized to determine which Bonneville Project features should be included in the Major Rehabilitation Report and what features should be included in one or more Major Maintenance Reports. The purpose of a major rehabilitation study is to establish the engineering condition of a structure and determine the need to reduce risks and/or invest in reliability or efficiency improvements. The fish ladders and spillway were identified, among other features, to be analyzed for potential failure modes in fiscal year 2015. The results of the study will be used by the Corps to establish priorities and budget funds for repairs/replacement.

To address the BiOp Conservation Recommendations for Bonneville Dam Adult Trap Modifications, a Project Delivery Team was organized in 2012 to work in collaboration with FPOM and the Fish Facility Design Review Workgroup (FFDRWG) to improve handling, passage conditions, and survival of fish passing through the Adult Fish Facility. Structural and operational modifications completed in 2014 resulted in significantly less mortality during the 2014 research season compared to recent years.

The Dalles Dam

2. *East ladder emergency auxiliary water supply system and/or modifications that return adult salmon and steelhead use of the North ladder to pre-spillwall conditions to improve reliability of upstream adult passage (2013).*

The Corps, in coordination with the FFDRWG, identified a preferred alternative for an emergency backup for the east ladder back-up auxiliary water supply in 2012, developed a design documentation report in 2013, and completed plans and specifications in 2014. The contract for construction of those improvements was awarded in 2015.

North Ladder Passage: In 2004, a 150-foot spillway training wall was constructed between spillbays 6 and 7, and a 6-bay spill pattern was implemented to improve juvenile fish survival. Adult passage through the north ladder was notably reduced following the change in spill operation due to the new training wall and spill patterns, particularly during periods of high spill (e.g., >100 kcfs). In 2010, a longer training wall was constructed between spillbays 8 and 9, and an 8-bay spill pattern was implemented. A 2010 radio-telemetry study suggested that adult spring-summer Chinook passage was not delayed as a result of the new tailrace conditions and structure, but the percentage of tagged salmon using the north ladder was lower during higher spill conditions (100-150 kcfs) (Jepson et al. 2011). The percent of fish using the north shore ladder before construction of the spillwall (2000-2003) versus after construction of the extended wall (2010–2012) was assessed as well based on the fish count data. There has been no substantial reduction in north shore ladder use by Chinook and steelhead. Sockeye use of the north shore ladder, however, was substantially lower post-spillwall vs. pre-spillwall. A two year radio-telemetry study was initiated in 2013 and continued through 2014. Results suggest that as spill levels increase above 100 kcfs, a higher proportion of adult salmon use the east ladder. The shift from the north ladder to the east ladder does not appear to delay adult salmon. Passage times, which are among the fastest at The Dalles Dam compared to the other seven FCRPS dams, were within the historical range (Frick et al. 2015).

The large fall Chinook run in 2013 prompted an investigation into the potential for overcrowding in The Dalles Dam east ladder after spill ends on August 31 and there is no attraction flow to the north ladder. The investigation involved a 2014 trip to the physical model of the project at the Corps' Engineer Research and Development Center in Vicksburg, Mississippi, to develop a new spill pattern with the goal of attracting more fish to the north ladder and reducing overcrowding at the east ladder should overcrowding be identified. The spill pattern developed during that trip was field tested during the 2014 fall Chinook run, resulting in some increase in north ladder passage during the test periods. The Corps and BPA are continuing to coordinate with FPOM to review the test results to inform the development of a pattern and to define triggers for implementation.

John Day Dam

3. *Adult ladder systems modifications to improve upstream adult passage conditions (2011).*

Structural improvements to the count station and control (exit) section of the North Fish Ladder were completed in spring 2010, and modifications to the lower ladder, entrance, and auxiliary water supply system were completed in 2013. A two year radio-telemetry study was conducted in 2013 and 2014 to evaluate the effectiveness of these improvements. Results from the two years of study showed that spring and summer Chinook salmon passed the north ladder slightly faster in post-modification years than in pre-modification years. While there were no pre-modification years to compare sockeye passage to, passage times for sockeye were equal or faster than those for Chinook (Frick et al. 2015). Additionally, the passage improvements appear to have increased ladder entrance efficiency for adult Pacific lamprey.

Ice Harbor Dam

4. *Repair or replace north shore fishway auxiliary water supply equipment, as needed, so that any two of the three pumps can meet flow criteria.*

Improvements to the Ice Harbor Dam auxiliary water supply were completed in 2009.

Little Goose Dam

5. *Investigate adult passage and determine whether structural, operational, or tailrace modifications can alleviate adult passage delays or blockages during spill operations for optimum juvenile passage (See RME Action 54).*

   Beginning in 2011, a new spill pattern, with spillbay 8 operating first, was implemented to reduce adult passage delay. This operation was continued in 2015. The Little Goose Dam 1:55 scale physical hydraulic model was utilized in 2015 to further investigate adult passage effects of spill pattern adjustments such as spillway weir closure during low flow events (inflows <30-50 kcfs), which was tested for brief periods of time during the extreme water temperature regime that affected adult passage through all FCRPS projects during summer 2015. Results indicated that closure of the spillway weir when inflow is 30-40 kcfs provided benefit by reducing the mixing of heated surface water with cooler deep layer water passed through turbines and deep spill. Analysis indicated that the weir should be closed near a trigger of 48-50 kcfs inflow to improve adult and juvenile passage.

   In 2013 a design was developed for construction of a new adjustable spillway weir. The design allowed closure of the weir and provided more flexibility in meeting passage goals for adult and juvenile fish. In 2014, a contract was issued to build and install the weir, but was later cancelled. In 2014 and continuing in 2015, a new adjustable weir is being designed and will be contracted to be built in 2016 and 2017. The current plan is to have the new weir operational for the juvenile fish outmigration in 2017.

Lower Granite Dam

6. *Investigate and, if necessary, provide additional auxiliary water supply for the new adult trap at lower Granite so that it can operate at full capacity when the forebay is operated at MOP without affecting the fishway auxiliary water supply (2012).*

   In 2010 a valve was replaced, allowing the adult trap to receive adequate water supply at MOP. In addition, the modifications to the new juvenile bypass system will route excess water to the adult trap (JBS Phase 1 completion anticipated March 2018).

7. *Adult fishway modification to improve upstream adult passage conditions impaired by temperature differentials (the need will be determined by results of further research).*

   In 2014 and 2015, in response to high temperature differentials in the adult fishway at Lower Granite Dam and resulting passage delays, three temporary pumps were used to add cooler water from deeper in the forebay directly to the front of diffuser 14 inlet. In addition, spill and turbine operations were varied to minimize passage delay. During the winter of 2015-2016 permanent modifications were made to the auxiliary ladder pump intakes and discharge routing to cool the Lower Granite Dam adult fish ladder. These improvements will be evaluated during the 2016 fish passage season.

RPA Action 29 – Spill Operations to Improve Juvenile Passage

The Corps and BPA will provide spill to improve juvenile fish passage while avoiding high TDG supersaturation levels or adult fallback problems. Specific spill levels will be provided for juvenile fish passage at each project, not to exceed established TDG levels (either 110 percent TDG standard, or as modified by State water quality waivers, currently up to 115 percent TDG in the dam forebay and up to 120 percent TDG in the project tailwater, or if spill to these levels would compromise the likelihood of meeting performance standards (see RPA action table, RME Strategy 2). The dates and levels for spill may be modified through the implementation planning process and adaptive management decisions. The initial levels and dates for spill operations are identified in Table 2 of the RPA action table. Future Water Management Plans will contain the annual work plans for these operations and spill programs, and will be coordinated through the TMT. The Corps and BPA will continue to evaluate and optimize spill passage survival to meet both the hydrosystem performance standards and the requirements of the Clean Water Act (CWA).

Spill operations were implemented in accordance with the 2015 FOP consistent with the 2014 Supplemental BiOp. The FOP is Appendix E of the 2015 FPP (ACOE 2015a, see RPA Action 32 below). Implementation of these operations and regional coordination on in-season adjustments are reported on a monthly basis during the migration season and can be found in Appendix D of the 2015 TDG Report (ACOE 2015b). This report describes the Corps' Columbia River Basin spill and water quality monitoring program for 2015 and covers the Columbia and Snake River dams located in Washington, Idaho and Oregon. The report provides information requested by Oregon and Washington water quality agencies, and also includes the following additional technical information:

- Flow and runoff conditions for the spill season.
- Duration and volume of spill for fish passage versus spill for other reasons for each project.
- Data from the physical and biological monitoring programs, including incidences of gas bubble trauma.
- Progress on implementing measures contained in the lower Columbia and lower Snake rivers TDG total maximum daily load documents.

Spring Fish Passage Spill Operations

During 2015, spring fish passage spill at the lower Columbia and lower Snake River projects was implemented consistent with the 2015 FOP (Appendix E of the 2015 FPP, ACOE 2015a) and the TDG Management Plan (Appendix 4 of the 2015 WMP, BPA et al. 2014a). Spring fish passage spill began April 3, 2015, and continued through June 20 at the lower Snake River projects. In the lower Columbia River, spring fish passage spill began April 10, 2015, and continued through June 15.

The 2015 FOP called for the following spill operations:

- Lower Granite Dam: 20 kcfs, 24 hours per day.
- Little Goose Dam: 30 percent of total project outflow, 24 hours per day.
- Lower Monumental Dam: TDG Cap, 24 hours per day.

- Ice Harbor Dam: 45 kcfs during the daytime and TDG Cap from April 3 – April 28, then alternating between (a) 30 percent of total project outflow 24 hours per day and (b) 45 kcfs during the day and TDG Cap at night through June 20.
- McNary Dam: 40 percent of total project outflow.
- John Day Dam: 30 percent of total project outflow from April 10 through April 27; alternating between 30 and 40 percent of total project outflow from April 28 through June 15.
- The Dalles Dam: 40 percent of total project outflow.
- Bonneville Dam: 100 kcfs, 24 hours per day.

Consistent with the 2014 Supplemental BiOp, in-season adjustments addressing real-time conditions were implemented in coordination with regional sovereigns.

Summer Fish Passage Spill Operations

During 2015, consistent with the FOP, summer spill began June 21 and continued through August 31 at the lower Snake River projects. Summer spill on the lower Columbia River began June 16 at McNary Dam, John Day, The Dalles, and Bonneville dams. Spill continued through August 31.

The 2015 FOP called for the following summer spill operations:

- Lower Granite Dam: 18 kcfs, 24 hours per day
- Little Goose Dam: 30 percent of total project outflow, 24 hours per day
- Lower Monumental Dam: 17 kcfs, 24 hours per day
- Ice Harbor Dam: From June 16 through July 13, spill alternating between (a) 30 percent of the river flow 24 hours per day and (b) 45 kcfs during the day and TDG Cap at night. From July 13 through August 31, 45 kcfs during the day and TDG Cap at night.
- McNary Dam: Spill 50 percent of total project outflow
- John Day Dam: Alternating between 30 and 40 percent of total project outflow from June 16 through July 20, and 30 percent of total project outflow, 24 hours per day from July 21 through August 31.
- The Dalles Dam: 40 percent of total project outflow.
- Bonneville Dam: Spill alternating between (a) 85 kcfs during the day and 121 kcfs during the night and (b) 95 kcfs 24 hours per day.

Consistent with the 2014 Supplemental BiOp, in-season adjustments addressing real-time conditions were implemented in coordination with regional sovereigns.

2015 River Conditions and TDG Monitoring

During the 2015 fish passage spill season, system flows were very low and below average due to the below average runoff volume (as seen at The Dalles). This resulted in below average releases at the FCRPS projects as demonstrated in the three examples below: Bonneville for the lower Columbia, Ice Harbor for the lower Snake, and Chief Joseph for the middle Columbia reach. For most of the fish migration season, spill for fish passage was provided at the lower Snake and Columbia River fish passage projects at the levels specified in the 2015 spring and summer FOPs. On intermittent occasions, additional spill occurred at individual projects in circumstances when river flows exceeded powerhouse hydraulic capacity, due to equipment malfunction or modeling and forecasting uncertainties, or for other purposes, such as ensuring power and transmission system stability, passing debris, or FRM.

Daily average total river flows on the lower Columbia River, as measured at Bonneville Dam, from April 1 through August 31, ranged from 104 kcfs to 239 kcfs, averaging 161 kcfs. Daily average flow peaked on April 1. Total river flows began to recede gradually in the first half of April and continued a steady recession until the end of August when flows reached 104 kcfs.

On the lower Snake River, as measured at Ice Harbor Dam, daily average total river flow from April 1 through August 31, ranged from 15 kcfs to 90 kcfs, averaging 40 kcfs. Daily average flow peaked on April 3. Flows began to recede after the April peak with a gradual recession, ending the month of August at about 15 kcfs.

Daily average total river flows on the mid-Columbia River, as measured at Chief Joseph Dam from April 1 through August 31, ranged from 63 kcfs to 129 kcfs, averaging 101 kcfs. Peak flows occurred on August 18 (the maximum), and began to decrease and continued to recede until the end of August when flows dropped to 78 kcfs on August 31.

There were a total of 167 instances out of 2,448 gauge-days in 2015 where TDG exceeded[2] the modified State water quality standards. These included 116 instances due to malfunctioning gauges, and 43 managing TDG production and achieving the juvenile dam passage survival performance standards at Lower Monumental Dam as specified in the 2014 Supplemental BiOp. The unique reservoir configuration combined with environmental conditions downstream of Lower Monumental Dam often results in very little degassing of the water spilled at this project once the water reaches the Ice Harbor Dam forebay. As a result, providing fish passage spill to achieve performance standards at Lower Monumental Dam while not exceeding the 115 percent TDG limit in the Ice Harbor Dam forebay is challenging and often results in TDG levels that exceed 115 percent TDG. Consequently, maintaining performance standard spill for fish passage is prioritized over managing to 115 percent in the Ice Harbor Dam forebay. The TDG instances related to this approach for benefitting juvenile fish migration occurred only at the Ice Harbor forebay gauge. This information with additional detail is provided in the 2015 TDG Report (ACOE 2015b).

Excessive TDG levels can result in gas bubble trauma (GBT). Examination of data obtained from the Fish Passage Center (under "Smolt Data" at http://www.fpc.org) showed that in 2015 10,577 juvenile fish were examined for GBT at Corps dams from April through August. Of the fish examined, 20 (0.19 percent) were found to have non-severe signs of GBT, and

---

[2] *The magnitude and duration of exceedences varies.*

none exhibited severe signs. The symptoms occurred during periods of high river flows. The overall incidence of GBT in 2015 was in the lower range among the past 19 years.

RPA Action 30 – Juvenile Fish Transportation in the Columbia and Snake Rivers*

The Corps and BPA will continue the juvenile fish transportation program toward meeting system survival performance metrics of Snake and Columbia River salmon and steelhead with some adaptive management modifications based on results of RME. The Corps and BPA will continue to collect and transport juvenile fish at Lower Granite, Little Goose, Lower Monumental, and McNary dams, although under a modified operation as described in Table 3 and Table 4 of the RPA action table. While the dates mentioned in this section should be considered firm planning dates, if in-season information or results of ongoing RME indicates a need for adaptive management (for example, if modifying these dates are likely to increase in-river or system survival and would be likely to provide equivalent or increased SARs of the species transported), the Action Agencies will consider revising the dates and operations through the Regional Forum.

**** The language below reflects changes made by the 2014 BiOp:***

Table 3 is no longer in effect. Instead the Action Agencies will continue transport operation at Snake River collector dams according to the following criteria and schedule (See Section 3.3.3.4 Juvenile Transport and IP RPA Action 30 for more details):

Annual Review of Information

- *Data on fish survival, adult returns, current year inriver conditions, and water supply forecast will be reviewed with RIOG each year to determine the best operation for the fish.*

Transport Start Date

- *TMT will review the results of transport studies annually and provide an annual recommendation on how to operate the juvenile transport program to achieve the goal of transporting about 50% of juvenile steelhead.*
- *Planning dates to initiate juvenile transport at Lower Granite Dam will be April 21 to April 25, unless the Corps adopts a recommendation by TMT that proposes a later start date (No Later Than May 1) and accompanying alternative operation in their annual recommendation to achieve the goal of transporting about 50% of juvenile steelhead.*
- *Transport will begin up to 4 days and up to 7 days after the Lower Granite start date at Little Goose and Lower Monumental dams, respectively.*
- *Transport will continue until approximately September 30 at Lower Monumental and through October 31 at Lower Granite and Little Goose dams.*

Table 4 is no longer in effect. Transportation operations have ceased at McNary Dam.

The 2015 transportation program was conducted in accordance with the Juvenile Fish Transportation Program criteria listed in the 2015 FPP. The start dates for transport operations were coordinated with the TMT and implemented simultaneously at Snake River operating projects. Collection of juvenile fish for barge transport began May 1, 2015, at Lower Granite, Little Goose, and Lower Monumental dams. Before transport began, sampling operations were conducted at the Lower Granite, Little Goose, and Lower Monumental facilities in support of research activities, BPA-sponsored smolt monitoring activities, and assessment of bypass system conditions. Smolt Monitoring Program activities occurred daily at Lower Granite Dam throughout the entire season. Transport operations at the Snake River facilities continued through October 1 at Lower Monumental Dam and through October 31 at Little Goose and Lower Granite dams. Since fish are no longer transported from McNary Dam, sampled and collected fish at this location were bypassed to the tailrace. Routine fish sampling operations did take place at McNary Dam every other day from April 9, 2015 to September 30, 2015, to support research and BPA-sponsored smolt monitoring activities, as well as to assess bypass system conditions.

Juvenile fish barged during 2015 were released at varying locations below Bonneville Dam consistent with past permit requirements. The ending collection date for the barging season in 2015 was August 14 at Lower Monumental, Little Goose, Lower Granite dams. On July 29, collected fish were trucked instead of being barged from Lower Granite Dam due to a navigation lock outage at Little Goose Dam. Snake River facilities transported juvenile fish by truck from August 16 through the end of the transport season. Most trucked fish were released into the Bonneville Juvenile Monitoring Facility outfall flume. Trucking operations continued to October 1 at Lower Monumental Dam and to October 31 at Lower Granite and Little Goose dams. No early season (April) trucking took place in 2015.

Estimates of the number of fish collected, bypassed, and transported as part of the juvenile fish transportation program are based on sampling portions of the fish collected. Sampled numbers were expanded according to the percentage of the time sampling occurred and are not meant to be an exact enumeration of individuals. At Snake River operating projects, the sampled fish were hand-counted and differentiated by species and the presence of adipose fins. Approximately 6,688,226 juvenile fish were collected at Lower Granite Dam, with 2,653,853 of these fish bypassed to the river and 4,029,934 transported. At Little Goose Dam, approximately 2,260,329 juvenile salmon and steelhead were collected in 2015. Of these, 477,086 were bypassed to the river, and 1,780,151 were transported. At Lower Monumental Dam, approximately 1,167,619 juvenile salmon and steelhead were collected in 2015. Of these, 98,227 fish were bypassed, and 1,067,935 were transported. At McNary Dam in 2015, approximately 1,944,347 juvenile salmon and steelhead were collected; 1,943,172 of the fish collected were bypassed to the river, and no juvenile fish were transported. A total of 10,116,174 juvenile salmon and steelhead were collected at all transport program locations (Lower Granite, Little Goose and Lower Monumental dams) in 2015, with 6,878,020 fish transported (68 percent) and 3,229,166 bypassed (32 percent). Of the fish transported, 6,849,900 were transported by barge (99.6 percent) and 28,120 were trucked (0.4 percent). Estimates of the percent of fish transported collectively from Snake River projects by species and rearing origin are contained in Table 10.

Table 10. Estimated proportion of non-tagged spring/summer Chinook and steelhead smolts transported in the Snake River in 2015 (Faulkner et al. 2016).

Species	Percent Transported in 2015
Snake River Spring Chinook—Wild	11.4
Snake River Spring Chinook—Hatchery	13.6
Snake River Spring Steelhead—Wild	12.4
Snake River Spring Steelhead—Hatchery	13.9

RPA Action 31 – Configuration and Operational Plan Transportation Strategy*

The Corps, in coordination with the Regional Forum, will initiate a Configuration Operational Plan in 2009. The plan will be completed in 2010 and will present a strategy for prioritizing and carrying out further transportation actions at each dam. Comments developed by NOAA Fisheries on the draft COPs shall be reconciled by the Corps in writing to NOAA Fisheries' satisfaction before release of the final COP. Construction actions for transportation are primarily in the context of changes to juvenile bypass systems. Changes meant to increase adult salmon returns through the juvenile fish transportation process are being evaluated. Some changes include additional barges, a new juvenile fish facility at Lower Granite Dam and modifications to the juvenile fish facilities at Little Goose, Lower Monumental and McNary dams.

**** The language below reflects changes made by the 2014 BiOp:***

McNary Dam will no longer be considered in the Configuration and Operational Plan Transportation Strategy.

The Transport COP draft was completed in September 2013 and distributed to regional entities for review. The draft contained broad alternatives for transport and focused on increasing smolt-to-adult return ratios (SARs) for ESA-listed Snake River salmonids. The COP was then modified in response to comments received in 2013 and changes to RPA Action 31 in the 2014 supplemental FCRPS BiOp. A final draft was distributed for regional review in December, 2015. Additional comments were received from NOAA Fisheries February, 2016, and the final COP was released in August, 2016.

RPA Action 32 – Fish Passage Plan*

The Corps will annually prepare a FPP in coordination with NOAA Fisheries and the Regional Forum through the FPOM. The Corps will operate its projects (including juvenile and adult fish passage facilities) year-round in accordance with the criteria in the FPP. Comments developed by NOAA Fisheries on the draft FPP shall be reconciled by the Corps in writing to NOAA Fisheries' satisfaction before release of the final FPP. Key elements of the plan include:

- *Operate according to project-specific criteria and dates to operate and maintain fish facilities, turbine operating priorities, and spill patterns;*
- *Operate according to fish transportation criteria;*
- *Maintain turbine operations within the 1 percent of best efficiency range;*
- *Maintain spillway discharge levels and dates to provide project spill for fish passage;*
- *Implement TDG monitoring plan;*
- *Operate according to protocols for fish trapping and handling;*
- *Take advantage of low river conditions, low reservoir elevations or periods outside the juvenile migration season to accomplish repairs, maintenance, or inspections so there is little or no effect on juvenile fish;*
- *Coordinate routine and non-routine maintenance that affects fish operations or structures to eliminate and/or minimize fish operation impacts;*
- *Schedule routine maintenance during non-fish passage periods;*

- *Conduct non-routine maintenance activities as needed; and*

- *Coordinate criteria changes and emergency operations with FPOM.*

Operations and Maintenance

- *Provide redundancy or contingency plans, developed in coordination with NOAA Fisheries and the Regional Forum, which will assure that key adult fish passage facility equipment operates as necessary to minimize long-term adult passage delays.*

- *Evaluate the condition of items necessary (e.g., spillway hoist systems, cranes, turbine units, auxiliary water supply systems, etc.) to provide safe and effective fish passage and develop a prioritized list of these items that are likely to require maintenance now or within the term of this Opinion.*

**** The language below reflects changes made by the 2014 BiOp:***

The Action Agencies will no longer consider transport at McNary Dam in the development of Transportation Strategy Configuration and Operation Plan

The draft 2015 FPP was released in October 2014. The final FPP (ACOE 2015a) was released in March 2015 at: http://www.nwd-wc.usace.army.mil/tmt/documents/fpp/2015/index.html. The FPP was completed in full coordination with the region. Corps fish passage facilities were operated in accordance with criteria in the FPP. Any deviations from the FPP were coordinated with the region and were necessary to protect fish or conduct emergency repairs on vital equipment.

RPA Action 33 – Snake River Steelhead Kelt Management Plan

The BPA and Corps will prepare a Snake River Kelt Management Plan in coordination with NOAA Fisheries and the Regional Forum. The BPA and Corps will implement the plan to improve the productivity of interior basin B-Run steelhead populations as identified in Sections 8.5. Key considerations in the development and implementation of the plan should include:

- *Measures to increase the in-river survival of migrating kelts,*

- *Potential for the collection and transport (either with or without short-term reconditioning) of kelts to areas below Bonneville Dam,*

- *Potential for long-term reconditioning as a tool to increase the number of viable females on the spawning grounds, and*

- *Research as necessary to accomplish the elements of this plan.*

BPA and the Corps completed the 2015 Kelt Management Plan (KMP) supplement. The goal of kelt management actions is to improve survival and productivity of listed steelhead by allowing kelts, female steelhead that continue living after spawning, to successfully survive and spawn in a subsequent year. The 2015 version of the KMP built upon the framework of previous plans, but also identified future direction through the remainder of the BiOp (2014-2018). The 2015 KMP reviews the goals of the plan and summarizes progress on reconditioning efforts.

In 2015, Snake River B-Run kelts were reconditioned at Dworshak National Fish Hatchery (NFH) through funding in BPA Project 2007-401-00. Thirty-four reconditioned wild female

B-Run kelts were released to the Columbia River below Bonneville Dam in December of 2015. An additional 23 fish were determined to be skip spawners and retained for release in 2016. A total of 140 kelts were collected at juvenile bypass facilities in Prosser and Lower Granite dams, and at Dworshak NFH and the Fish Creek weir. These fish were reconditioned at Prosser and Dworshak National fish hatcheries. Several categories of reconditioning research were continued in 2015 including assessments of fish culture techniques such as diet composition, monitoring of ocean return rates of kelts released from different reconditioning programs, experimental treatments, and stock origins, and estimation of reproductive success rates including long-term reconditioned kelts which did not undergo a repeat ocean migration. Additional information can be found in the KMPs at https://www.salmonrecovery.gov/Hatchery/kelt-reconditioning.

The 2015 reconditioning release represents progress towards meeting the Snake River six percent increased abundance target. As part of further efforts to develop the reconditioning program, CRITFC and the Nez Perce Tribe produced a Draft Reconditioning Master Plan for review in 2015 that recommends the long term facility needs of the program. The Master Plan describes the preferred alternative of constructing a small facility adjoining the Nez Perce Tribal Hatchery. The master plan was submitted to the Northwest Power and Conservation Council in the spring of 2016.

No transportation of kelts occurred in 2015. In-river migration and reconditioning strategies are currently prioritized over the transportation strategy when there is a shortage of kelts available for full program implementation. The Action Agencies may resume transportation when the number of collected kelts exceeds the capacity of reconditioning programs.

In 2015, kelts passing Lower Granite Dam experienced conditions similar to those experienced in recent previous years. This includes passing downriver primarily through spillway, turbine, or JBS routes. For kelts passing through the JBS, upon passing the extended length submersible bar screens and entering the gatewell environment, kelts passed through one of the existing 10-inch orifices or single prototype 14-inch orifice, into the juvenile collection channel, pressurized underground bypass pipe, and into the separator at the JFF. Upon entering the separator at the JFF, fish were either returned to the Snake River via the adult return flume or bypassed to the kelt holding tanks, where they were processed by the Nez Perce Tribe for transport to Dworshak NFH for reconditioning or were returned to the Snake River.

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

A hydroacoustic study of spillway weir passage for adult steelhead was conducted at McNary Dam from November 2014 to April 2015. The study included a comparison of passage during TSW_Spill and No_Spill treatments in a randomized block design. Fish guidance screens were installed in the turbine units during the first experimental period (Screens_In) from November 15, 2014, to December 14, 2014. Fish guidance screens were not installed during the second experimental period (Screens_Out) from February 15, 2015, to March 16,

2015. Both experimental periods focused on the passage distributions of adult steelhead during TSW_Spill or No_Spill treatment conditions. During the Screens_In experimental period, a statistically significant difference was found among treatments for fish passage efficiency (the proportion of fish passing non-turbine routes) and for total passage. Spillway weir operation (TSW_Spill) resulted in fewer adults passing via turbines and more fish passing the dam overall. Other passage trends were suggestive of fish being drawn away from guided passage by spillway weir operation operation, though none of those trends led to a statistically significant difference among treatments. The increase in downstream passage by adults during TSW_Spill treatments suggests that a number of fish upstream of McNary Dam were not actively passing the dam during No_Spill treatments (Ham et al. 2015).

Habitat Implementation Reports, RPA Actions 34–38

Table 11. Habitat strategy reporting

RPA Action No.	Action	Comprehensive Evaluation Reporting
Habitat Strategy 1		
34	Tributary Habitat Implementation 2007 to 2009 – Progress Toward 2018 Habitat Quality Improvement Targets	No specific Comprehensive Evaluation reporting requirement.
35	Tributary Habitat Implementation 2010–18 – Achieving Habitat Quality and Survival Improvement Targets	• Comprehensive report on status of project implementation, by project, (including project milestones) for all actions identified in implementation plans. • Comprehensive report of physical metrics for implementation achieved (e.g. miles of access, cfs streamflow acquired #s of screens installed, miles or acres of habitat protected or enhanced, and miles of complexity enhanced by benefited population(s)) and still remaining, by project. • By population, report progress toward overall habitat quality improvement targets and population-specific survival benefit. • Where population-specific survival benefits are not achieving Progress Guidelines above, identify processes or projects to place to ensure achievements by the next comprehensive report. • Report results of all biological effectiveness monitoring/studies, including new scientific information, and identify how results will be applied to future implementation, if appropriate. • Where new scientific or other information suggests that habitat quality improvement estimates for projects from the previous cycle were significantly in error, the Action Agencies will describe the analytical approach used to re-evaluate the estimated habitat and survival benefits for each project affected.
Habitat Strategy 2		
36	Estuary Habitat Implementation 2007 to 2009	No specific Comprehensive Evaluation reporting requirement.
37	Estuary Habitat Implementation 2010–18 – Achieving Habitat Quality and Survival Improvement Targets	• Comprehensive report on status of project implementation by project, (including project milestones) for all actions identified in implementation plans. • Comprehensive report of physical metrics for implementation achieved (e.g. # of acres protected/restored/enhanced; riparian miles protected; # of pile dikes removed) and still remaining, by project. • Where ESU-specific survival benefits are not achieving Progress Guidelines above, identify processes or projects in place to ensure achievement by the next comprehensive report. • Report results of all RME studies, including information from expert regional technical group, and identify how results will be applied to future implementation, if appropriate. • Where new scientific or other information suggests that survival improvement estimates for projects from the previous cycle were significantly in error, the Action Agencies will describe the analytical approach used to re-evaluate the estimated survival benefits for each project affected.
38	Piling and Piling Dike Removal Program	• Comprehensive report on status of project implementation (including project milestones) for all actions identified in implementation plans. • Comprehensive report of physical metrics for implementation achieved (E.G. # of pilings/pile dikes removed). • Report describing the effect of piling and pile dike removal projects implemented on survival of salmonids by ESU/DPS.

RPA Action 34 – Tributary Habitat Implementation 2007 to 2009 – Progress Toward 2018 Habitat Quality Improvement Targets

The Action Agencies will provide funding and technical assistance necessary to implement the specific projects identified for implementation in 2007 to 2009 as part of a tributary habitat program to achieve the population-specific overall habitat quality improvement identified in Table 5 of the RPA action table.

If projects identified for implementation in 2007-2009 prove infeasible, in whole or in part, the Action Agencies will implement comparable replacement projects in 2010-2013 to maintain estimated habitat quality improvements to achieve equivalent survival commitments at the population level, or alternatively at the major population group (MPG) or ESU level. Habitat and population-specific survival benefits in each implementation plan cycle must also compensate for not meeting estimated benefits in the previous implementation plan cycle. Replacement project selection will follow Action 35 below.

This RPA Action is complete and, as envisioned by the RPA, tributary habitat implementation through 2018 is being continued under RPA Action 35. Previous FCRPS Annual Progress Reports and the 2013 Comprehensive Evaluation have reported the progress on RPA 34 actions by Reclamation, BPA, and partners.

RPA Action 35 – Tributary Habitat Implementation 2010–2018 – Achieving Habitat Quality and Survival Improvement Targets

This section reports on the implementation of tributary habitat improvements for the 56 populations in Table 5 of RPA 35. Included are the 2015–16 expert panel results and process descriptions for the work windows 2012–15 and estimates for 2016–18. Results of the expert panel workshops are explained below and summarized in Appendix A, Table A-2 below.

Below, we provide details regarding habitat action implementation status for the ten populations specifically discussed in the 2014 Supplemental BiOp section 3.1.2.3. In support of demonstrating the Action Agencies' implementation achievements, the Action Agencies are including in this CE current information regarding the status of habitat implementation achievements at the ESU/DPS, MPG, and population level based on the results and analysis from the 2015–2016 expert panel process.

Representation of implementation achievements at the ESU/DPS and MPG levels utilizes the ICTRT population sizes and the HQI multipliers associated with those populations, according to Appendix D to the 2014–2018 Implementation Plan. As explained in Appendix D, the HQI multipliers allow exceedances of Table 5 commitments to "be carried over to populations of the same species within the same MPG or ESU where the HQIs are below the 2018 Table 5 HQI." As that Adjusted HQI Table shows (Appendix A, Table A-2, below), the HQI percentages through 2018 for habitat implementation actions all exceed the BiOp commitments, in some cases by a large amount, reflecting the significant program of work delivering benefits to fish at the ESU/DPS scale.

A total of 50 populations out of 56 are projected to meet the HQI by 2018, many of which are expected to far exceed their respective HQI. For example, as explained in more detail below, implementation of habitat actions for the Tucannon population is expected to yield nearly double the HQI. Likewise, as detailed later, implementation actions for the Pahsimeroi River population are anticipated to realize twice the HQI. While some populations are not expected to meet their respective HQIs by 2018, the Action Agencies have overcome significant pre-implementation practical challenges associated with a program that requires willing land owners in those subbasins, and those successes will allow implementation to proceed more rapidly and effectively in the future. The Action Agencies will consider this information as they develop their proposed action for the next consultation with NOAA Fisheries.

The maps below portray HQI accomplishments at the ESU/DPS, MPG, and population levels.

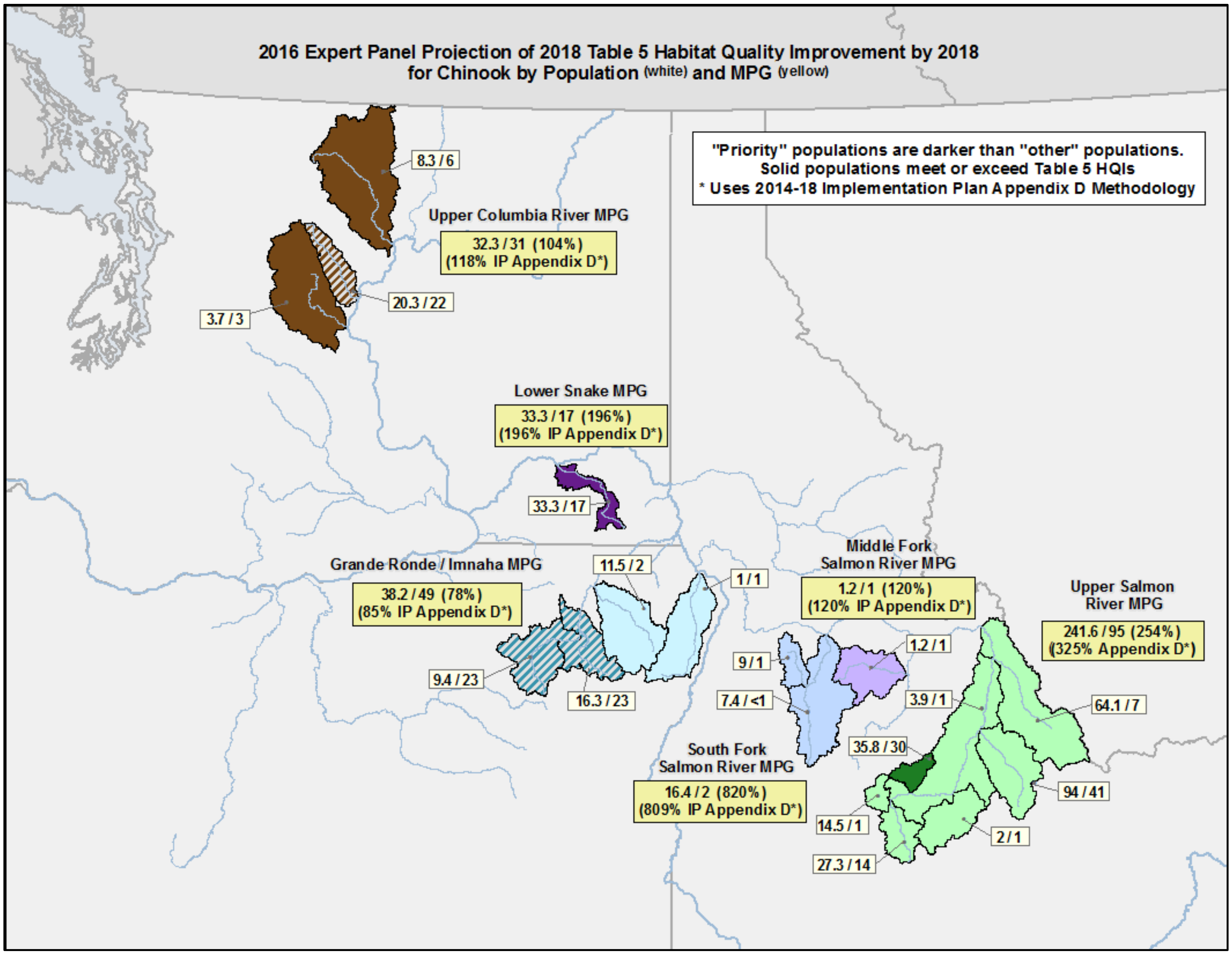


Figure 10. 2016 Expert Panel results of 2008 BiOp Table 5 Habitat Quality Improvement by 2018 for Chinook Salmon. This map of the Columbia River Basin in Oregon, Washington, and Idaho, depicts (in color) the tributary basins where habitat is being improved by the Action Agencies and partners. Darkest shades depict areas with priority populations. Projected 2018 HQIs based on expert panel results are shown in the white boxes and the MPG roll-up in yellow boxes near each basin. The number to the left of the slash represents the percent HQI projected through 2018; the number to the right of the slash represents the percent HQI to be achieved by 2018 for Chinook salmon (RPA Action 35, Table 5).

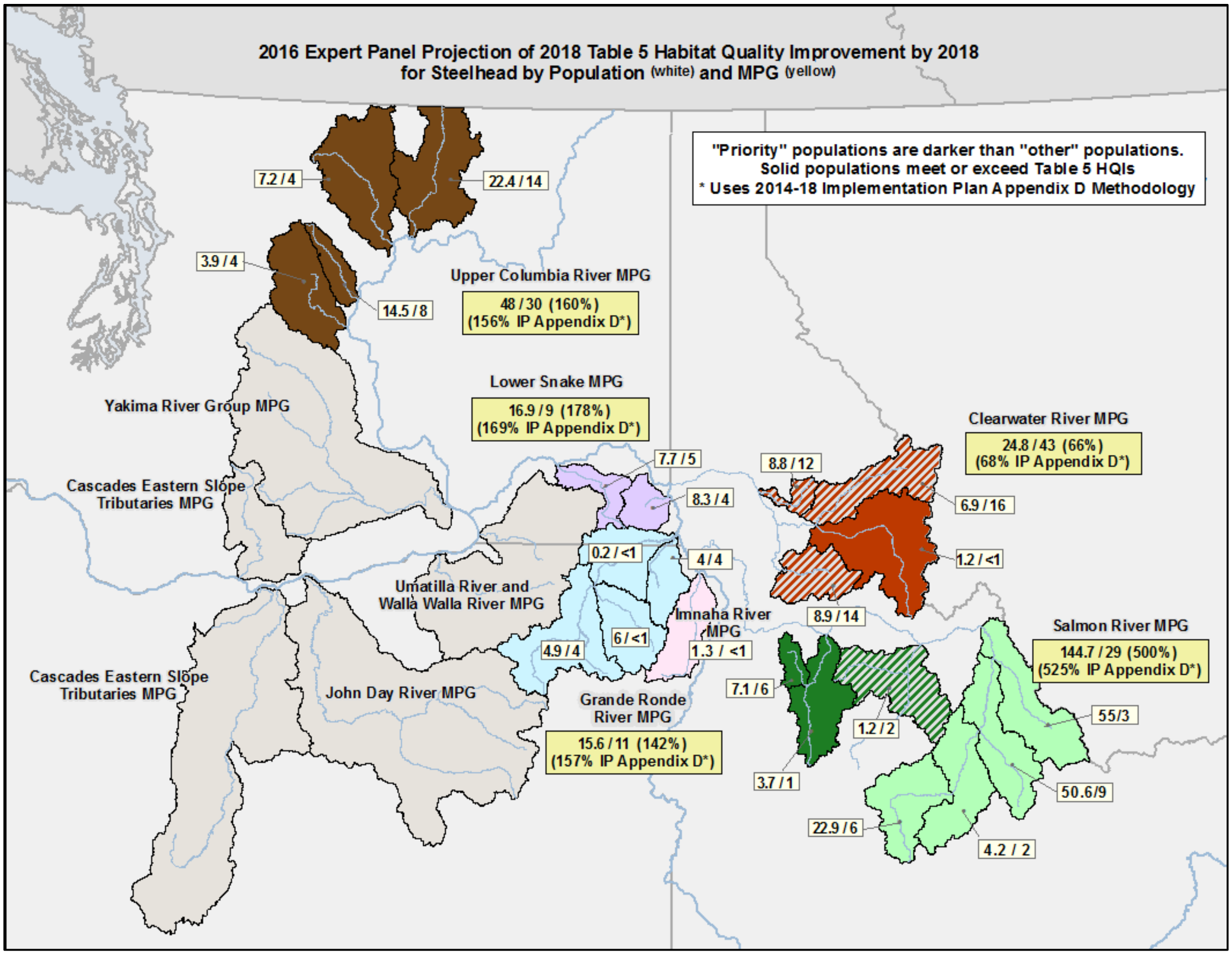


Figure 11. 2016 Expert Panel results of 2008 BiOp Table 5 Habitat Quality Improvement by 2018 for Steelhead. This map of the Columbia River Basin in Oregon, Washington, and Idaho, depicts (in color) the tributary basins where habitat is being improved by the Action Agencies and partners. Darkest shades depict areas with priority populations. Projected 2018 HQIs based on expert panel results are shown in the white boxes and the MPG roll-up in yellow boxes near each basin. The number to the left of the slash represents the percent HQI projected through 2018; the number to the right of the slash represents the percent HQI to be achieved by 2018 for steelhead (RPA Action 35, Table 5).

The Action Agencies' record of accomplishments clearly reflects the commitment to continue to implement habitat improvement actions to benefit the listed populations in the Interior Columbia Basin. BPA and Reclamation continue to fund implementation of actions and provide technical assistance to improve habitat for 56 Interior Columbia Basin spring/summer Chinook and steelhead populations for which survival improvement HQI were identified in Table 5, Action 35, of the 2008 BiOp RPA. Actions completed through 2015 were guided by the 2010–2013 Implementation Plan[3] (2010–2013 IP) (FCRPS 2010a)

[3] *RPA Action 35 calls for development of implementation plans at three-year intervals between 2010 and 2018. The first implementation plan (IP) was developed for the period between 2010 and 2013 (FCRPS 2010). The 2014-2018 IP (BPA et al. 2014a) includes specific habitat actions for a five-year (rather than a three-year) period, in response to the 2011 Court Order on the remanded 2010 FCRPS BiOp. The actions in the 2014-2018 IP specify location, treatment/action type, limiting factor (ecological concern), population, metrics, and estimated biological benefits.*

and the 2014–2018 IP (BPA et al. 2014b), watershed planning efforts, tributary and reach assessments, and the Atlas process in the Upper Grande Ronde and Catherine Creek. Physical metrics (e.g., acres of habitat, acre feet of flow) associated with habitat actions are reported in similar framework as previous Annual Progress reports and the 2013 Comprehensive Evaluation. Cumulative habitat quality improvement and survival estimates for the 56 populations from 2007 through 2011 were reported in the 2013 Comprehensive Evaluation (2013 CE) (BPA et al. 2014c). This document reports on 2015–16 expert panel results, updates HQI information through 2015 and estimates HQI information out to 2018 in Appendix A, Table A-2.

Section 1 of this Comprehensive Evaluation summarizes the metrics of habitat actions completed between 2007 and 2015 for water quantity and quality, instream habitat complexity, and riparian condition; restored access, and reduced entrainment at irrigation diversions consistent with previous Annual Progress Reports. The BPA business management systems for tracking contracted work and accomplishments (e.g., Pisces and Taurus) are discussed in detail in the 2013 CE and the 2014–2018 IP as well as in the 2014 FCRPS Supplemental BiOp. Details of BPA-funded actions can be accessed in the project web pages on http://www.cbfish.org. Further details on tributary habitat accomplishments with Reclamation involvement can be accessed at: http://www.usbr.gov/pn/fcrps/habitat/projects/index.html.

2015–2016 Expert Panel Summary

The expert panels that were convened in 2015 and 2016 evaluated actions implemented between and including 2012 and 2015 and planned for implementation between 2016 and 2018. Based on an agreement between NOAA Fisheries and the Action Agencies, the workshops were convened beginning in late 2015 and carried into 2016, which allowed for the evaluation of benefits from actions implemented in 2015. This approach combined more intensive coordination with stakeholders and panelists, data management, and technical expertise with effective facilitation to engage participants, develop an administrative record, and facilitate a process for quality assurance and quality control. The work plan was effective in engaging participants; reinforcing goals and objectives, presenting complex relevant material, and documenting panel deliberations. More details can be found in the "Improvements to the Expert Panel Process" section below.

The Action Agencies developed a blueprint for soliciting data and information that could be used in the expert panel process. That document, titled *Research, Monitoring, and Evaluation Habitat Information Resources for Snake River Spring/Summer Chinook Salmon, Snake River Steelhead, and Upper Columbia Spring Chinook* (and available at http://www.usbr.gov/pn/fcrps/habitat/panels/reference/index.html), identified the assessment units (AUs), limiting factors, and treatment types for each population where data and information could be used to inform expert panel deliberations.

Prior to convening the expert panels, the Action Agencies requested panel members to bring related monitoring and other information that would aid in understanding changes to habitat limiting factors. This information was used during the expert panel workshops to understand context of changes to habitat limiting factors and create a foundation for measured improvements. One example is for Catherine Creek habitat complexity and large wood enhancements: the Columbia Habitat Monitoring Program (CHaMP) large wood measurements from the Lostine River were used as a measure to rate the increase in pieces of large wood in an AU to base the improvement to the habitat limiting factor on a related and comparable numeric metric. Additionally, any relevant data for action implementation were used such as length of treatment, pieces of large wood added to floodplain and in-channel habitat to help with numeric improvements to various limiting factors.

The Action Agencies are currently involved in efforts to summarize what has been learned from the various effectiveness monitoring programs active in the Columbia Basin to develop a revised Research, Monitoring, and Evaluation (RME) framework for large scale monitoring programs like CHaMP and the Integrated Status and Effectiveness Monitoring Program (ISEMP), and to provide funding through 2018 to continue Reclamation's tributary and reach assessments and studies like the Oregon Department of Fish and Wildlife (ODFW) juvenile Chinook Salmon tracking study in Catherine Creek and the Upper Grande Ronde River that have shed light on the relative importance and benefit of tributary habitat actions. The Action Agencies documented how the products from these efforts were used during the expert panels to inform panel deliberations. A record of these discussions is included in the biological notes recorded during each panel.

NOAA Fisheries and the Action Agencies also discussed how the Action Agencies would evaluate benefits for the populations identified in 2012 CE with supplemental actions needed to meet the HQI by the end of 2018 based on the results of the 2012 expert panel reviews and those not yet attaining 33 percent by the end of 2011. (e.g., Catherine Creek, Grande Ronde Upper Mainstem, Yankee Fork, Upper Salmon Above Redfish Lake Creek, Tucannon, Entiat, Lochsa, South Fork Clearwater, Lolo Creek, Middle Fork Salmon Big, Camas, and Loon Creeks). Specific information can be found below.

During the 2015–16 round of expert panels, the AAs departed slightly from the guidance in the CHW method (Appendix C of the CA) and from the panels conducted previously with regard to the benefits estimated out to 2033. The Action Agencies and NOAA Fisheries agreed to solicit expert panel input on the estimate of benefits out to 2033 for a select number of populations slower to attain HQI, recognizing, however, that both the benefits and some actions evaluated by the panels at this point in time apply to only a subset of limiting factors (e.g., riparian condition); that there is a high degree of subjectivity in estimates projected out to 2033; and that the estimates are based on best available science *and* the current knowledge about the long term benefits of habitat actions. Additionally, it was deemed important to estimate benefits through 2033 (even given the added uncertainty noted by the AAs and the expert panels) included consistency with the guidance and past practice as well as desirability of acknowledging that for many actions, benefits accrue over a longer time period that the time frame of the BiOp. These results are not reported in this document but can be used in other analyses.

Improvements to the Expert Panel Process

The Action Agencies in coordination with NOAA Fisheries have sought to continuously learn from and improve upon the expert panel process since the panels were first convened in 2007. In the 2014 FCRPS Supplemental BiOp, NOAA recommended additional improvements. The Action Agencies and NOAA Fisheries discussed the recommendations and how to incorporate process improvements into the panel processes. The details of those efforts are addressed below.

For this Comprehensive Evaluation NOAA Fisheries specifically requested feedback on how the Action Agencies addressed recommendations for the expert panels in the 2014 FCRPS Supplemental BiOp. NOAA Fisheries' recommendations and Action Agency efforts to address these are documented below.

> ***Recommendation:*** *The Action Agencies need to better document and describe how the expert panels arrive at their estimates of habitat improvements, including documentation of the type and quality of information used to make each estimate. Defining where data and/or professional opinion are used will help clarify the process.*

The Expert Panel process involved extensive coordination between AAs and the local Expert Panels to compile, organize, and update technical data and information related to the actions being evaluated. Deliberate efforts were made to increase the documentation and logic pathways of the workshops and data. The following structure was formalized for each panel:

Biological Notes:

The Action Agencies recorded detailed biological notes during each expert panel workshop. The content includes the panels' decision criteria and rationale for changes in uplift to limiting factors from various habitat actions. The panels utilized data from StreamNet and local knowledge to determine the extent of fish use/distribution for each species in each assessment unit to better quantify the extent of benefits. These details were captured in the calculation spreadsheet that was developed for each assessment unit and limiting factor. The practice was adopted to increase transparency and address concerns about subjectivety in decisions regarding improvements to the limiting factors being evaluated.

GIS Information and Displays:

Geographic information system (GIS) data layers and assembling electronic maps were used during each meeting. A series of visual aids were necessary to move through the meetings and to orient panels to geography, habitat action locations, previous expert panel information and context. These aids most commonly included maps, Excel spreadsheets, and notes. An ArcGIS map developed prior to the meetings was used to orient the panel to assessment units and location within the subbasin. The layers included (parenthetical notes indicate how frequently each layer was used):

- AU Boundaries and Limiting Factors including "Pie Maps."
- StreamNet Fish Distribution Layers (Chinook and steelhead as separate layers). Panels often referenced these data for denominators in uplift calculations.
- NOAA Intrinsic Potential Layers (Chinook and steelhead as separate layers). Panels often referenced these data as a second source for fish distribution when they felt StreamNet was inadequate for uplift calculations.
- River Miles (referenced very often): river mile layers facilitated rapid measurement along streams by panels during meetings.
- Habitat Actions from Pisces Database (2012–2015, completed actions for Look Back process only, referenced often). Panels used this layer to locate projects.
- NOAA Passage Barriers
- NorWEST Stream Temperature Layer (U.S. Forest Service)
- Columbia Habitat Monitoring Program (CHaMP) GIS Layers on various landscape attributes.
- Basemaps included a recent aerial image and U.S. Geological Survey topographic maps.

Uplift Calculation Spreadsheet:

A calculation spreadsheet tool was developing based on various data and information to create consistent approaches to stream length and relative importance of metrics addressing habitat limiting factors. "Uplift" refers to the improvement to a habitat limiting factor from an action or series of actions in an AU. These spreadsheets included steelhead and Chinook stream miles for all Assessment Units (AU) using StreamNet fish distribution layers, estimates at "pro-rating" benefits to habitat limiting factors, other AU specific adjustments based on local knowledge and information. The data were used to produce a table of stream length and metric denominators that were used to calculate percent uplift to each limiting factor in each AU.

The spreadsheet used to calculate functional uplift was continuously displayed and filled out onscreen. This approach proved to be especially helpful with tracking projects as they applied to each limiting factor and creating a consistent calculation approach. Display of the spreadsheet at all times helped engage panel members by allowing them to see calculations being completed as a direct result of their conversation and input, and enabled continuous quality control.

Workshop Documents:

Prior to each Expert Panel meeting, a series of documents were printed to track actions, functions, and general progress throughout the meeting. These documents were distributed periodically throughout the meeting as discussions of separate fish populations were completed. The main documents distributed included the following:

- Habitat actions tables were distributed for each population throughout the meeting. These spreadsheets were generated from Taurus database downloads (http://www.cbfish.org) of habitat action data submitted by the panels prior to the meeting. Table documents were printed on colored paper by population, which was particularly helpful for the facilitation team with organization during the meeting.
- Habitat functions tables were distributed for each population throughout the meeting. These spreadsheets were generated from Taurus downloads (http://www.cbfish.org).
- Tables of AUs and limiting factors with columns for check boxes and written notes helped the facilitation team track meeting progress and follow-up items.
- Stream Mile Denominator Tables provided an initial estimate of fish use in each AU based on the StreamNet fish distribution layer.
- Research Monitoring and Evaluation Expert Panel Summary Documents included sub-basins, and their AUs. http://www.usbr.gov/pn/fcrps/habitat/panels/reference/index.html
- Graphic documents showing CHaMP summary metrics by AU were provided by the Northwest Fosheries Science Center to be used as supporting data for uplift calculations. http://www.usbr.gov/pn/fcrps/habitat/panels/reference/index.html

__Recommendation:__ The limiting factors identified for each assessment unit seem reasonable, but additional analysis confirming which factors are actually limiting each population would be helpful in prioritizing actions.

During the look back and the look forward the expert panels discussed each limting factor and the need (or not) to update the limiting factors and their weights. The Action agencies helped provide data and information to the expert panels to help guide and inform decisions. These data included information from CHaMP and other monitoring efforts. Details are described below.

Watershed, tributary, and reach assessments were used by the panels where applicable. Specific information was used in the Yankee Fork, Entiat, Methow and Okanogan Rivers. The Atlas processes was used in the Grande Ronde River upper mainstem and Catherine Creek to further assess and understand limiting factors and habitat improvement benefits.

__Recommendation:__ The estimates of baseline percent function for each limiting factor come from a variety of sources, including empirical data, other planning documents, modeling, and professional judgment. The panels used the best data available, although data quality varied within and among basins. Converting measures of habitat condition to a percent of properly functioning condition requires, for the most part, best professional judgment. The Action Agencies should provide guidelines to the expert panels on how to determine a percent of optimal condition so that it is done consistently across populations and expert panels.

The Action Agencies provided each expert panel with copies of NOAA's matrix of pathways and indicators and NOAA's table of standardized limiting factor definitions.[4] In certain circumstances when there were questions about the definitions and treatments that would result in benefits to a specific limiting factor, together with the Expert Panel members the Action Agencies reviewed NOAA's table of standardized limiting factors and how best to consider actions that would result in improvements to those factors. The Action Agencies also created an RME summary document for each ESU presentted to panelists prior to and during workshops that displayed limiting factors indentified for each AU for each population with a simple analysis of the weighting and frequency in each AU.

Additionally, CHaMP products presented to each panel and used at each workshop. Specific CHaMP summaries were provided by the Northwest Fisheries Science Center for the Lemhi River, Yankee Fork Salmon River, Upper Salmon River above Redfish Lake Creek, Big Creek (MF Salmon River), Secesh River, Lochsa River, Lolo Creek, Lower Clearwater River tributaries, South Fork Clearwater River, Upper Grande Ronde River and the Entiat River.[4]

As briefly described above, an organic outcome of an early Expert Panel meeting (Upper Salmon, Look Back) was the "Calculation Spreadsheet" (or uplift calculation spreadsheet) suggested by the panel and adapted by each subsequent panel. Its main purpose was uplift calculation for each limiting factor in each AU, based upon the list of relevant actions. It was composed of sheets dedicated to each AU. Within each AU sheet, uplift calculations were performed for each limiting factor listed within that AU.

[4] *These documents summarizing various data layers from the CHaMP Program can be found at: http://www.usbr.gov/pn/fcrps/habitat/panels/reference/index.html*

PRC1 - LF 6.2 (Channel Structure and Form: Instream Structural Complexity)			
Action	Miles treated	2018 % Improvement (prorating factor)	Realized Change in 2018 (mi)
Patterson Big Springs Creek 10 Restoration	0.1	25%	0.025
BLM below P-16 - IDFG	0.8	75%	0.6
Furey to Hooper	4	85%	3.4
Pahs. River Bank Restoration (Dixon and Dowton) - TU	0.25	35%	0.0875
Flying Joseph - Dam Removal	0.5	10%	0.05
Total Project Length	5.65		4.1625
Total # Projects	5		
Total Stream Miles Affected (Weighted for 2018)	4.1625		
Total Stream Miles (Denominator)	95	mi.	
% Uplift (2018)	**4.4%**		

Figure 12. Example uplift calculation from Assessment Unit PRC1, Limiting Factor 6.2. Projects (actions) are listed in the left column, with metrics and weighting factors to the right.

While calculations of uplift varied by panel and limiting factor, panels arrived upon a common calculation form for a large majority of uplift calculations. As shown in the example (Figure 12), uplift was typically calculated as the sum of the weighted project metrics, divided by an AU-specific denominator. In mathematical terms, uplift calculations took the following form:

$$Uplift\ \% = \frac{\sum(Project\ Metric\ x\ Project\ Proration\ Factor)}{AU\ Denominator}$$

Panels most commonly performed calculations using stream mile length metrics (project length) and denominators (AU length in terms of fish use). In other cases (typically related to streamflow, injury and mortality, and temperature limiting factors), panels used project metrics and denominators related to streamflow or number of projects (e.g., number of screens removed).

Pro-rating factors allowed panels to numerically describe the efficacy or habitat value of a given action, independent of its size or extent. Panels determined project-specific proration factors (see second column from right in Figure 12) according to various criteria, including but not limited to: project maturity at the end of the BiOp period (2018), progress toward properly functioning condition (PFC) within a project reach, or the importance of the project reach to Chinook or steelhead in the context of the entire AU.

The above proration approaches often varied systematically by limiting factor. The maturity approach, for example, was common in calculations of riparian vegetation uplift (Limiting Factor 4.1). In this case, the panels decided on a reasonable annual progress toward a properly functioning riparian condition based on vegetation growth rates, and then applied that annual “growth rate” to the BiOp period. Therefore, a riparian planting project completed in 2015 with a 1 percent annual growth rate would have a 4 percent weighting factor for growth from 2015 to 2018. Panels commonly saw the benefits of other activity types as more immediate and measurable. For instance, uplift calculations of instream structural complexity (Limiting Factor 6.2) in response to large woody debris placement projects often were assigned much larger weighting factors to account for the immediate benefits of having placed wood in the stream and creating desired habitat improvements.

From a facilitation and data capture standpoint, the uplift calculation spreadsheet was a major advance. First, it provided a visual, real-time tracking system for the facilitators and panelists. As panel members discussed each relevant project, the project's attributes were simultaneously placed into the spreadsheet by the operator. This allowed panel members to perform all aspects of each calculation except for the simple act of pressing computer keys. Therefore, once a calculation was complete, little confirmation of accuracy was needed from the panels given that they had observed the data entry and calculation process in action.

The uplift calculation spreadsheet also provided a "back-up" for the biological note taker. In the absence of the uplift calculation spreadsheet, the note taker did all of the recording of project data, calculations, and decision rationale in narrative form, which was difficult. With the uplift calculation spreadsheet, the biological note taker could focus on the decision rationale and key input values for providing context to the calculations (e.g., denominators and number and type of projects). Use of the calculation spreadsheet coupled with the detailed biological notes enhanced the record keeping of the proceedings.

Biological notes were the core document developed during each workshop. The notes were taken by a fish habitat restoration biologist who understood technical jargon that was referred to when the uplift calculations and weighting decisions were being reconciled. The primary purpose of the biological notes was to create a record of the expert panel decision process and criteria. The biological notes are intended to be used in tandem with the calculation spreadsheet, with the latter serving as a repository of project metrics and transparent formulas. The notes focused on technical concepts, data attributes, logic pathways, the panels' considerations and consensus, and the supporting rationale for panel decisions.

The biological notes were entered directly into the "Habitat Functions" spreadsheet, with the text organized according to the specific species/population/AU/limiting factor under discussion by the panel. Depending on the panel's concerns, the notes could encompass specific local biological information, recent scientific data and insights relevant to population limiting factors, additional projects to consider (not included in Taurus), conceptual discussions (e.g., metric selection, denominator data sources), reevaluation of low bookends, interim calculations (e.g., denominator mileage), benefit time scales/rates, project-specific proration values, and functional uplift changes and the consensus rationale for the change in percent function. Specific peer-reviewed and gray literature citations were included in the notes when provided by the panels. Other broader context discussions regarding the Expert Panel process, limiting factor definitions, and properly functioning condition reference conditions were included in the notes only if they were specific enough to affect the function values being considered by the panel. The biological notes frequently referred to and summarized the uplift calculation spreadsheet tables.

Because habitat actions often benefited both Chinook and steelhead, the panels often directed the facilitation team to apply the same metrics and technical rationale to steelhead after having discussed Chinook. Because different denominators were used for each limiting factor, "uplift" differed between species. In those cases, the panel's intention to replicate the Chinook rationale was recorded in brief general terms, with the uplift calculation spreadsheet later developed for steelhead following the panel's request. The notes for those steelhead cells, therefore, reference the Chinook rationale for the geographically equivalent AU.

Panel discussions were not always linear, so the raw notes captured the circuitous path travelled before a decision was made. Every effort was made to ensure that the notes were factual, complete, and captured how the panel arrived at consensus. A subset of these notes, representing the rationale for the final panel consensus, were later entered into the Taurus database by BPA staff.

> ***Recommendation:*** *In developing estimates of how limiting factor function will improve as a result of implementing actions, the expert panels should use the range of responses reported in the literature to bracket and help estimate restoration response.*

Prior to convening the expert panel workshops, the Action Agencies travelled throughout the basin and discussed, in advance, the expectations for the 2015 and 2016 panels. The Action Agency presentation included a discussion of the need for incorporating more scientific and monitoring data in the expert panel process and a specific request to panel participants to bring that information to the workshop. Each panel was notified by mail prior to workshops about the need for data and information that could inform the process. Finally, the Action Agencies provided a "Research, Monitoring and Evaluation" (RME) summary document for each Chinook salmon ESU and steelhead DPS to use as a reference in preparing materials for the workshop. Additionally, the AAs maintained numerous reference and process guidance documents such as "*Science and the evaluation of habitat improvement projects in Columbia River tributaries*" (BPA 2013) at http://www.usbr.gov/pn/fcrps/habitat/panels/reference/index.html

The Action Agency approach was prompted by discussions of an Action Agency, NOAA, and Northwest Fisheries Science Center working group that identified a strategy for making CHaMP data available to the expert panels. For populations where CHaMP products were available they were customized for each MPG and in some cases population and were distributed in advance of the workshops. To varying degrees the panels used this information in association with local data, information, on-the-ground-knowledge, and professional judgment to evaluate habitat improvement benefits.

> ***Recommendation:*** *Expert panels should include independent scientists from outside the basin in question to help ensure objective evaluation of habitat actions.*

As staff from the Northwest Fisheries Science Center were available, they attended the expert panel workshops as observers and provided regional perspectives.

Populations

These populations are described in more detail below as described in the 2014 Supplemental BiOp and their relative progress and meeting the HQI. Ten populations were identified in the 2014 Supplemental BiOp: those progressing less than 33 percent of their respective HQI and those where supplemental actions were identified in the 2013 Implementation Plan. These are the Yankee Fork Salmon River (spring/summer Chinook), Salmon River above Redfish Lake Creek (spring/summer Chinook), Catherine Creek (spring/summer Chinook), Grande Ronde upper mainstem (spring/summer Chinook), Tucannon River (spring/summer Chinook),Entiat River (spring Chinook), Lochsa River steelhead, Lolo Creek steelhead, South Fork Clearwater River steelhead, Lower Middle Fork Salmon River steelhead.

Snake River Spring/Summer Chinook:

The Snake River Spring/Summer Chinook ESU includes the following MPGs, for which the associated populations noted in parentheticals were evaluated in the 2014 Supplemental BiOp and are thus analyzed here: Upper Salmon (Yankee Fork, Upper Salmon River above Redfish Lake Creek), Grande Ronde/Imnaha (Catherine Creek, Upper Grande Ronde Mainstem), and the Lower Snake (Tucannon River).[5]

Under the 2014–2018 Implementation Plan, Appendix D, HQI multiplier process, implementation actions for the entire Snake River Spring/Summer Chinook ESU are expected to realize 254 percent of the HQI by 2018. Implementation actions are expected to achieve 325 percent of the HQI for the Upper Salmon MPG by 2018, and 85 percent for the Grande Ronde/Imnaha MPG. For the Lower Snake MPG, the Action Agencies' implementation actions are expected to achieve nearly double the HQI by 2018.

Both of the Upper Salmon populations are expected to far exceed the HQI by 2018. Implementation actions in the Upper Salmon River population above Redfish Lake Creek, for example, are expected to achieve about 200 percent of the HQI by 2018. While two of the three populations in the Upper Grande Ronde/Imnaha MPG are not expected to meet the HQI by 2018, the Action Agencies have employed implementation models proven successful elsewhere to ramp up action implementation. Moreover, despite the implementation challenges the Action Agencies have encountered for these two populations, the Action Agencies have nonetheless made substantial progress (e.g., expected implementation of 70 percent of the HQI for the Catherine Creek population).

Yankee Fork Population

The RPA Action 35 Table 5 2018 HQI for the Yankee Fork population is 30 percent. Based on expert panel estimates and the Collaborative Habitat Workgroup (CHW) method (2007 FCRPS Comprehensive Analysis Appendix C) for estimating habitat improvements, implementation of tributary habitat actions through 2015 was sufficient to achieve a 30.6 percent habitat quality improvement. Actions evaluated by the expert panel for implementation between 2016 and 2018 are projected to achieve an additional 5.2 percent improvement, bringing the total to 35.8 percent. Although the Action Agencies experienced significant delays in implementing actions to achieve the HQI, utilization of a systematic process to identify beneficial actions led to a substantial increase in the speed of implementation and, thus, a projected exceedence of the HQI.

In 2008, the Action Agencies anticipated a potential for delay in implementation for this population due to the complicated nature of planning and the drastic modification of the Yankee Fork from historic mining, dredging, and logging. The activities caused extensive damage to riparian areas, instream structure, substrate, and hydrologic conditions that limited juvenile rearing. The Action Agencies committed to improving conditions in the Yankee Fork and construction began in earnest in 2012, after several years of extensive planning and public engagement and details discussed below. Highlighted in the success of the Action Agencies work in the Yankee Fork is a strategy that incorporated Reclamation's tributary and reach assessments and the Yankee Fork Fluvial Habitat Rehabilitation Plan

---

[5] *The Snake River Spring/Summer Chinook Salmon ESU also includes the Middle Fork Salmon River and South Fork Salmon River MPGs, neither of which contained populations identified in the 2014 Supplemental BiOp.*

(Lyon and Galloway, 2013) that identify habitat improvement actions that can be implemented through 2018. These tied directly to habitat limiting factors the expert panel modified and clarified during the January 2013 workshop focused on improving floodplain, chanel structure and substrate condtions.

Work Between 2012 and 2015

Habitat actions evaluated by the expert panel in 2016 include the Yankee Fork Pond Series 3 (PS3) (completed in 2012); Yankee Fork Pond Series 2 (PS2) (completed in 2013); Yankee Fork Preacher's Cove (completed in 2014); and Yankee Fork Large Wood Enhancement Project (completed in 2015). These actions address bed and channel form, instream complexity, floodplain condition, large wood recruitment, and sediment quantity. The 2016 expert panel evaluated these projects after they had been implemented, and determined that the expected benefits were higher than what was anticipated by the 2012 expert panel. Additionally, some actions, including the Yankee Fork Large Wood Enhancement, were not evaluated by the 2012 expert panel. Details of the large scale actions implemented between 2012 and 2015 are included below.

The PS3 project created a high-flow refuge and year-round rearing habitat for juvenile Chinook salmon through modifications to dredge tailing ponds. In addition to stream channel improvements, riparian and wetland enhancements were completed along a 0.5 miles segment of off-channel habitat. See two videos at: http://www.usbr.gov/pn/fcrps/habitat/projects/uppersalmon/index.html

The PS2 project created additional side channel juvenile rearing habitat that was lost as a consequence of historic dredging associated with gold mining. The project entailed conversion of a series of off-channel ponds into complex side-channel spawning and rearing habitat that is more suitable for use by juvenile and adult Chinook salmon, steelhead, and bull trout. Research shows these fish prefer side-channel habitat over pond habitat (Lyon and Galloway, 2013). The project enhanced channel complexity along 0.5 miles, removed three barriers, and created access to 0.5 miles. See video at: https://vimeo.com/128256709

The Preacher's Cove Channel Complexity Project restored natural channel function to a section of the main Yankee Fork by increasing habitat complexity. Channel complexity that was lost as a consequence of historic dredging associated with gold mining was restored through placement of engineered rock and wood structures (>100 logs) to create additional spawning and rearing habitat that is more suitable for use by juvenile and adult Chinook, steelhead and bull trout. The project also added 120 yards of spawning gravel to the reach. Benefits of the action include enhanced complexity in 0.85 miles of the channel. See video at: https://vimeo.com/121694464

The U.S. Forest Service Large Wood Enhancement Project increased large-wood in a 7.4-mile reach of the Yankee Fork. The first phase of the project that was implemented in 2014 entailed placement of 340 trees and 70 yards of rock and gravel in a 3-mile section of the reach between Jordan and Eightmile creeks. Trees and rock were placed in the river to mimic natural recruitment from streamside, avalanche, and debris flows. The second phase that was implemented in 2015 placed 388 trees in a 4-mile reach of the stream. See videos at https://vimeo.com/149908973 and https://vimeo.com/121881971

Work Projected for Completion Between 2016 and 2018

Work planned for implementation between 2016 and 2018 will continue to utilize the Rehabilitation Plan, building on previous work in the dredged reach. The West Fork Yankee Fork and Bonanza City actions are large scale actions and address multiple limiting factors through a number of treatments. The West Fork Yankee Fork project will reestablish the historical Yankee Fork channel, substantially increasing habitat complexity and cover. The action will also activate floodplain and side channel habitat and re-establish riparian and wetland conditions. This project was initiated in 2015 and completed in 2016. See Video at: https://vimeo.com/148228623

The Bonanza City project, planned for 2017 and 2018, is a large-scale floodplain and habitat complexity enhancement action along approximately one mile of the dredged reach of the Yankee Fork. The Bonanza City project is much like the West Fork project insofar as the treatments are considered. Another action upstream of the West Fork project (e.g., Preachers Plus) will implement treatments to enhance floodplain connectivity and channel complexity near the Preachers Cove Complexity Project.

HQI and Population Status

Tributary habitat actions through 2015 were sufficient to achieve a 30.6 percent improvement in habitat quality. Actions evaluated by the expert panel for implementation between 2016 and 2018 are projected to achieve an additional 5.2 percent improvement, bringing the total to 35.8 percent.

These projections reflect the continued success of the Action Agencies and their partners to improve conditions for salmon in the Yankee Fork. Progress in the Yankee Fork exemplifies how a science based planning and stakeholder coordination lays a strong foundation necesasry for implementing large-scale habitat improvement actions. Habitat improvements addressing key limiting factors in the Yankee Fork also and sheds light on the large-scale planning efforts and time necessary to achieve the habitat benefits to meet the BiOp HQI.

The shared objectives of the Action Agencies with the Idaho Office of Species Conservation, Custer County, Shoshone-Bannock Tribes, Upper Salmon Basin Watershed Project, IDFG, Trout Unlimited, the U.S. Forest Service, Yankee Fork Interdisciplinary Team, landowners, and others affords the opportunity to develop projects of the scope and scale that have and will continue to be implemented in the Yankee Fork.

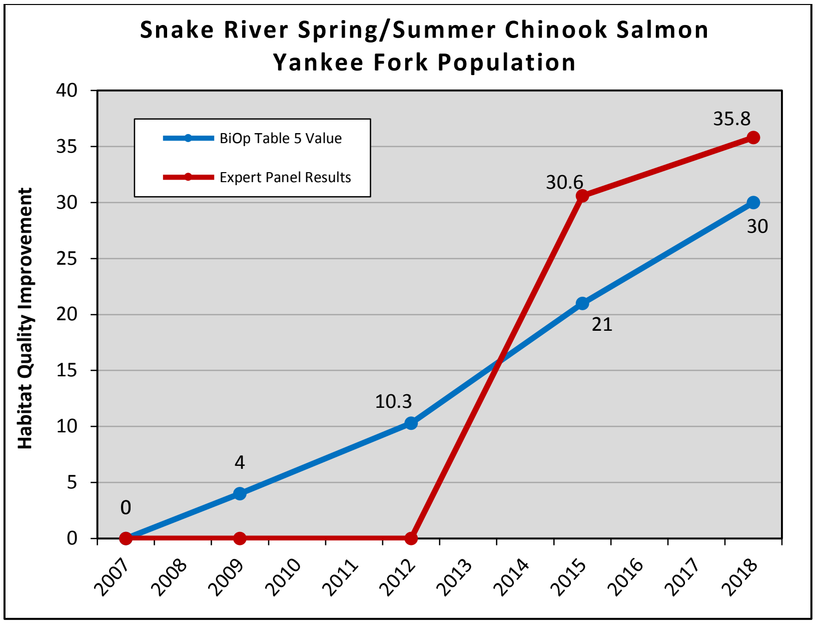


Figure 13. Habitat Quality Improvement, obtained through 2015 and projected through 2018, for the Yankee Fork population of Snake River Spring/Summer Chinook Salmon.

Upper Salmon above Redfish Lake Creek Population

The RPA Action 35 Table 5 2018 HQI for the Upper Salmon above Redfish Lake Creek population is 14 percent. Based on expert panel estimates and the Collaborative Habitat Workgroup (CHW) method (2007 FCRPS Comprehensive Analysis Appendix C) for estimating habitat improvements, implementation of tributary habitat actions through 2015 was sufficient to achieve a 16.9 percent habitat quality improvement. Actions evaluated by the expert panel for implementation between 2016 and 2018 are projected to achieve an additional 10.4 percent improvement, bringing the total to 27.3 HQI percent. Even though the Action Agencies were not projected to meet the HQI in the 2013 CE, the Agencies increased efforts on key limiting factors to yield greater benefits from projects already planned.

Since 2008 the Action Agencies have addressed stream flow, screening of diversions, passage barriers, and riparian and stream improvements to improve habitat and access. In 2012, the expert panel results projected a shortfall in achieving the HQI for this population. Since that time, with the strong commitment of partners including the Shoshone-Bannock Tribes, IDFG, U.S. Forest Service, and Custer SWCD, the Action Agencies implemented actiosn projected to exceed the standard for this population. With their partners the Action Agencies were able to expand the scope of projects like the Pole Creek project which addressed key limiting factors of barriers, flow, riparian conditions, sediment and water temperature and ultimately exceed the HQI. Pole Creek, a major tributary to the Upper Salmon River that contains important spawning and rearing habitat, achieved benefits far in excess of what was initially anticipated in planning with the landowner starting in 2008. Due to the large-scale opportunity to improve habitat access and increase instream flow via the Pole Creek suite of actions, the partners focused on this location rather than other areas in the AU. A shared interest in the need to enhance instream flows, improve riparian conditions, and remove barriers in Pole Creek led to actions that will allow private land owners to continue agricultural production while accelerating the ability of the stream to support salmon.

Work Between 2012 and 2015

Habitat actions evaluated by the expert panel in 2016 directly address key limiting factors and included changes in grazing management, flow enhancement, barrier removal, and riparian restoration. In 2014 and 2015 projects implemented in Pole Creek were especially critical to the overall success of addressing key limiting factors specifically replacing irrigation diversions to enhance instream flows (minimum 17 cfs), excluding livestock and planting riparian vegetation to improve riparian conditions and improve water temperatures along the margins of Pole Creek that were once grazed to the water's edge.

Work Projected for Completion Between 2016 and 2018

Although the HQI for this population has been met as of 2015, future work in the Upper Salmon above Redfish Lake Creek will continue to prioritize flow enhancement in Pole Creek and in other tributaries. One project referred to as the "Pole Creek Meadows" project channel relocation and instream habitat enhancement will complement previous efforts that enhanced flows, improved habitat, and removed barriers. Pole Creek Meadows project will restore the stream channel that was "abandoned" as a consequence of overgrazing and trampling by cattle. The channel to be restored has numerous active beaver dams and is heavily vegetated. The action will move 0.25 mile of Pole Creek from the incised channel back into the historic channel. Moving forward, the Action Agencies and their partners have initiated an assessment in the Upper Salmon to better understand habitat limiting factors and actions to improve them. The assessment will integrate information on geomorphology with biological information including estimates of carrying capacity and fish distribution to better characterize the location and treatment types necessary to improve conditions for fish.

Figure 14. Aerial view of the straightened, incised section of Pole Creek and the remnants of the historical channel.

HQI and Population Status

Tributary habitat actions implemented through 2015 were sufficient to achieve a 16.9 percent improvement in habitat quality. Actions evaluated by the expert panel for implementation between 2016 and 2018 are projected to achieve an additional 10.4 percent improvement, bringing the total to 27.3 percent.

These projections reflect the success of the partnership that has grown over time through the leadership of the U.S. Forest Service, the Custer SWCD, and the Shoshone-Bannock Tribes. Progress to date exemplifies what can be achieved through strong partnerships and stakeholder coordination. To build on this success, the Action Agencies and their partners will apply the results of the Tributary Assessment being developed for the Upper Salmon to better understand habitat limiting factors and actions to improve them.

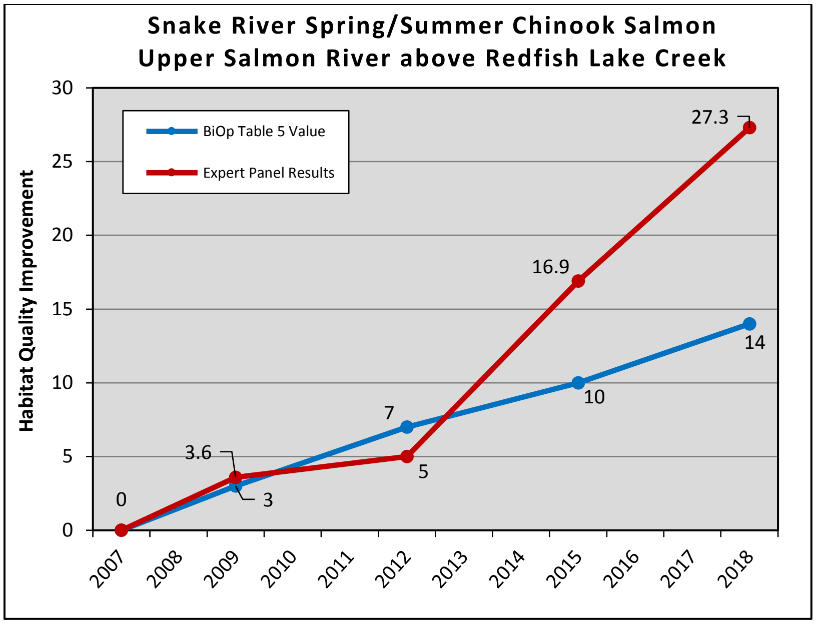


Figure 15. Habitat Quality Improvement, obtained through 2015 and projected through 2018, for the population of Snake River Spring/Summer Chinook Salmon on the Salmon River upstream of Redfish Lake Creek.

Catherine Creek Population

The RPA Action 35 Table 5 2018 HQI for the Catherine Creek population is 23 percent. Based on expert panel estimates and the Collaborative Habitat Workgroup (CHW) method (2007 FCRPS Comprehensive Analysis Appendix C) for estimating habitat improvements, implementation of tributary habitat actions through 2015 was sufficient to achieve a 10.8 percent habitat quality improvement. Actions evaluated by the expert panel for implementation between 2016 and 2018 are projected to achieve an additional 5.5 percent improvement, bringing the total to 16.3 percent. The anticipated shortfall is the result of significant implementation challenges the Action Agencies faced early during the implementation period, chief among them severely degraded habitat conditions throughout the majority of the river. The causes of habitat degradation included channel manipulation, agricultural development and grazing of the floodplain, vegetation removal and alteration, surface irrigation development, and the near extirpation of beaver. Cumulatively, these actions severely degraded salmon habitat quantity and complexity.

Thus, to implement beneficial actions in such severely degraded habitat, the Action Agencies had to develop and implement a systematic approach to identify and prioritize those actions that would be most likely to improve habitat—the Atlas Process and Tributary and Reach Assessments. The Action Agencies have implemented those systems, which produced the recent increases in the speed of action implementation. The Action Agencies experienced similar challenges in the Yankee Fork, but have shown their ability to overcome those challenges and successfully reach HQI, despite implementation delays.

Consistent with these themes, since 2008, the Catherine Creek population has been the focus of considerable effort by the Action Agencies and others to evaluate limiting factors and identify priority areas for habitat improvement. These efforts have included tributary and reach assessments completed by Reclamation and a fish tracking study (Favrot and

Jonasson 2015)[6,7]. The Action Agencies also facilitated a strategic prioritization process called the "Atlas" process to further identify the most appropriate and beneficial actions for implementation during the period of the BiOp. The Atlas process includes key elements from the watershed restoration principles as articulated in Roni et al. (2002, 2008) and Beechie et al. (2008, 2010), and based on a review of previous limiting factors assessments for the Catherine Creek population. This information showed habitat improvement targeted in the CCC3a and CCC3b AUs would provide the best biologically significant reaches to address limiting factors and focus on the key spawning and rearing locations. The AAs and partners focused implementation in the areas during the 2012–15 work window and plan to continue in 2016–18.

Expert panel deliberations in 2016 continued to focus on actions to improve summer rearing habitat, peripheral and transitional habitats, instream habitat complexity and floodplain function. As well, the panel continued to emphasize channel structure and form, temperature, water quantity, sediment, riparian enhancement, and barriers that remain among key limiting factors needing improvement.

The Action Agencies continue to use tributary and reach assessments, the Atlas Process and other information to identify habitat improvement actions focused in the assessment units and reaches with the greatest opportunity for change and targeted at the most significant limiting factors.

Work Between 2012 and 2015

Between 2012 and 2015 the Action Agencies and their partners prioritized reducing juvenile mortality and improving habitat conditions in critical spawning and rearing habitat. Habitat improvement work focused on increasing access, enhancing flow, increasing riparian cover, and increasing instream complexity are among the key limiting factors in Catherine Creek, between 2012 and 2015 one large scale multi-phase action was implemented to address limiting factors identified by the expert panel. The action centered around a key reach of Catherine Creek referred to by the expert panel as "CCC3b." The treatments, completed in three phases, were implemented in a four-mile reach near RM 44 and included substantial increases in pool habitat with large wood and cover, increased side-channel habitat and increased instream flow, improving conditions for juveniles[8].

---

[6] *Favrot, S., and B. Jonasson, Spring Emigration Reach-Specific Survival And Travel Time Of Catherine Creek Juvenile Spring Chinook Salmon Through The Grande Ronde Valley, March 2015. Based in the idea that understanding the location, magnitude, and sources of smolt mortality upstream of the hydrosystem is necessary for fisheries managers to allocate resources to improve survival (Monzyk et al. 2009), Favrot and Johasson examined natural and hatchery spring Chinook salmon smolt mortality within the Grande Ronde Valley migration corridor.*

[7] *This information, which the expert panel considered in identifying and weighting limiting factors, indicates that most existing fish production is in assessment unit (AU) CCC3b, and that this AU and AU CCC3a (the next reach downstream, which had significant productive habitat historically) are limited by a lack of summer rearing habitat and flow.*

[8] *In general, adult salmon access the higher reaches of Catherine Creek to access better quality habitat (e.g., cooler water temperatures) to spawn. Juveniles that emerge from the headwaters to rear in Catherine Creek in assessment units CCC3a and CCC3b suffer different degrees of mortality. Some fish move downstream out of Catherine Creek and into the Grande Ronde in the fall of the year. At this point it is unclear what happens to these fish. The fish that over winter in Catherine Creek suffer to some degree from density dependent mortality related to lack of quality habitat.*

The treatments included consolidating diversions that resulted in increased instream flows (3 cfs); adding several large wood structures to improve complexity; increasing the number of pools in the reach; enhancing floodplain connectivity; and increasing side-channel habitat. Other actions included screen replacements and securing a number of water leases to increase instream flows. The interaction and outreach with private landowners that is necessary to forge agreements for these actions can take as much if not more time than project implementation; nevertheless, this investment helps build trust and an improved understanding, which faciliates additional work in other areas of Catherine Creek.

Work Projected for Completion Between 2016 and 2018

Actions prioritized and planned for implementation between 2016 and 2018 will continue to focus on the same limiting factors that were addressed between 2012 and 2015. Both the tributary and reach assessments and the Atlas will continue to be used to prioritize the locations and the types of actions to be implemented. The Southern Cross Ranch project, a large-scale action located in CCC3b involved a land acquisition that facilitated instream work and almost one mile of channel reconstruction that occurred in 2016. The project was designed to address changes to Catherine Creek that resulted when the stream channel was moved to make room for a pasture decades ago. The new channel was engineered to approximate the sinuosity and depth of the historical channel. The new channel includes large deep pools, wood structures, and riparian enhancements. Functionally, the new channel is designed to access its floodplain annually. Other work planned for implementation between 2016 and 2018 includes flow acquisition, riparian enhancement, and instream work at existing high priority Chinook production areas in CCC3a and CCC3b (e.g., Southern Cross Ranch and Hall Ranch).

HQI and Population Status

Tributary habitat actions through 2015 were sufficient to achieve a 10.8 percent improvement in habitat quality. Actions evaluated by the expert panel for implementation between 2016 and 2018 are projected to achieve an additional 5.5 percent improvment, bringing the total to 16.3 percent.

Expert panel estimates of habitat improvements in Catherine Creek are not projected to meet HQI for this population by 2018. That said, improvements in Catherine Creek are trending as expected, and are anticipated to achieve the HQI over a longer period of time. The 2007 Comprehensive Analysis and the 2008 Supplemental Analysis acknowledged that it would take decades for habitat improvement actions in Catherine Creek to show substantial results in fish survival.[9,10] The logic underlying conclusions in the 2007 and 2008 analyses recognized that historical impacts to tributaries in Catherine Creek from water withdrawal, grazing, and timber production would take years to address.

Then, when they out-migrate the following spring they suffer high mortality prior to reaching the Grande Ronde (Favrot and Jonasson 2015).

9 *Making the needed productivity improvements for Catherine Creek and the Upper Grande Ronde populations, in particular, is expected to take a decades-long effort on the part of the Federal Government working with State, Tribal, and local interests, public and private (Page 5-31, CA).*

10 *For these populations, the problems that must be addressed in order to have higher R/S will take longer than 10 years to resolve. In particular, the water quality and quantity problems in the lower reaches of the Upper Grande Ronde and Catherine Creek will require a long-term program working with private landowners (Page 8.3-26 SCA).*

Since 2008, the Action Agency partners working with private land owners have become adept at implementing large scale projects like the Southern Cross Ranch project that substantially address key limiting factors. Implementing habitat improvement actions of the scale and complexity of actions in Catherine Creek depends on the participation of private landowners, many of whom rely on commodity production as an economic mainstay. Fostering understanding and support for habitat actions that are perceived to undermine commodity production can take time. As conditions across the sociopolitical and economic landscape allow, private landowners will continue to be brought into the work that benefits salmon in areas like Catherine Creek.

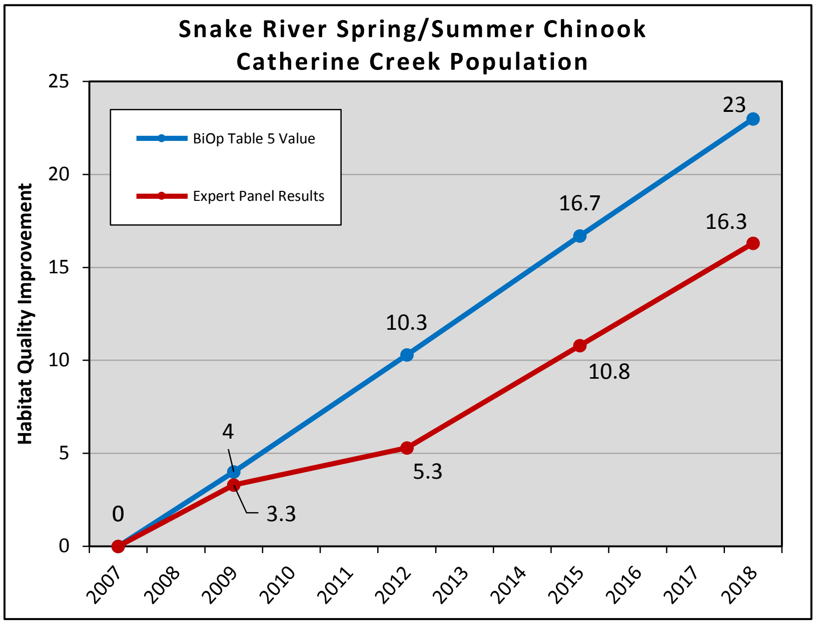


Figure 16. Habitat Quality Improvement, obtained through 2015 and projected through 2018, for the Catherine Creek population of Snake River Spring/Summer Chinook Salmon.

Grande Ronde Upper Mainstem Population

The RPA Action 35 Table 5 2018 HQI for this population is 23 percent. Based on expert panel estimates and the Collaborative Habitat Workgroup (CHW) method (2007 FCRPS Comprehensive Analysis Appendix C) for estimating habitat improvements, implementation of tributary habitat actions through 2015 was sufficient to achieve a 6.6 percent improvement. Actions evaluated by the expert panel for implemtation between 2016 and 2018 are projected to achieve an additional 2.6 percent improvement, bringing the total to 9.2 percent. As in Catherine Creek, the Action Agencies expect implementation actions in the Grande Ronde Upper Mainstem to fall short of the HQI. Here too, the anticipated shortfall is the result of significant implementation challenges the Action Agencies faced early during the implementation period, chief among them severely degraded habitat conditions throughout the majority of the river. Similar to Catherine Creek, watershed-wide changes to the landscape and the stream channel have significantly altered the historic habitat. Specific baseline negative impacts included channel alteration from splash-dam logging practices, agricultural development and grazing of the floodplain, vegetation removal and alteration, surface irrigation development, and the near extirpation of the beaver, all of which cumulatively reduced the quantity and quality of available salmon habitat. The Action Agencies faced the additional challenge here of an absence of landowner interest.

Therefore, to implement beneficial actions in such severely degraded habitat, the Action Agencies had to develop and implement a systematic approach to identify and prioritize those actions that would be most likely to improve habitat—the Atlas Process and Tributary and Reach Assessments. The Action Agencies have implemented those systems, which produced the recent increases in the speed of action implementation. Moreover, the Action Agencies have found increasing landowner interest in supporting habitat improvement projects. The Action Agencies experienced similar challenges in the Yankee Fork, but have shown their ability to overcome those challenges and successfully reach HQI, despite implementation delays.

Accordingly, since 2008 the Action Agencies have implemented actions to address key limiting facotrs to improve passage, increase habitat complexity, address degraded riparian conditions, improve water temperature, and reduce fine sediment. Because the actions evaluated by the 2012 expert panel were not projected to reach the HQI for this population the Action Agencies adapted a strategic approach to identify locations and actions anticipated to provide greater benefits to this population. This effort involved developing tributary and reach assessments to further guide actions implemented in the Upper Grande Ronde. In addition, the Action Agencies facilitated a strategic prioritization process called the "Atlas" process to further identify the most appropriate and beneficial actions for implementation during the period of the BiOp. Both processes show the upper reaches of the Grande Ronde mainstem have the best Chinook salmon production potential. Actions are prioritzed to address key limitin gfactors in these reaches. Some difficulty has been encountered at implementing substantial actions by 2018 with some landowners.

Expert panel deliberations in 2016 continued to emphasize the need to improve summer rearing habitat, peripheral and transitional habitats, and floodplain function.

Work Between 2012 and 2015

Between 2012 and 2015 the Action Agencies and their partners prioritized actions to be implemented in key tributary streams and headwater areas . The Atlas process added clarification and focused on improving high production Chinook spawning and rearing habitats. Working with the Grande Ronde Model Watershed, the CTUIR, Union Soil and Water Conservation District, ODFW, and the U.S. Forest Service to adjust the scope and scale of actions in the headwaters, the Action Agencies addressed riparian improvement, floodplain reconnection and reactivation, improved instream complexity, flow acquisition, and changes in grazing management. Through these efforts conditions in the Upper Grande Ronde tributaries were improved. The ODFW juvenile tracking study showed overwintering Chinook salmon juveniles extensively utilizing complex pool an dlarge wood and boulder structures previously implemented on U.S Forest Service lands. Because the planing an ddevelopment of the "anchor" project area in the higher meadows of the Grande Ronde River did not solidify, the partners moved to the next best areas during the work window to address key limiting factors. This strategy continues into the 2016–18 work window.

Work Projected for Completion Between 2016 and 2018

Work planned for implementation between 2016 and 2018 will continue to prioritize the limiting factors that were addressed between 2012 and 2015. Both the tributary and reach assessments and the Atlas were used to prioritize the locations and the types of actions to be implemented. One action planned is Bird Track Springs project, a large scale action located near Meadow Creek, in assessment unit UGC2, that will affect about one mile with treatments to enhance habitat complexity, restore floodplain function, and improve riparian condition. The action will restore features appropriate to the geomorphic characteristics of the valley and is just downstream of the highest Chinook salmon production area. Large wood enhancement, creation of pools, floodplain reactivation, and side channel reconnection are the primary features of this action. Work planned in other major tributaries to the Upper Grande Ronde on U.S. Forest Service land includes riparian enhancement and road decommissioning that will reduce stream temperatures.

HQI and Population Status

Tributary habitat actions through 2015 were sufficient to achieve a 6.6 percent improvement in habitat quality. Actions evaluated by the expert panel for implementation between 2016 and 2018 are projected to achieve an additional 2.6 percent improvement, bringing the total to 9.2 percent.

Expert panel estimates of habitat improvements in the Upper Grande Ronde are not projected to meet HQI for this population by 2018; however, substantial improvements continue to be planned and implemented, and are anticipated to achieve the HQI over a longer period of time. Since 2008, the partners have become adept at implementing large scale projects like the Bird Track Springs project that address key limiting factors. The 2007 Comprehensive Analysis and the 2008 Supplemental Analysis acknowledged that it would take decades for watershed-scale habitat improvement actions in the Upper Grande Ronde to show substantial results in fish survival.[11,12] The logic underlying conclusions in the 2007 and 2008 analyses recognized that historical impacts to tributaries in the Upper Grande Ronde from splash dam logging, grazing, and water withdrawals would take years to address.

Implementing habitat improvement actions of the scale and complexity of actions in the Upper Grande Ronde depends on the participation of private landowners, many who rely on commodity production as an economic mainstay. Fostering understanding and support for habitat actions that are perceived to undermine commodity production can take time. As conditions across the sociopolitical and economic landscape allow, private landowners will continue to be brought into the work that benefits salmon in areas like the Upper Grande Ronde.

[11] *Making the needed productivity improvements for Catherine Creek and the Upper Grande Ronde populations, in particular, is expected to take a decades-long effort on the part of the Federal Government working with State, Tribal, and local interests, public and private (Page 5-31, CA).*

[12] *For these populations, the problems that must be addressed in order to have higher R/S will take longer than 10 years to resolve. In particular, the water quality and quantity problems in the lower reaches of the Upper Grande Ronde and Catherine Creek will require a long-term program working with private landowners (Page 8.3-26 SCA).*

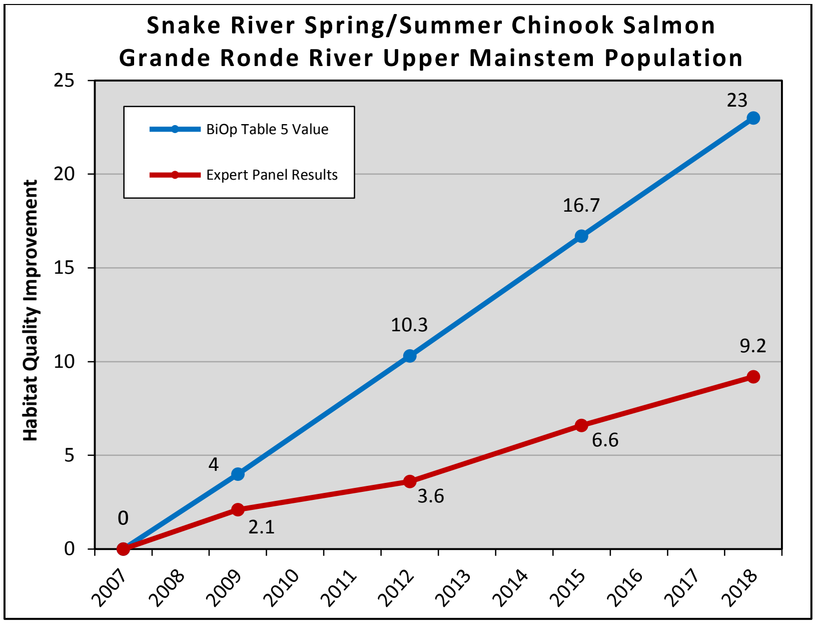


Figure 17. Habitat Quality Improvement, obtained through 2015 and projected through 2018, for the Grande Ronde River upper mainstem population of Snake River Spring/Summer Chinook Salmon.

Tucannon River Spring Chinook Population

The RPA Action 35, Table 5, 2018 HQI for this population is 17 percent. Based on expert panel estimates and the Collaborative Habitat Workgroup (CHW) method (2007 FCRPS Comprehensive Analysis Appendix C) for estimating habitat improvements, implementation of tributary habitat actions through 2015 was sufficient to achieve a 28.2 percent habitat improvement for this population. Actions evaluated by the expert panel for implementation between 2016 and 2018 are projected to achieve an additional 2.5 percent improvement, bringing the total to 30.7 percent. Though implementation efforts on the Tucannon River were slow to start, due to frontloaded ramp-up efforts, implementation speed has increased significantly, leading to the anticipated exceedence of the HQI by 2018.

The Tucannon River has been impacted by historical land uses for agriculture, logging, and grazing and by a history of wildfire. These, combined with channel straightening and diking, have degraded Chinook salmon spawning and rearing habitat. Substantial improvements over the past two decades have not yet reversed damage to the riverine ecosystem in the Tucannon, largely because of the magnitude of the damage and the effort needed to restore this system.

In 2012 when the expert panel determined that habitat improvement efforts were not sufficient to achieve the HQI for this population by 2018, the Action Agencies and their partners increased the level of support for habitat improvement actions in the subbasin. Specifically, BPA with the Salmon Recovery Board developed the details for the Tucannon River Programmatic Habitat Project. The development of the programmatic resulted in administrative efficiencies and greater flexibility in planning and timing the implementation of large scale actions. This greatly enhanced the Salmon Recovery Boards ability to implement actions in the Tucannon. Among the greatest benefits was the ability to implement large scale wood complexity projects in the upper reaches of the Tucannon.

The Salmon Recovery Board's efforts have also capitalized on the data developed as a function of the Tucannon River Geomorphic Assessment & Habitat Restoration Study Report (April 2011), the CHaMP project, and an EDT analysis that the Recovery Board commissioned. This information has shown where the highest production areas for Chinook salmon and the best locations and types of treatments to address key limiting factors. With outputs from these efforts the Salmon Recovery Board has been better able to focus their efforts.

Work Completed Between 2012 and 2015

Work evaluated by the expert panel for the 2012–15 period included a number of large multi-stakeholder efforts to increase habitat complexity and restore floodplain and side-channel habitat function in key Chinook spawning and rearing areas. This reach ustream of Pataha Creek (upper Tucannon River) was shown in the assessments described above to be the best reach to improve habitat for Chinook salmon. A fire in the upper reaches of the Tucannon in 2012 produced a significant amount of wood available for use instream. Efforts focused on dropping individual trees and installing large wood structures in a 10-mile reach to enhance pools and to reactivate the floodplain. A second focus between 2012 and 2015 addressed floodplain confinement along nine miles of the upper Tucannon. Levee and rip-rap removal, wood placement, and side channel reconnection were treatments designed to enhance channel complexity.
https://www.youtube.com/watch?v=kD9WChd2n6A
https://www.youtube.com/watch?v=FkTazatIX4Q

Figure 18. Large wood and habitat complexity treatments in the upper Tucannon River.

Work Planned for Completion Between 2016 and 2018

Work planned for implementation between 2016 and 2018 will continue to focus on the higherst salmon production reach (upper Tucannon), where riparian improvement, floodplain enhancement, side channel restoration, and enhanced instream complexity continue to be priorities for implementation. The Salmon Recovery Board has dedicated considerable time to monitor the effects of tributary habitat actions. This data as well as data developed from the CHaMP project will continue to be the foundation for "science-based" habitat improvement planning.

HQI and Population Status

Tributary habitat actions through 2015 achieved a 28.2 percent improvement in habitat quality. Actions evaluated by the expert panel for implementation between 2016 and 2018 projected an additional 2.5 percent improvement, bringing the total to 30.7 percent for this population. Since the [Tucannon River Geomorphic Assessment & Habitat Restoration Study Report (April 2011)] and local habitat improvement planning, actions have been quickly and extensively implemented to directly address key limiting factors.

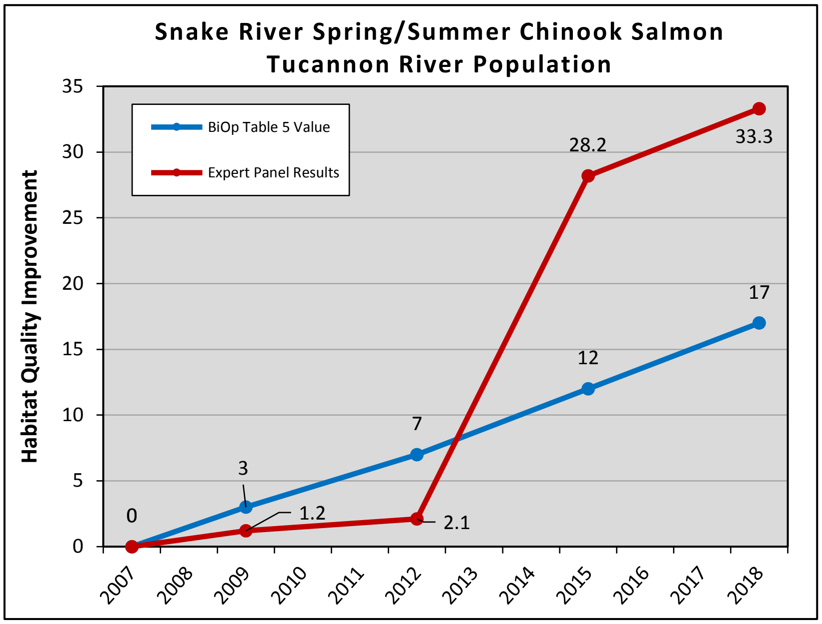


Figure 19. Habitat Quality Improvement, obtained through 2015 and projected through 2018, for the Tucannon River population of Snake River Spring/Summer Chinook Salmon.

Upper Columbia Spring Chinook:

For the Upper Columbia Spring Chinook ESU, implementation actions are expected to achieve 118 percent of the HQI by 2018 under the 2013 Implementation Plan Appendix D process. The Wenatchee River and Methow River populations are expected to exceed the HQI by 2018. While the Entiat River population is not expected to meet the HQI by 2018, the Action Agencies have employed implementation processes proven successful elsewhere to ramp up action implementation. Moreover, despite the implementation challenges the Action Agencies have encountered for the Entiat population, the Action Agencies have nonetheless made substantial progress (e.g., expected implementation of 92 percent of the HQI).

Entiat River Population

The RPA Action 35 Table 5 2018 HQI for the Entiat population is 22 percent. Based on expert panel estimates and the Collaborative Habitat Workgroup (CHW) method (2007 FCRPS Comprehensive Analysis Appendix C) for estimating habitat improvements, implementation of tributary habitat actions through 2015 was sufficient to achieve a 9 percent habitat quality improvement. Actions evaluated by the expert panel for implementation between 2016 and 2018 are projected to achieve an additional 11.3 percent improvement, bringing the total to 20.3 percent. The anticipated shortfall is the result of significant implementation challenges the Action Agencies faced early during the implementation period. To implement beneficial actions, the Action Agencies had to develop and implement a systematic approach to identify and prioritize those actions that would be most likely to improve habitat—the Tributary and Reach Assessments and resulting "Map Books" describing beneficail actions that are in geomorphic harmony with natural river processes. The Action Agencies are implementing the recommendations from those assessments, which are expected to produce increases in the speed of action implementation. The Action Agencies experienced similar challenges in the Yankee Fork, but have shown their ability to overcome those challenges and successfully reach HQI, despite implementation delays.

Since 2008, the Entiat population has been the focus of considerable effort by the Action Agencies and others to evaluate limiting factors and identify priority areas for habitat improvement. These efforts have included development of tributary and reach assessments and associated map books that have been used to prioritize actions and direct work that will be more effective in addressing limiting factors. These tools are designed to guide work based on geomorphological conditions of the stream. Specifically, actions are planned and developed to be in harmony with natural river processes that will be able to maintain their habitat characteristics after natural flooding and channel events post-implementation. In the Action Agencies view, the Entiat is another example of using a science-based approach to plan, design, and implement tributary habitat improvement actions. Testimony to the benefits of such an approach in the Entiat is movement from relatively simple complexity actions located in the confined portion of the lower Entiat to actions larger in scale and complexity in the unconfined middle Entiat where most of the spring Chinook salmon production has been recorded. This approach and information from monitoring that is illustrating the benefits of complexity projects (Polivka et al. 2015)[13] will continue to inform the Action Agencies in their efforts to design and implement projects to address key limiting factors in the Entiat.

Work Completed Between 2012 and 2015

Actions evaluated by the expert panel in 2012 were not projected to reach the RPA Action 35 Table 5 HQI for this population. Additional planning and development was started for the Middle Entiat reaches where the bulk of the spring Chinook salmon production takes place. Thework evaluated by the 2015–16 expert panel revealed a noteworthy increase in habitat improvements. The tributary and reach assessments and associated map books guided work on projects like the Harrison Side Channel Enhancement; the Tyee Floodplain, Side Channel, and Instream Complexity project; and the Dillwater Habitat Complexity project that will improve complexity and enhance floodplains and side channels. In 2013, the Action Agencies adopted a more targeted approach to solicite, plan and fund actions for implementation in the Entiat, guided by the assessments and expected to provide greater benefits to key limiting factors.

Work Planned to be Completed Between 2016 and 2018

Actions planned for implementation during 2016 to 2018 continue to build from the science based process that incorporates results of the tributary and reach assessments, details in

[13] *Polivka, K.M., E. Ashley Steele, and J.L. Novak. 2015. Juvenile salmon and steelhead occupancy of stream pools treated and not treated with restoration structures, Entiat River, Washington. Can. J. Fish. Aq. Sci. 72:1-9. Higher Chinook abundance was observed at restored pools and was apparently attributable to habitat capacity and not due to movement of fish from other natural habitat in the same reach (e.g., fish were not displaced from marginal habitat in the same reach).*

the map books, and monitoring results that were intended to identify the best ways to address key limiting factors at locations and with treatments that are appropriate given the geomorphology of the area. Treatments to address floodplain, side channel, and instream complexity enhancements in the Gray and Stormy reaches will affect four miles of the middle Entiat. Noteworthy about the work in the Gray and Stormy reaches is the scale and the scope of the treatments that will include the largest focused suite of channel enhancements implemented in a single assessment unit in the Upper Columbia.

Major challenges facing the Action Agencies and their partners in the Upper Columbia include the diversity of partners, complex permitting issues, conflicting legal mandates, the threat of litigation associated with floodplain development, and policies of the various partner agencies. Overcoming some of the obstacles to project implementation has taken time to conduct planning, project development, and public outreach

HQI and Population Status

Tributary habitat actions through 2015 were sufficient to achieve a 9 percent improvement in habitat quality. Actions evaluated by the expert panel for implementation between 2016 and 2018 are projected to achieve an additional 11.3 percent improvement, bringing the total to 20.3 percent. The HQI for this population is 22 percent to be achieved by 2018; and although the Action Agency efforts are projected to result in benefits slightly below that target, the Action Agencies are continuing to plan for and implement projects in the Entiat that will deliver benefits well beyond 2018.

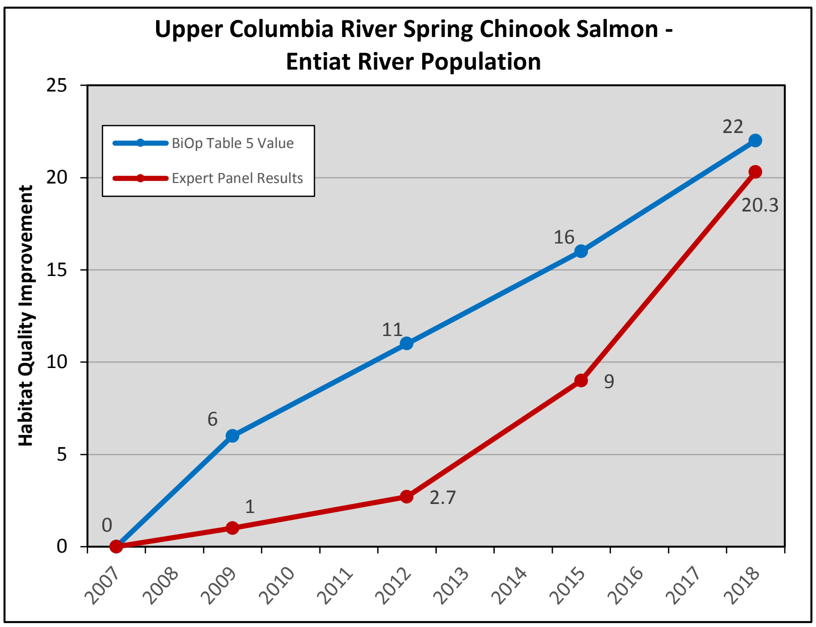


Figure 20. Habitat Quality Improvement, obtained through 2015 and projected through 2018, for the Entiat River population of Upper Columbia River Spring Chinook Salmon.

Snake River Steelhead:

The Snake River Steelhead DPS includes the following MPGs, for which the associated populations noted in parentheticals were evaluated in the 2014 Supplemental BiOp and are thus analyzed here: Clearwater River MPG (Lochsa River, Lolo Creek, and the South Fork Clearwater River) and the Salmon River MPG (Middle Fork Salmon River tributaries (Big, Camas, Loon creeks)

Under the 2013 Implementation Plan Appendix D HQI multiplier process, implementation actions are expected to realize 240 percent of the HQI for the entire Snake River Steelhead DPS by 2018. Implementation actions for the Clearwater River MPG are expected to achieve 68 percent and the Salmon River MPG is expected to achieve 525 percent of the HQI by 2018.

While three out of the four populations in the Clearwater River MPG are not expected to meet the HQI by 2018, the Action Agencies have employed implementation models proven successful elsewhere to ramp up action implementation. Moreover, despite the implementation challenges the Action Agencies have encountered for these three populations, the Action Agencies have nonetheless made substantial progress (e.g., expected implementation of 73 percent of the HQI for the Lolo Creek population and 64 percent of the HQI for the South Fork Clearwater River population) including implementation in the Lower Clearwater population not specifically identified in the 2008 BiOp Table 5.

Additionally, the Lower Snake MPG is expected to achieve 178 percent HQI and the Grande Ronde River MPG are expected to achieve 157 percent HQI for steelhead by 2018 using the Appendix D HQI multiplier process.

Lochsa River Population

The RPA Action 35 Table 5 2018 HQI for the Lochsa population is 16 percent. Based on expert panel estimates and the Collaborative Habitat Workgroup (CHW) method (2007 FCRPS Comprehensive Analysis Appendix C) for estimating habitat improvements, implementation of tributary habitat actions through 2015 was sufficient to achieve a 6.3 percent habitat quality improvement. Actions evaluated by the expert panel for implementation between 2016 and 2018 are projected to achieve an additional 0.6 percent improvement, bringing the total to 6.9 percent.

The Lochsa Subbasin contains 1,180 square miles of forest land, past and present management of which has degraded stream and riparian function and other processes critical to aquatic organisms. Factors limiting the abundance and productivity of the Lochsa steelhead include sediment, temperature, and loss of large wood and structural complexity. An extensive road network constructed to access timber on U.S. Forest Service and private lands is the primary reason for degradation of riparian condition, reduction of habitat complexity, and increase in water temperature passage (Ecovista 2003).

In 2012 the expert panel results indicated that actions identified for implementation through 2018 were not projected to meet the RPA 35 Table 5 HQI. Because of the success developing the Atlas in Catherine Creek, the Atlas process has begun for the Lochsa River. By focusing the efforts of local biologists on examining existing data to verify reaches of biological significance to the fish, project partners could identify opportunities for actions that would deliver more benefits to fish. Although the Atlas process in the Lochsa was not initiated in time to guide the actions implemented between 2012 and 2015, the effort is now underway and results should be available to guide future work. The Atlas process affords the opportunity to bring more data and information into setting priorities for implementation of habitat actions consistent with NOAA objectives to use a science based approach for identifying actions that better address key limiting factors.

Work Between 2012 and 2015

Between 2012 and 2015 the Action Agencies and their partners prioritized actions to reduce sediment in the Lochsa system to address key limiting factors and the historic impacts from logging and road building. Unique to the Lochsa is the extensive work to understand the sediment budget in the system. The U.S. Forest Service's GRAIP[14] model has been used to better understand where and how to prioritize road decommissioning and sediment stabilization projects. With the increase in understanding of the key limiting factors and the best way to address them, the AAs and partners have a better, more science-based approach to habitat improvement. Specific treatments included road decommissioning and relocation, improving riparian conditions, and controlling invasive plant species.

Work Projected for Completion Between 2016 and 2018

The expert panel evaluated sediment reduction and invasive plant control actions planned for implementation between 2016 and 2018. The work that continues to emphasize sediment reduction will be addressed by road decommissioning and relocation, riparian planting, and invasive plant control. In addition to efforts to reduce sediment inputs to the Lochsa, barrier removal and large wood treatments in tributaries of the Lochsa will also be implemented. In 2016 the expert panel also discussed the opportunity that the Action Agencies and their partners anticipate as they develop the Atlas and a more strategic approach for identifying actions for implementation in the Lochsa and its tributaries.

HQI and Population Status

Tributary habitat actions through 2015 were sufficient to achieve a 6.3 percent improvement in habitat quality. Actions evaluated by the expert panel for implementation between 2016 and 2018 are projected to achieve an additional 0.6 percent improvement, bringing the total to 6.9 percent.

After the 2012 expert panel evaluation the Action Agencies recognized that achieving the HQI in the Lochsa would require more time and a more strategic approach for identifying actions to benefit fish. The Lochsa watershed and the extent of impacts from historic land use are vast. Given this, the Action Agencies recognized the need for a long-term and well thought out process for identifying actions to improve conditions for steelhead in this system. To accomplish this, the Action Agencies and partners initiated the Atlas process in the Lochsa. The success of the Atlas process rests in the data and information that can be brought to bear on decisions regarding "where" and "how" to implement actions that will result in the greatest benefits for fish in this system. To date, the Atlas team has assembled GIS data and interactive maps that will be used to identify the intrinsic potential and biological significance of various reaches. When completed, the product of the Atlas process will be used to identify priorities for implementing tributary habitat actions.

---

[14] http://www.fs.fed.us/GRAIP/
http://www.treesearch.fs.fed.us/pubs/40655

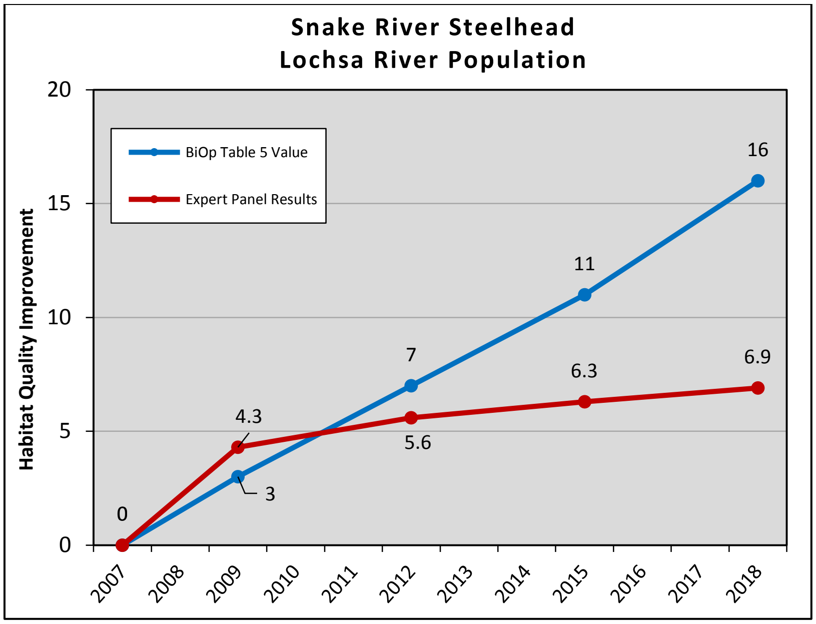


Figure 21. Habitat Quality Improvement, obtained through 2015 and projected through 2018, for the Lochsa River population of Snake River steelhead.

South Fork Clearwater River Population

The RPA Action 35, Table 5, 2018 HQI for this population is 14 percent. Based on expert panel estimates and the Collaborative Habitat Workgroup (CHW) method (2007 FCRPS Comprehensive Analysis Appendix C) for estimating habitat improvements, implementation of tributary habitat actions through 2015 was sufficient to achieve a 7 percent improvementActions evaluated by the expert panel for implementation between 2016 and 2018 are projected to achieve an additional 2 percent improvement, bringing the total to 9 percent.

Aquatic ecosystems in the Clearwater have been impacted by road construction, timber harvest, livestock grazing, and mining (Ecovista 2003). Because much of the Clearwater is steep and typified by high gradient drainages the logistics necessary to implement habitat improvement actions in the Clearwater is difficult. Local knowledge and investigations from IDFG and the Nez Perce Tribe have shown the high-use steelhead areas which have guided the partners implementing habitat actions in the South Fork Clearwater to derive steelhead benefits in the most important locations. Floodplain reconnection, side channel enhancement, instream structural improvement, and reclamation of historic mine sites are among the actions that have been implemented in the South Fork Clearwater since 2008. These actions are addressing stream complexity, degraded riparian condition, and impaired floodplain function to provide access to quality spawning and rearing habitat and improve water quality.

Work Between 2012 and 2015

Between 2012 and 2015 the Action Agencies and their partners prioritized actions to enhance complexity, improve degraded riparian habitat, restore floodplain connectivity, and provide access to habitat that address the key limiting factors. The partners working in the

South Fork Clearwater have a sound understanding of the issues and so have worked to address what would be considered the obvious problems. Livestock grazing and mining that have severely impacted low gradient reaches of the South Fork Clearwater have benefitted from large-scale habitat improvement actions. The partners have used monitoring data to identify the key steelhead spawning habitats and to guide where habitat improvement actions have been implemented up to this point. Specific treatments included barrier removal, riparian enhancement, road decommissioning, floodplain reconnection, and reclamation of historic mine sites. Specific work has been focused in Newsome Creek, Crooked Creek, American River, Red River and Meadow Creek.

Work Projected for Completion Between 2016 and 2018

The expert panel evaluated barrier removal, riparian enhancement, side channel and floodplain enhancement, sediment reduction, and instream structural complexity actions for implementation in areas that are the most important for steelhead production. The scope and scale of actions planned for implementation in the South Fork Clearwater necessitates a multi-year approach to planning, design, and implementation.

HQI and Population Status

Tributary habitat actions through 2015 were sufficient to achieve a 7 percent improvement in habitat quality. Actions evaluated by the expert panel for implementation between 2016 and 2018 are projected to achieve an additional 2 percent improvement, bringing the total to 9 percent.

After the 2012 expert panel workshop the Action Agencies recognized that achieving the HQI in the South Fork Clearwater would require more time and a more strategic approach for identifying actions to benefit fish. The extent of impacts from historic land use in the South Fork Clearwater is vast. Given this, the Action Agencies recognized the need for a long-term approach to implementing actions and improving conditions for steelhead in this system. For this reason the Action Agencies have continued to support an approach that facilitates implementation of actions that are large in scope and scale and projected for implementation over a long timeframe.

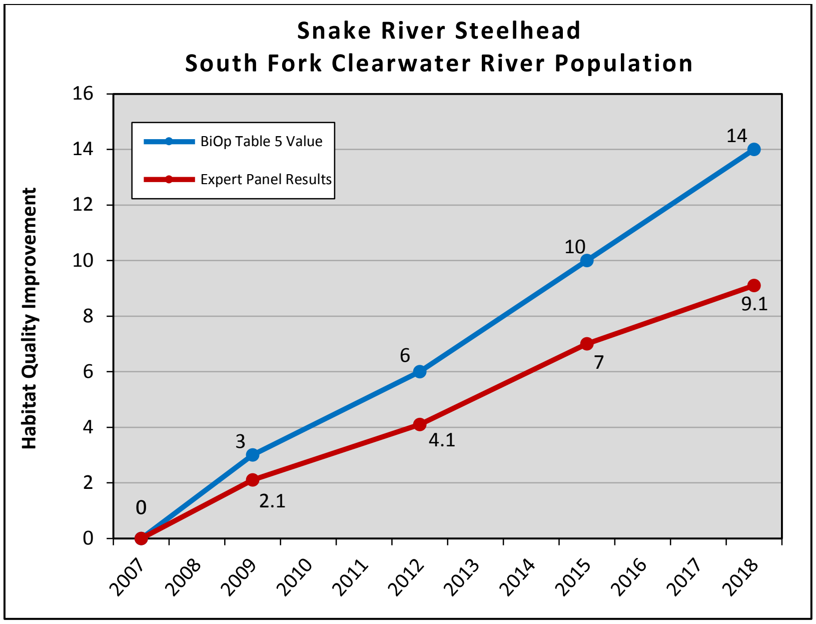


Figure 22. Habitat Quality Improvement, obtained through 2015 and projected through 2018, for the South Fork Clearwater River population of Snake River steelhead.

Lolo Creek Population

The RPA Action 35, Table 5, 2018 HQI for this population is 12 percent. Based on expert panel estimates and the Collaborative Habitat Workgroup (CHW) method (2007 FCRPS Comprehensive Analysis Appendix C) for estimating habitat improvements, implementation of tributary habitat actions through 2015 was sufficient to achieve a 7.1 percent habitat improvement. Actions evaluated by the expert panel for implementation between 2016 and 2018 are projected to achieve an additional 1.7 percent improvement, bringing the total to 8.8 percent.

Previous estimates of the benefits from habitat improvement actions showed greater progress in Lolo Creek than is reported here. This relates, in part, to a better understanding of the habitat available to steelhead in Lolo Creek that resulted in reconsideration of the benefits realized to date in Lolo Creek. Regardless, treatments continue to address impacts from historic logging, mining, livestock grazing, and recreation. Timber harvest and road construction and grazing and mining in localized areas have degraded conditions that continue to be addressed by actions to remove barriers, improve riparian condition, restore channel structure and habitat complexity and improve water quality.

Work Between 2012 and 2015

The Lolo Creek population and the lower watershed is in a steep inaccessible canyon with little alteration. That said, the Action Agencies and partners remain committed to improving steelhead production areas in the headwaters of Lolo Creek. Between 2012 and 2015 the Action Agencies and their partners prioritized barrier removal, floodplain reconnection, riparian enhancement, sediment reduction, improving instream habitat complexity, and improving water temperature.

Work Projected for Completion Between 2016 and 2018

The expert panel evaluated floodplain restoration and road decommissioning actions planned for implementation between 2016 and 2018. The Action Agencies will continue to implement actions to improve Lolo Creek based on local knowledge of the primary areas of fish use and of sites impacted by timber harvest, grazing, and mining that would most benefit from treatment.

HQI and Population Status

Tributary habitat actions through 2015 were sufficient to achieve a 7.1 percent improvement in habitat quality. Actions evaluated by the expert panel for implementation between 2016 and 2018 are projected to achieve an additional 1.7 percent improvement, bringing the total to 8.8 percent.

Previous estimates of the benefits from habitat improvement actions showed greater progress in Lolo Creek than is reported here. With better understanding of the habitat available to steelhead in Lolo Creek the expert panel "recalibrated" how the estimate of benefits to this population from habitat actions. Thus, improvements from treatments to address impacts from historic logging, mining, and livestock grazing were adjusted by the panel to more accurately reflect progress in achieving HQI. With this in mind, the Action Agencies will continue to implement actions necessary to remain on the trajectory toward improved conditions for this population.

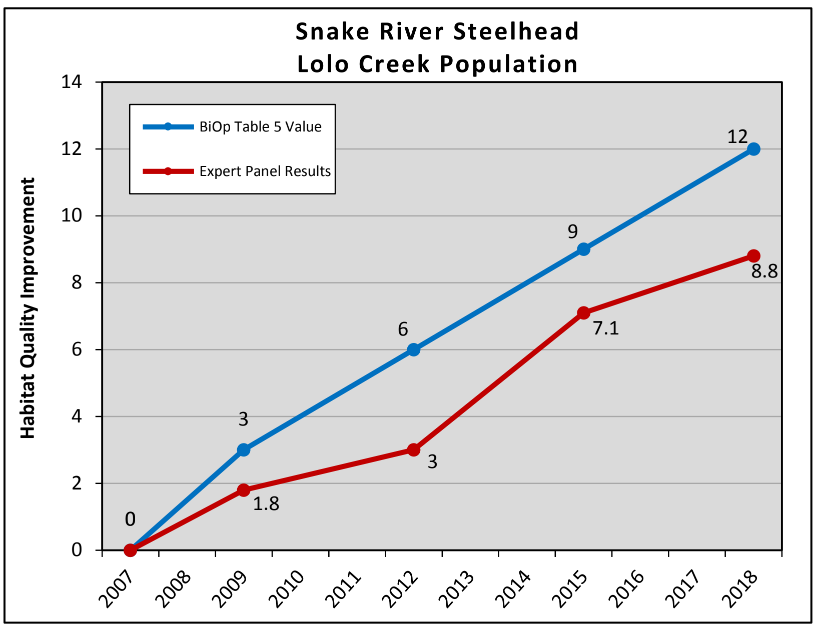


Figure 23. Habitat Quality Improvement, obtained through 2015 and projected through 2018, for the Lolo Creek population of Snake River steelhead.

Lower Middle Fork Mainstem (Big, Camas, Loon creeks) Steelhead Population

The RPA Action 35, Table 5, 2018 HQI for this population is 2 percent. Based on expert panel estimates and the Collaborative Habitat Workgroup (CHW) method (2007 FCRPS

Comprehensive Analysis Appendix C) for estimating habitat improvements, implementation of tributary habitat actions through 2015 was sufficient to achieve a 0.5 percent improvement. Actions evaluated by the expert panel for implementation between 2016 and 2018 are projected to achieve an additional 0.7 percent improvement, bringing the total to 1.2 percent.

The Big, Camas, and Loon creek steelhead populations have been impacted by grazing and impediments to passage. In general, there are limited opportunities for habitat improvement in these drainages that are generally remote with few roads and limited overall disturbance. The primary disturbance in these drainages is from grazing. Thus, in the past actions to reduce sediment inputs and minimize livestock impacts to the creeks has been the primary focus.

Work Completed Between 2012 and 2015

In 2015 the expert panel evaluated work in upper and lower Big Creek to remove barriers and change grazing management to reduce impacts on stream habitat. Work in Loon Creek was addressed by prior expert panels.

Work Planned for Completion Between 2016 and 2018

Worked planned for implementation between 2016 and 2018 includes road decommissioning, securing changes in grazing management, and barrier removal in Big Creek. Changes in administration of U.S. Forest Service land in Big and Camas creeks are a primary interest of the Action Agencies because it is believed such a change would produce greater benefits to fish in these drainages. Big, Camas, and Loon creeks are core “sub-populations” of the Lower Middle Fork Salmon population. Considered at the ESU scale concerns, if Big and Camas creek represent sub-populations of importance (the status that would influence conclusions about recovery potential), then efforts to change grazing management in Big and Camas creeks should be pursued.

HQI and Population Status

Tributary habitat actions through 2015 were sufficient to achieve a 0.5 percent improvement in habitat quality. Actions evaluated by the expert panel for implementation between 2016 and 2018 are projected to achieve an additional 0.7 percent improvement, bringing the total to 1.2 percent. Treatments to address impacts from historic grazing will continue to be implemented to keep the Action Agencies on the trajectory toward improved conditions for this population.

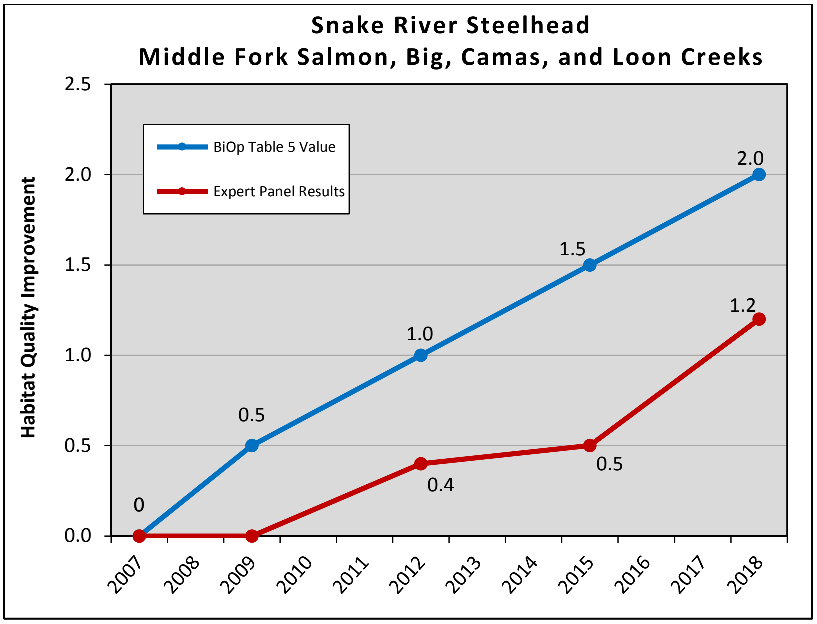


Figure 24. Habitat Quality Improvement, obtained through 2015 and projected through 2018, for the Lower Middle Fork Salmon River (Big, Camas and Loon creeks) population of Snake River steelhead.

RPA Subaction Implementation

The Action Agencies will identify additional habitat projects for implementation based on the population specific overall habitat quality improvement still remaining in Table 5 (of the 2008 FCRPS BiOp RPA) below. Projects will identify location, treatment of limiting factor, targeted population or populations, appropriate reporting metrics, and estimated biological benefits based on achieving those metrics. Pertinent new information on climate change and potential effects of that information on limiting factors will be considered.

The Action Agencies continue to uphold the commitment to improve tributary habitat conditions for 56 populations of ESA-listed salmon and steelhead in the Interior Columbia River Basin. Since 2008 the Action Agencies have implemented hundreds of tributary habitat improvement actions at an aggressive pace throughout the Interior Columbia River basin and have provided estimates of the projected survival benefits consistent with methods described in the 2008 BiOp.

The results from the 2012 expert panel process were reported in the 2013 Comprehensive Evaluation and were additionally analyzed and discussed in the 2014 FCRPS Supplemental BiOp. Most of the populations had achieved the HQI outlined in the 2008 BiOp or were estimated to meet them by 2018. The ten populations that were <33 percent and/or because supplemental actions had not yet reviewed by an expert panel by the end of 2011 were discussed in more detail in the 2014 Supplemental BiOp.

In 2012, when expert panel results indicated that progress along the trajectory to achieving the BiOp's HQI for habitat quality improvement was lagging for some populations, the Action Agencies worked with their implementation partners to identify and develop supplemental actions in efforts to improve progress. These populations specifically discussed in the 2014 Supplemental BiOp.

a. *During 2010 to 2018, the Action Agencies will provide funding and/or technical assistance to implement specific habitat projects to achieve the specified habitat quality improvements listed in Table 5. Habitat quality improvements associated with projects will be estimated in advance of project selection by expert panels. The Action Agencies will convene expert panels to estimate changes in habitat limiting factors from the implementation of Action Agency habitat actions.*

1) *The Action Agencies shall convene an expert panel to evaluate the percent change in overall habitat quality at the population scale from projects implemented previously (if quantitative objectives not met) and projects proposed for the implementation until the next check-in.*

The Action Agencies convened expert panel workshops in the following locations and during the following dates:

Table 12. 2015 and 2016 Expert Panel meeting locations and dates.

Panel	Workshop Dates	Location
Lower Snake, Look Back	Oct 27–28, 2015	Dayton, WA
Lower Snake, Look Forward	May 18–19, 2016	Dayton, WA
Upper Grande Ronde, Look Back	Dec 1–3, 2015	La Grande, OR
Upper Grande Ronde, Look Forward	Mar 8–10, 2016	La Grande, OR
Clearwater, Look Back	Feb 9–11, 2016	Lewiston, ID
Clearwater Look Forward	Jun 7–9, 2016	Lewiston, ID
Upper Salmon, Look Back	Nov 17–19, 2016	Salmon, ID
Upper Salmon, Look Forward	Mar 22–24, 2016	Salmon, ID
Lower Salmon, Look Back and Look Forward	Apr 20–22, 2016	McCall, ID
Wallowa/Lostine, Look Back and Look Forward	May 3–4, 2016	Enterprise, OR
Upper Columbia, Look Back	Feb 24–25, 2016	Wenatchee, WA
Upper Columbia, Look Forward	Jun 21–23, 2016	Wenatchee, WA

2) *The Action Agencies will continue to maintain a data management system for storing the material compiled, reviewed, and finalized by the expert panels. The expert panel will use methods consistent with the NWF v NOAA Fisheries E Remand Collaboration Habitat Workgroup process.*

The Action Agencies continue to maintain the Pisces and Taurus data management systems for storing expert panel work products. The expert panel work products are developed as output of the Collaboration Habitat Workgroup process to evaluate changes in habitat limiting factors associated with completed and planned actions. Any changes to planned actions are revised as necessary during the expert panel workshop are updated in cbfish.org where the expert panel data are stored.

3) *Project proposals will clearly describe the completed project in terms of quantitative habitat metrics which can be used to quantitatively evaluate progress and completion of individual projects.*

Project proposals that are developed and tracked in the Pisces and Taurus systems, which BPA administers includes a breakdown of habitat work elements and metrics that support BiOp accomplishments. Similarly, Reclamation’s annual report of completed habitat projects includes a breakdown of the metrics and other project details that support BiOp accomplishments.

4) *The Action Agencies will use the expert panels to provide input on changes in habitat quality and function as a result of limiting factor improvements from project actions for the priority population areas and this information will be used to assess improvements to salmonid survival.*

   The Action Agencies convened expert panel workshops in 2015 and 2016, during which time the panels estimated changes in limiting factor function expected to result from habitat improvement actions implemented between 2012 and 2015 as well as any actions planned for implementation that had not yet been evaluated by an expert panel. Habitat Quality Improvement (HQI) estimates were then compiled and calculated by the Action Agencies for the "Look Back" (2012 to 2015) and the "Look Forward" (2016 to 2018).

5) *If actions from the previous cycle prove infeasible, in whole or in part, the Action Agencies will ensure implementation of comparable replacement projects in the next implementation plan cycle to maintain estimated habitat quality improvements at the population level and achieve equivalent survival benefits. If infeasible at the population level, then alternatively replacement projects will be found to provide benefits at the MPG or ESU/DPS level. Selection of replacement projects to ensure comparable survival benefits will be made based on input from expert panels, regional recovery planning groups, the Northwest Power and Conservation Council, and NOAA Fisheries.*

   The Action Agencies will continue to fund, provide technical assistance for, and implement habitat actions identified in the 2014–2018 IP and the "Look Forward" list from the 2016 expert panels through 2018. Actions determined to be infeasible, in whole or in part, will be replaced with comparable actions. Local watershed groups, which generate proposals for the expert panel process, typically maintain lists of actions that can replace actions determined to be infeasible. The Action Agencies record of accomplishments clearly reflects the commitment to continue to implement habitat improvement actions to benefit the listed priority and non-priority populations in the Columbia Basin. For the 56 populations under this FCRPS consultation, actions completed in 2015 were guided by assessments from the 2012 Expert Panels, the 2010–2013 Implementation Plan[15] (2010–2013 IP) (FCRPS 2010a) and the 2014–2018 IP (BPA et al. 2014b), watershed planning efforts, tributary and reach assessments, and in some cases products from the Atlas process. Physical metrics for 2015 (e.g., acres of habitat, acre feet of flow) associated with habitat actions are reported consistent with the format of RPA Action 35 Table 5 (Table A-1 in Appendix A, below)). Cumulative habitat quality improvement and survival estimates for the 56 populations from 2007 through 2011 were reported in the 2013 Comprehensive Evaluation (2013 CE) (BPA et al. 2014c). Updated estimates are included in this document in Appendix A, Table A-2, below.

[15] *RPA Action 35 calls for development of implementation plans at three-year intervals between 2010 and 2018. The first implementation plan (IP) was developed for the period between 2010 and 2013 (FCRPS 2010a). The 2014-2018 IP (BPA et al. 2014b) includes specific habitat actions for a five-year (rather than a three-year) period, in response to the 2011 Court Order on the remanded 2010 FCRPS BiOp. The actions in the 2014-2018 IP specify location, treatment/action type, limiting factor (ecological concern), population, metrics, and estimated biological benefits.*

6) *The Action Agencies will continue to work cooperatively with the Council to identify priorities and obtain ISRP review of projects proposed for BPA funding.*

The Action Agencies continue to cooperate with the Northwest Power and Conservation Council (NPCC) to identify program priorities and obtain Independent Scientific Review Panel (ISRP) review of projects as appropriate. Since 2008, project sponsors have been directed to identify the BiOp relevance of proposed actions in their proposals. The Action Agencies included charts showing limiting factors and their weights in the template for the geographic categorical review to encourage proposals for habitat actions that would result in the greatest benefits to fish populations.

7) *RME will inform the relationship between actions, habitat quality and salmon productivity for use in a model developed through the FCRPS RME Strategy 3, Action 57 and new scientific information will be applied to estimate benefits for future implementation.*

The Action Agencies have entered into the sixth year of monitoring under the Columbia Habitat Monitoring Program (CHaMP) project. CHaMP and the Integrated Status and Effectiveness Monitoring Program (ISEMP) provide data on habitat status and trends and fish presence and abundance that are being used to develop population specific life cycle models and models developed for meta-population analysis. Recognizing the unique benefits of site specific and large scale monitoring efforts, the Action Agencies are currently involved in summarizing what has been learned from action effectiveness monitoring, to develop a Research, Monitoring, and Evaluation (RME) framework for large scale monitoring programs like CHaMP and ISEMP, and to provide funding through 2018 to continue Reclamation's tributary and reach assessments and studies like the ODFW study in Catherine Creek, that have shed light on the importance and benefit of tributary habitat actions. RME products were used during the 2015–16 expert panel workshops and are described in the Improvements to the Expert Panel Process section above.

8) *If new scientific or other information (except incomplete implementation or project modifications) suggests that habitat quality improvement estimates for projects from the previous cycle were significantly in error, the Action Agencies will examine the information and review the project or projects in question and their estimated benefits. This review will occur as part of the 2009 Annual Report and the Comprehensive RPA Evaluations in 2013 and 2016 and will be performed in conjunction with NOAA Fisheries. In the event such review finds that habitat quality improvement benefits were significantly overstated, the Action Agencies will implement replacement projects (selected as per Action 35 above) to provide benefits sufficient to achieve the habitat quality improvement and population-or MPG-specific survival benefit estimated for the original project or projects.*

New scientific or other information has not suggested that previous habitat quality improvement estimates are significantly in error. RME data and result were utilized during the 2015–16 Expert Panel process and used in discussions of habitat limiting factors and estimates of habitat quality improvement. New information on the habitat quality improvement estimates and discussions of habitat limiting factors for actions from 2012 to 2015 "Look Back" and from the 2016 to 2018 "Look Forward" were examined as part of the 2016 expert panel workshops. The AAs and the expert panels did not see any changes to the process from previous information or conclusions.

b. *During 2010–2018, for non-bolded populations in Table 5, the Action Agencies may provide funding and/or technical assistance for replacement projects should they become necessary for the Action Agencies to achieve equivalent MPG or ESU survival benefits.*

The Action Agencies continue to uphold the commitment to improve conditions for listed priority and non-priority salmon and steelhead populations in the Columbia Basin. Since 2008 the Action Agencies have implemented numerous habitat actions at an aggressive pace throughout the Columbia River basin and have provided detailed accounting of the benefits to listed priority and non-priority populations from these actions. In 2012, when expert panel results indicated that progress along the trajectory to achieving the BiOp's HQI was lagging for some populations, the Action Agencies worked with their implementation partners to identify and develop supplemental actions in efforts to improve progress. As displayed in the previous sections, based on the latest information and analysis from the expert panel process, some of these remaining populations are expected to meet the HQI by the end of 2018, and some are not. The Action Agencies will consider this information as they develop their proposed action for the next consultation with NOAA.

In addition, the Action Agencies are including in this CE current information regarding the status of habitat implementation achievements at the ESU/DPS level, utilizing the ICTRT population sizes and the HQI multipliers associated with those populations, as previously described in Appendix D to the 2013 CE. As that Adjusted HQI Table shows (Appendix A, Table A-2 below), the HQI percentages through 2018 for habitat implementation actions all exceed the BiOp commitments, in some cases by a large amount, reflecting the significant program of work delivering benefits to fish at the ESU/DPS scale.

The Action Agencies' record of accomplishments clearly reflects the commitment to continue to implement habitat improvement actions to benefit the listed priority and non-priority populations in the Columbia Basin. BPA and Reclamation continue to fund and provide technical assistance to improve habitat for more than 80 interior Columbia Basin spring/summer Chinook and summer/winter steelhead populations. For the 56 populations under this FCRPS consultation, actions completed in 2015 were guided by the 2010–2013 IP[16] (FCRPS 2010a) and the 2014–2018 IP (BPA et al. 2014b), watershed planning efforts, tributary and reach assessments, and in some cases products from the Atlas process. Physical metrics for 2015 (e.g., acres of habitat, acre feet of flow) associated with habitat actions are reported consistent with the format of RPA Action 35, Table 5, (Table A-1 in Appendix A, below). Cumulative habitat quality improvement and survival estimates for the 56 populations from 2007 through 2011 were reported in the 2013 Comprehensive Evaluation (2013 CE) (BPA et al. 2014c). Updated estimates are included in this document in Table A-2 in Appendix A.

[16] *RPA Action 35 calls for development of implementation plans at three-year intervals between 2010 and 2018. The first implementation plan (IP) was developed for the period between 2010 and 2013 (FCRPS 2010a). The 2014-2018 IP (BPA et al. 2014a) includes specific habitat actions for a five-year (rather than a three-year) period, in response to the 2011 Court Order on the remanded 2010 FCRPS BiOp. The actions in the 2014-2018 IP specify location, treatment/action type, limiting factor (ecological concern), population, metrics, and estimated biological benefits.*

RPA Action 36 – Estuary Habitat Implementation 2007 to 2009

The Action Agencies will provide funding to implement specific actions identified for implementation in 2007–2009 as part of a 10-year estuary habitat program to achieve the estimated ESU survival benefits of 9.0 percent and 6.0 percent for ocean type and stream-type ESUs, respectively. Projects in an early state of development such that quantitative physical metrics have not been related to estimated survival benefits will be selected per Action 37. If projects identified for implementation in 2007–2009 prove infeasible, in whole or in part, the Action Agencies will implement comparable replacement projects in 2010–2013 to provide equivalent habitat benefits needed to achieve equivalent survival benefits.

Actions for this RPA Action are found in the 2009 FCRPS Annual Report (FCRPS 2010b). Some projects scheduled for completion in 2007–2009 were carried forward to the 2010–2013 period and the associated benefits are included in the estimates for the 2010–2013 implementation cycle.

During the 2007–2009 implementation period some projects proved infeasible in whole or in part. The Action Agencies implemented additional projects in 2010–2013 to provide survival benefits equivalent to those of the projects that proved infeasible. This RPA Action is complete and, as envisioned by the RPA, estuary habitat implementation through 2018 is being continued under RPA Action 37.

RPA Action 37 – Estuary Habitat Implementation 2010 – 2018 – Achieving Habitat Quality and Survival Improvement Targets

The Action Agencies will provide funding to implement additional specific projects as needed to achieve the total estuary survival benefits identified in the FCRPS BA. Projects will identify location, treatment of limiting factor, targeted ESU/DPS or ESUs/DPSs, appropriate reporting metrics, and estimated biological benefits based on the achieving of those metrics. Pertinent new information on climate change and potential effects of that information on limiting factors will be considered.

In 2015, the Action Agencies provided funding for projects that would contribute toward achieving the total FCRPS BiOp estuary survival benefits called for by 2018. Most projects implemented in the estuary are selected on an annual basis. Out year planning and scheduling was also conducted.

The Action Agencies use the Expert Regional Technical Group (ERTG) to evaluate the design and likely biological benefits of specific estuary habitat projects to juvenile salmonids form interior Columbia populations. The ERTG members base their advice on a combination of the best available scientific and technical information and their individual expert opinions. They evaluate habitat quality and quantity, access (which includes fish entering the site and prey organisms exported from the site to the main channel), and the likelihood that the project will function as designed. The ERTG incorporates the results of the RPA RME findings for estuary habitat (RPA actions 58-61) into their evaluation process as they become available.

In 2015, the Action Agencies completed on-the-ground habitat actions for seven projects in the estuary. (See Appendix B, Table B-1 for status of projects.) These projects yielded 3.40 Ocean Survival Benefit Units (SBUs) and 1.20 Stream SBUs by restoring 1,321 acres throughout the Columbia River estuary. The Action Agencies continue to plan, develop and implement additional projects. Projects completed in 2016 yielded 3.73 Ocean SBUs and 1.20 Stream SBUs.

Through 2016, cumulatively, the Ocean and Stream SBUs total 18.18 and 6.94 respectively (Figure 25). These represent a 3.6 percent survival improvement for ocean-type salmonids and a 1.4 percent survival improvement for stream-type salmonids, compared to the BiOp standards of 9 percent and 6 percent improvements respectively. Table B-1 in Appendix B is the document the action agencies use to track progress in accomplishing the 9 percent and 6 percent survival targets.

The Action Agencies continue to use the Columbia Estuary Ecosystem Restoration Plan (CEERP) to guide their estuary restoration efforts. The purpose of CEERP is to establish the strategic, adaptively managed scientific basis for the ecosystem restoration and associated RME that the Action Agencies are funding in the Lower Columbia River estuary (LCRE). In 2015, the CEERP documents were again updated to include any new lessons and associated adaptive management (BPA and ACOE 2015; 2016). These adjustments include the removal of floodplain lakes from consideration until further data on fish densities/use are available; the importance of site-specific data concerning topographic heterogeneity, addressing the establishment of non-native reed canary grass to site design; and giving priority to projects located within 7-8 km of the mainstem.

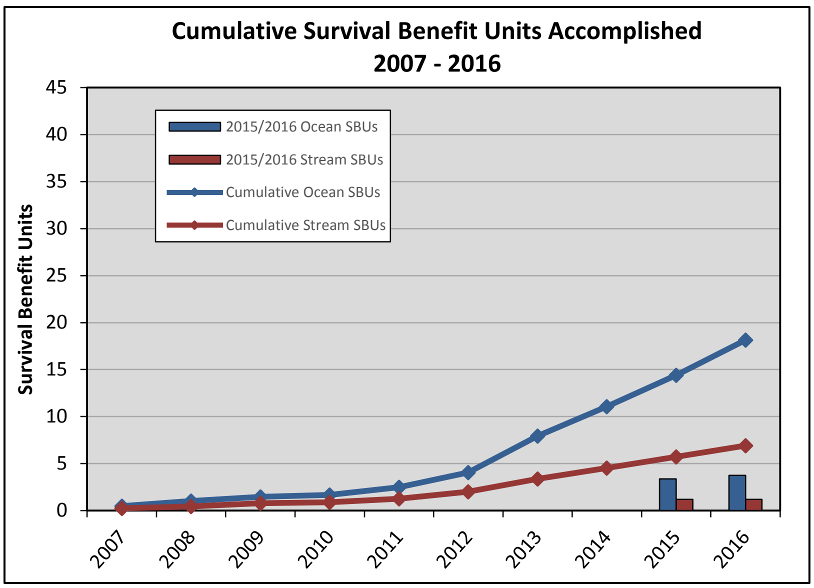


Figure 25. Cumulative survival benefit units (SBUs) accomplished from 2007 through 2016.

As part of the CEERP, the Action Agencies have developed an out-year prioritization process that evaluates cost, SBUs, and implementation likelihood of all potential estuary actions. This process was described in detail in the 2013 Comprehensive Evaluation. In 2015, the Action Agencies met monthly with project sponsors to refresh the cost, SBU, and implementation likelihood data of current and future actions. All changes to estuary action data are catalogued at http://www.cbfish.org/EstuaryAction.mvc/Index. If these changes resulted in an action being revised or no longer feasible, the Action Agencies drew on the reserve of candidate projects developed in cooperation with implementation partners to ensure the total estuary habitat project portfolio includes a sufficient number of SBUs that will collectively achieve the percent estuary survival improvements called for in the RPA. See Appendix B for more details.

In 2015, the Action Agencies funded, and with their partners, completed the following actions:

Buckmire Slough Restoration (Phase 1) – The Columbia River Estuary Study Taskforce (CREST) restored hydrology and juvenile salmonid access to approximately 65 acres of Buckmire Slough in Phase I of a multi-phase project. Buckmire Slough is located approximately five miles west of Vancouver, Washington in the Vancouver Lowlands. Two damaged culverts and associated berms were removed from the slough to allow for full tidal exchange, natural channel-forming processes, and juvenile salmonid access to the slough. Improvements to native vegetated communities included invasive species control and native plantings. Two additional phases will connect Buckmire Slough to a planned restoration in Washington Department of Fish & Wildlife's Shillapoo – South Unit site.

North Unit Phase 3 – CREST restored hydrology and juvenile salmonid access to approximately 68 acres of wetland in their Phase 3 North Unit project located in the Sauvie Island Wildlife Area (north Sauvie Island). In total, approximately 329 acres have been restored over the three phases, and implementation of a fourth phase is planned in 2016. Three water control structures were removed in Phase 3 to return full hydrologic access to the Cunningham Lake area. The marsh plain was also scraped down in strategic locations to increase frequency and duration of inundation, benefitting native wetland vegetation species. Other improvements to native plant communities included invasive species control and native plantings.

Batwater Station – The Lower Columbia Estuary Partnership (LCEP) restored hydrology and juvenile salmonid access to approximately 26 acres of tidal floodplain. The site is located in Oregon near the confluence of Bradbury Slough and the Columbia River at river mile 56 (across the slough from Crims Island). The project includes removal of approximately 500 feet of levee and a relic tidegate. Additional project elements included tidal channel enhancements, placement of large wood, and invasive plant control.

La Center Wetlands Restoration – LCEP improved hydrology and juvenile salmonid access to approximately 453 acres of East Fork Lewis River floodplain. The site is located near the City of La Center, Washington, approximately six miles from the Columbia River estuary. Restoration actions included the removal of derelict water control structures and levee breaches designed to increase the frequency of tidal and fluvial inundation. Additional elements of the project included channel excavation and vegetation enhancements.

Elochoman Restoration (West) – The Washington State Department of Fish & Wildlife (WDFW), in partnership with the Columbia Land Trust (CLT), improved hydrology and juvenile salmonid access to approximately 255 acres of tidally-influenced Elochoman River floodplain. The site is located north of Cathlamet, Washington adjacent to intact habitats of the nearby Hunting Islands. Elochoman West is Phase I of a two-phase restoration effort to reconnect the site with its historical tidal connection with the Elochoman Slough. Actions included the installation of two large culverts under State Highway 4. Other aspects of the project included road decommissioning and nearly a mile of riparian plantings. A future phase will breach the northern levee in three locations to further enhance hydrology.

In addition to the above restoration projects, the Action Agencies also funded two key acquisitions in anticipation of additional restoration work in future years:

Brix Bay / Nelson – CLT acquired 27.6 acres of historical spruce swamp near the confluence of Deep River and Grays Bay, approximately 21 miles from the Pacific Ocean. The Nelson parcel is part of a larger site where both CLT and the Washington Department of Fish & Wildlife are purchasing land for a major restoration effort in the near future. CLT will begin implementing passive restoration activities to re-establish native vegetation while preparing for a future levee breach to restore hydrology and juvenile salmonid access to the entire site.

Crooked Creek / White – CLT acquired 18.3 acres of Sitka Spruce swamp located adjacent to Grays Bay, approximately 23 miles from the Pacific Ocean. The White parcel is part of a larger site where CLT is purchasing land for a major restoration effort in the near future. CLT will begin implementing passive restoration activities to re-establish native vegetation while preparing to remove a water control structure and lower a relic levee. These actions, along with other planned actions at adjacent parcels, will improve hydrology and fish access to an important historical, but increasingly rare habitat in the lower Columbia River.

In 2016, the Action Agencies funded, and with their partners, completed construction at the following projects:

Trestle Bay Jetty Breach – The Army Corps of Engineers and CREST restored approximately 628 acres of tidally influenced wetlands and shallow water habitat near the town of Hammond, Oregon. Trestle Bay was cut off from the mainstem during construction of the South Jetty in the late 1800s by the placement of large rock rubble used as an equipment and material haul road. Trestle Bay is located in a key area of the lower river landscape due to the lack of suitable habitats along the Oregon shoreline west of Astoria, and physiological changes that occur in juvenile salmonids as they enter saltwater environments. Sediment accretion helped form good habitat along the protected shoreline; however, the trestle also created a barrier to juvenile salmonid access to the newly formed habitats. This project removed seven 50-foot sections of the rock jetty, increased habitat complexity through placement of large wood, removed invasive plant species, and planted native species like eel grass.

Wallacut River – CLT restored approximately 113 acres of isolated floodplain habitat in the lower Wallacut River adjacent to Baker Bay, a large embayment near the mouth of the Columbia River on the Washington side of the river. Habitats of Baker Bay are heavily impacted by flood risk management measures and conversion of wetlands to pasture lands. Historically, Baker Bay and its adjacent floodplain contained Sitka Spruce swamps which are considered important and unique wetland habitats for juvenile salmonids. Columbia Land Trust acquired the Wallacut site in 2012 specifically for future restoration. This project removed approximately 790 feet of levee along the lower Wallacut River, removed failed tidegates, and demolished relic structures on the site. Invasive plant control and native plantings will jumpstart natural processes.

Kerry Island – CLT restored approximately 110 acres of island floodplain habitat in Westport Slough, approximately two miles from the Columbia River mainstem in the vicinity of Puget Island. Westport Slough is a large tidal channel within Clatskanie Flats in an important reach of the river where riverine forces give way to tidal influences of the Pacific Ocean. Kerry Island's historical tidal forested wetland habitats have been altered by site and landscape anthropomorphic activities over the past 150 years. At the site scale, the island was isolated by a levee that effectively eliminated hydrologic connectivity with Westport Slough and the river. The conversion of historical forested wetlands to agricultural production included extensive ditches and simplified pasture. As a result of these actions, the site has subsided approximately three feet. Restoration actions at Kerry Island included removal of the levee and tidegates, removal of interior culverts, filling of ditches, removal of invasive plants, and the planting of native species.

Westport Slough Floodplain Levee Removal (USFWS) #1 – CREST restored approximately 50 acres of floodplain wetlands in Westport Slough, approximately three miles from the confluence with Columbia River mainstem near the town of Westport. Westport Slough is a large tidal channel within Clatskanie Flats in an important reach of the river where riverine forces give way to tidal influences of the Pacific Ocean. The site is a mix of public and private ownership with restoration actions focused upon lands in US Fish & Wildlife Service ownership. Specific actions included the strategic removal of six relic levee sections to increase surface water connection with Westport Slough and provide additional habitat and refugia for juvenile salmonids. As a result of the levee breaches, channel enhancements are expected to occur at the breach sites.

Willow Bar – CREST restored approximately 8.7 acres of isolated floodplain wetlands within the Sauvie Island Wildlife Area. Willow Bar is adjacent to the mainstem Columbia River, on the Eastern side of Sauvie Island, about mid-island. The site was heavily impacted by dredge material placement with dense growth of reed canary grass inhibiting hydrologic connectivity to existing wetland habitats. This project removed approximately 16,700 cubic yards of dredge material to increase the frequency, extent, and duration of surface water inundation for juvenile salmonid rearing and refugia. Additional elements of the project included piloting a new wetland channel, controlling invasive plants, and planting native species.

Crane Slough-Domeyer Wetland – CREST restored approximately 38 acres of isolated floodplain within Crane Slough, a secondary channel connecting to Multnomah Channel approximately six river miles from its confluence with the mainstem Columbia River. The Crane/Domeyer wetland complex is the fourth phase of juvenile salmonid habitat restoration targeted within the Sauvie Island Wildlife Area. The sites are located in the northern half of Sauvie Island, near the City of Scappoose, Oregon. The two distinct but adjacent sites were hydrologically constrained by a defunct tidegate at the Crane Slough site and an undersized channel at Domeyer. Additional actions included strategic scrapedown of marsh surface to increase surface water elevations and support native plant propagation.

In 2015, the Action Agencies also took the following actions to implement the steps called for in RPA Action 37 above:

1. *Action Agencies will actively engage the LCREP Science workgroup to identify project benefits in coordination with other regional experts, using recovery planning products and the modified LCREP project selection criteria (FCRPS BA Attachment B.2.2-3) to identify projects that will benefit salmon considered in this RPA.*

   In 2015, the Action Agencies continued to use the ecosystem criteria developed by the Lower Columbia Estuary Program’s (LCEP’s) Science Workgroup to help select restoration and protection projects in the Lower Columbia River and estuary. Additionally, the LCEP's Project Review Committee was instrumental in reviewing all potentially BPA-funded projects to evaluate ecological benefits to the estuary. This review process generally takes place after BPA has approved a project moving forward into the design phase, and serves as a peer-review opportunity for the project to consider before taking to the ERTG for final review.

2. *To support project selection the Action Agencies will convene an expert regional technical group. This group will use the habitat metrics to determine the estimated change in survival which would result from full implementation.*

The ERTG was established in 2009 and began evaluating federal projects for their survival benefit potential. The ERTG has five members, representing the scientific expertise of: the Washington Department of Fish and Wildlife (WDFW); NOAA Fisheries' Northwest Fisheries Science Center; the Department of Energy's Pacific Northwest National Laboratory; and the Skagit River System Cooperative. In 2015, the ERTG completed the following:

- Reviewed and scored the SBUs for 6 proposed estuary actions (with another 6 scored in 2016 at the time of writing); and
- Produced one formal work product: "Large Wood in Estuaries: Structure, Hydrologic and Ecological Functions, and Influence on Fish Survival." (ERTG 2016)

3. *Project proposals will clearly describe the completed project in terms of quantitative habitat metrics which can be used to quantitatively evaluate progress and completion of individual projects.*

The ERTG continues to refine its template to ensure that it has the best available information on proposed projects. In 2013 the template was updated to include a requirement for a landscape level map in addition to the site specific map, which allows them to better evaluate how individual projects fit into the landscape scale of the CEERP Program. In 2014, the Independent Scientific Advisory Board (ISAB) reviewed the ERTG process (ISAB 2014) and recommended the ERTG develop a document outlining their process for reviewing and scoring estuarine ecosystem restoration projects, and submit that document for publication in a peer-reviewed journal. ERTG finalized development of that document in 2015, and it has been accepted for publication by the *Journal of Environmental Management*.

4. *The expert regional technical group will use the approach originally applied in the FCRPS BA (Attachment B.2.2) (Estimated Benefits of Federal Agency Habitat Projects in the Lower Columbia River Estuary) and all subsequent information on the relationship between actions, habitat and salmon productivity models developed through the FCRPS RME to estimate the change in overall estuary habitat and resultant change in population survival.*

The ERTG previously reviewed the approach for determining SBU values used in the FCRPS BA. They improved it by creating weighting factors for commonly used management action and by developing scoring criteria so that benefit estimates are tuned to the habitat features and restoration design at each site. The ERTG continued to use its improved approach to estimate biological benefits (SBUs) during 2015.

5. *If actions from the previous cycle prove infeasible, in whole or in part, the Action Agencies will ensure implementation of comparable replacement estuary projects in the next implementation plan cycle to maintain estimated habitat quality improvements at the ESU/DPS level and achieve equivalent survival benefits. Selection of replacement projects, to ensure comparable survival benefits, will be made based on input from expert panels, regional recovery planning groups, the Northwest Power and Conservation Council, and NOAA Fisheries.*

Some projects planned for implementation in 2015 proved infeasible. In 2015, the Action Agencies and project partners continued out-year planning and prioritization to identify future project opportunities, some of which may be drawn upon to replace SBUs from projects that have been revised or proven infeasible. This ongoing process prioritizes project opportunities based on cost, biological benefit (survival benefit units), and implementation likelihood. Out-year project selection continued to be guided by input from expert panels, regional recovery planning and implementation groups, the NPCC, and NOAA Fisheries.

6. *FCRPS RME results will actively inform the relationship between actions, estuary habitat change and salmon productivity and new scientific information will be applied to estimate benefits for future implementation.*

   As information from FCRPS estuary research and restoration project effectiveness monitoring becomes available, it is applied to the process of estimating benefits for projects implemented between 2010 and 2018. This process is outlined in the CEERP documents (BPA and ACOE 2015; 2016).

7. *If new scientific or other information (except incomplete implementation of project modification) suggests that habitat quality improvement estimates for projects from the previous cycle were significantly in error, the Action Agencies will examine the information and review the project or projects in question and their estimated benefits. This review will occur as part of the 2009 Annual Report and the Comprehensive RPA Evaluations in 2013 and 2016 and will be performed in conjunction with NOAA Fisheries. In the event such review finds that habitat based survival improvement were significantly overstated, the Action Agencies will implement replacement projects (selected as per new projects above) to provide benefits sufficient to achieve the ESU/DPS-specific survival benefit estimated for each affected project.*

   In 2013, in preparing the 2008–2012 Comprehensive Evaluation, the Action Agencies engaged research agencies, consultants, LCEP's Science Workgroup, the Corps' Anadromous Fish Evaluation Program (AFEP), the ERTG, and other sources regarding new scientific information. The Action Agencies examined that information, and found no indication that any habitat quality improvement estimates for projects completed in the 2010 implementation cycle were "significantly overstated." The Action Agencies have continued to coordinate with LCEP's Science Workgroup and the ERTG regarding new scientific information. The Action Agencies have examined the new information available since the 2013 Comprehensive Evaluation, and again have found no indication that habitat quality improvement estimates have been "significantly overstated".

RPA Action 38 – Piling and Piling Dike Removal Program*

**** The language below reflects changes made by the 2014 BiOp:***

RPA Action 38 is no longer required.

Based on the available information, it is not possible to determine whether the removal of pile structures would actually provide survival benefits to juvenile salmon and steelhead. All survival benefit units attributed to this program in the Action Agencies' 2007 Biological Assessment will now be acquired by implementing additional projects under RPA Action 37.

Hatchery Implementation Reports, RPA Actions 39–42

Table 13. Hatchery strategy reporting.

RPA Action No.	Action	Comprehensive Evaluation Reporting
Habitat Strategy 1		
39	FCRPS Funding of Mitigation Hatcheries – Programmatic	Status of submittal/approval of Hatchery and Genetic Management Plans (HGMPs), including site-specific application of Best Management Practices.
40	Reform FCRPS Hatchery Operations to Reduce Genetic and Ecological Effects on ESA-Listed Salmon and Steelhead	Status of implementation through December of the previous year for all reforms identified in the BiOp RPA table, action 40, Table 6. Status of implementation of future reforms identified by the Action Agencies following the Hatchery Scientific Review Group process.
Hatchery Strategy 2		
41	Implement Safety Net Programs to Preserve Genetic Resources and Reduce Short-term Extinction Risk	Status of implementation through December of the previous year for all safety net programs identified in the BiOp RPA table, action 41, Table 7.
42	Implement Conservation Programs to Build Genetic Resources and Assist in Promoting Recovery	Status of implementation through December of the previous year for all conservation programs identified in the BiOp RPA table, action 42, Table 8.

RPA Action 39 – FCRPS Funding of Mitigation Hatcheries – Programmatic

The FCRPS Action Agencies will continue funding hatcheries in accordance with existing programs, and will adopt programmatic criteria for funding decisions on mitigation programs for the FCRPS that incorporate BMPs. The Hatchery Effects Report, the August 2006 NOAA Fisheries paper to the PWG and the NOAA Fisheries 2007 Guidance Paper should be considered in developing these criteria in addition to the BMPs in the Action Agencies' BA. Site specific application of BMPs will be defined in ESA Section 7, Section 10, or Section 4(d) consultations with NOAA Fisheries to be initiated and conducted by hatchery operators with the Action Agencies as cooperating agencies.

In 2008 and 2009, NOAA Fisheries asked the Action Agency-funded hatchery operators to update the hatchery and genetic management plans (HGMPs) for their respective hatchery programs. The Action Agencies have since worked collaboratively with hatchery program operators on the development and submittal of HGMPs for consultation. Information from the reports of the USFWS Hatchery Review Team process, the Columbia Basin Hatchery Scientific Review Group process, and regionally reviewed best management practices has guided and informed the development of program-specific HGMPs.

In 2015, the Action Agencies continued to fund mitigation hatcheries in accordance with existing programs and used the programmatic funding criteria developed in 2008 to complete checklists for FCRPS mitigation program funding decisions. The hatchery programs funded by the Action Agencies are described briefly in Tables 14 through 16.

Table 14. FCRPS–funded hatchery programs in the upper Columbia region.

Program	Basin	Operator	Lead Action Agency	Status of Consultation Process, December 2015
Leavenworth National Fish Hatchery (NFH) Spring Chinook	Wenatchee	USFWS	Reclamation	USFWS submitted Supplemental BA November 17, 2014. NOAA completed BiOp May 2015
Entiat NFH Summer Chinook Program	Entiat	USFWS	Reclamation	NOAA Fisheries issued BiOp and permits April 18, 2013. Current BiOp and permits expire April 1, 2023.
Winthrop NFH Methow Composite Spring Chinook	Methow	USFWS	Reclamation	NOAA Fisheries issued a BiOp and permits for production for transfer to the Okanogan program. Methow production in Draft BiOp and permit review.
Winthrop NFH Steelhead	Methow	USFWS	Reclamation	NOAA Fisheries issued a letter of sufficiency on March 2013 and is working on drafting BiOp.
Methow Coho	Methow	Yakama Nation (YN)	BPA	NOAA Fisheries issued a letter of sufficiency in December 2010 and is working on drafting BiOp.
Wenatchee Coho	Wenatchee	YN	BPA	NOAA Fisheries issued a letter of sufficiency in December 2010 and is working on drafting BiOp.

Table 15. FCRPS-funded hatchery programs in the mid-Columbia region.

Program	Basin	Operator	Lead Action Agency	Status of Consultation Process, December 2015
Yakima Spring Chinook	Yakima	YN	BPA	NOAA Fisheries issued BiOp and permits November 2013.
Yakima Summer-Fall Chinook	Yakima	YN	BPA	NOAA Fisheries issued BiOp and permits November 2013.
Yakima Coho	Yakima	YN	BPA	NOAA Fisheries issued BiOp and permits November 2013.
Touchet Endemic Steelhead	Walla Walla	WDFW	Lower Snake River Compensation Program (LSRCP)	NOAA Fisheries issued a letter of sufficiency in March 2011. Status of consultation is ongoing in 2015, expected completion in summer 2016.
Lyons Ferry Summer Steelhead	Walla Walla	WDFW	LSRCP	NOAA Fisheries consultation completed in 2007.
Umatilla Spring Chinook	Umatilla	Oregon Department of Fish and Wildlife (ODFW) & Confederated Tribes of the Umatilla Indian Reservation (CTUIR)	BPA	NOAA Fisheries issued BiOp and permits April 2011.
Umatilla Fall Chinook	Umatilla	ODFW & CTUIR	BPA and Corps	NOAA Fisheries issued BiOp and permits April 2011.

Program	Basin	Operator	Lead Action Agency	Status of Consultation Process, December 2015
Umatilla Coho	Umatilla	ODFW & CTUIR	BPA	NOAA Fisheries issued BiOp and permits April 2011.
Umatilla Summer Steelhead	Umatilla	ODFW & CTUIR	BPA	NOAA Fisheries issued a letter of sufficiency in March 2011.

Table 16. FCRPS-funded hatchery programs in the Snake River region.

Program	Basin	Operator	Lead Action Agency	Status of Consultation Process, December 2015
Lyons Ferry Summer Steelhead	Lower Snake	WDFW	LSRCP	NOAA Fisheries issued a letter of sufficiency in May 2011. Status in 2015 is consultation in process, expected completion in summer 2016.
Snake River Stock Fall Chinook (Lyons Ferry Hatchery)	Lower Snake	WDFW	LSRCP	NOAA Fisheries issued BiOp and permits in 2012.
Tucannon Summer Steelhead Endemic	Tucannon	WDFW	LSRCP	NOAA Fisheries issued a letter of sufficiency in May 2011. Status in 2015 is consultation in process, expected completion in summer 2016.
Tucannon Spring Chinook	Tucannon	WDFW	LSRCP	NOAA Fisheries issued a letter of sufficiency in August 2011. Status in 2015 is consultation in process, expected completion in 2016.
NF Clearwater River Summer Steelhead (B-Run-Clearwater River Hatchery)	Clearwater	IDFG	LSRCP	NOAA Fisheries issued a letter of sufficiency in August 2011. Status in 2015 is hatchery co-operators are updating the HGMPs to reflect current program.
Clearwater River Basin Spring/Summer Chinook (Clearwater Hatchery)	Clearwater	IDFG	LSRCP	NOAA Fisheries issued a letter of sufficiency in August 2011. Status in 2015 is hatchery co-operators are updating the HGMPs to reflect current program.
Clearwater River Basin Spring/Summer Chinook (Kooskia Hatchery)	Clearwater	NPT	BPA, LSRCP	NOAA Fisheries issued a letter of sufficiency in August 2011. Status in 2015 is hatchery co-operators are updating the HGMPs to reflect current program.
NF Clearwater Summer Steelhead (B-Run-Dworshak NFH)	Clearwater	USFWS	Corps	Applicant updating the HGMP to reflect changes to the program that have occurred since the original HGMP submittal.

Program	Basin	Operator	Lead Action Agency	Status of Consultation Process, December 2015
NF Clearwater Spring Chinook (Dworshak NFH)	Clearwater	USFWS	LSRCP	HGMP submitted in 2011. Formal review and comments from NOAA Fisheries was pending until hatchery co-operators began updating the HGMPs to reflect current program in 2015.
Clearwater Spring Chinook (NPTH-Hatchery)	Clearwater	Nez Perce Tribe (NPT)	BPA	HGMP submitted in 2011. Formal review and comments from NOAA Fisheries was pending until hatchery co-operators began updating the HGMPs to reflect current program in 2015.
Clearwater Fall Chinook (NPTH-Hatchery)	Clearwater	NPT	BPA	NOAA Fisheries issued BiOp and permits in 2012.
Grande Ronde Summer Steelhead-Wallowa Stock (Cottonwood Creek/Lyons Ferry Hatchery)	Grande Ronde	WDFW	LSRCP	NOAA Fisheries issued a letter of sufficiency in May 2011. Status in 2015 is hatchery co-operators are updating the HGMPs to reflect current program.
Grande Ronde Summer Steelhead (Wallowa Stock)	Grande Ronde	ODFW	LSRCP	NOAA Fisheries issued a letter of sufficiency in May 2011. Status in 2015 is hatchery co-operators are updating the HGMPs to reflect current program.
Upper Grande Ronde River Spring/Summer Chinook Salmon Stock	Grande Ronde	ODFW & CTUIR	BPA, LSRCP	NOAA Fisheries issued a letter of sufficiency in August 2011. Status in 2015 is NOAA consultation in progress.
Catherine Creek Spring/Summer Chinook	Grande Ronde	ODFW & CTUIR	BPA, LSRCP	NOAA Fisheries issued a letter of sufficiency in May 2011. Status in 2015 is NOAA consultation in progress.
Wallowa/Lostine Spring Chinook	Grande Ronde	ODFW, NPT & CTUIR	BPA, LSRCP	NOAA Fisheries issued a letter of sufficiency in August 2011. Status in 2015 is NOAA consultation in progress.
Lookingglass Creek Spring/Summer Chinook	Grande Ronde	ODFW	LSRCP	NOAA Fisheries issued a letter of sufficiency in March 2012. Status in 2015 is NOAA consultation in progress.
Little Sheep Creek Summer Steelhead	Imnaha	ODFW	LSRCP	NOAA Fisheries issued a letter of sufficiency in August 2011.
Imnaha Spring/Summer Chinook	Imnaha	ODFW	LSRCP	NOAA Fisheries issued a letter of sufficiency in August 2011. Status in 2015 is NOAA consultation in progress.
Upper Salmon River B-Run Steelhead	Salmon	IDFG	LSRCP	NOAA Fisheries issued a letter of sufficiency in August 2011. Status in 2015 is hatchery co-operators are updating the HGMPs to reflect current program.

Program	Basin	Operator	Lead Action Agency	Status of Consultation Process, December 2015
Upper Salmon Spring Chinook (Sawtooth Hatchery)	Salmon	IDFG	LSRCP	NOAA Fisheries issued a letter of sufficiency in August 2011. Status in 2015 is hatchery co-operators are updating the HGMPs to reflect current program.
South Fork Salmon Summer Chinook (McCall Fish Hatchery)	Salmon	IDFG	LSRCP	NOAA Fisheries issued a letter of sufficiency in August 2011. Status in 2015 is hatchery co-operators are updating the HGMPs to reflect current program.
Johnson Creek Summer Chinook (South Fork Salmon)	Salmon	IDFG & NPT	BPA, LSRCP	Applicant subbmitted HGMP in 2011. Formal review and comments from NOAA Fisheries pending.
Yankee Fork Summer Steelhead Streamside Incubation Supplementation	Salmon	IDFG & Shoshone-Bannock Tribes	BPA	NOAA Fisheries issued a letter of sufficiency in August 2011. No consultation initiated.
Yankee Fork Summer Steelhead Supplementation	Salmon	IDFG & Shoshone-Bannock Tribes	BPA	NOAA Fisheries issued a letter of sufficiency in August 2011. No consultation initiated.
Yankee Fork Chinook Supplementation	Salmon	IDFG & Shoshone-Bannock Tribes	BPA	Operator finalizing HGMP, expected submittal to NOAA Fisheries in spring 2016.
Panther Creek Chinook Supplementation	Salmon	IDFG & Shoshone-Bannock Tribes	BPA	Operator finalizing HGMP, expected submittal to NOAA Fisheries in spring 2016.
SF Salmon-Dollar Creek Summer Chinook (McCall FH-Egg Box)	Salmon	IDFG & Shoshone-Bannock Tribes	BPA, LSRCP	HGMP submitted in 2011. Formal review and comments from NOAA Fisheries pending.
E. Fork Salmon River Natural integrated Steelhead (Sawtooth)	Salmon	IDFG	LSRCP	HGMP submitted in 2011. Formal review and comments from NOAA Fisheries pending.
Little Salmon River A&B Run Steelhead (Niagara/Magic Valley)	Salmon	IDFG	LSRCP	HGMP submitted in 2011. Formal review and comments from NOAA Fisheries pending.
Upper Salmon River A-Run Steelhead (Sawtooth/ Magic Valley/Hagerman National)	Salmon	IDFG	LSRCP	HGMP submitted in 2011. Formal review and comments from NOAA Fisheries pending.
Snake River Sockeye	Salmon	IDFG	BPA	NOAA Fisheries issued BiOp and permits in 2013.

RPA Action 40 – Reform FCRPS Hatchery Operations to Reduce Genetic and Ecological Effects on ESA-Listed Salmon and Steelhead

The Action Agencies will undertake/fund reforms to ensure that hatchery programs funded by the Action Agencies as mitigation for the FCRPS are not impeding recovery. The Action Agencies will work with FCRPS mitigation hatchery operators to cost effectively address needed reforms of current hatchery programs while continuing to meet mitigation responsibilities. Specific reforms to be implemented under this action (following any necessary regulatory approval) are listed in Table 6 of the RPA action table. Other reforms will be identified and implemented following the conclusion of the Columbia River Hatchery Scientific Review Group process.

1. *For Lower Columbia Chinook: The COE will review the John Day Hatchery Mitigation Program.*

   The Corps continues to develop and refine a Post Authorization Change Report with an integrated Environmental Assessment. The report completion date is currently spring of 2017. This report will recommend specific improvements to the current John Day Mitigation production program to assist in reducing negative ecological effects on ESA-listed species.

2. *For Snake River Steelhead: Fund the Tucannon River steelhead supplementation program to transition to local broodstock using BMPs.*

   This action is funded and implemented by the Lower Snake River Compensation Plan (LSRCP) program office and WDFW operates the Tucannon River steelhead supplementation program. For Tucannon steelhead, WDFW developed a revised HGMP (released September 22, 2011, with the latest sufficiency letter dated May 2, 2011) to eliminate releases of Lyons Ferry Hatchery steelhead in the Tucannon River and to increase production of the endemic Tucannon River summer steelhead program. To date, critically low numbers of natural-origin steelhead spawning in the Tucannon, have resulted in production/return goals not being met. A total of 50,363 (non-adipose clipped) Tucannon endemic stock were released at the Curl Lake Intake, and an additional 56,508 adipose clipped Tucannon endemic hatchery stock steelhead were released into the Tucannon River at Marengo (about midway in the Tucannon River) in April 2015.

3. *For Middle Columbia Steelhead: Fund the Touchet River steelhead supplementation program to transition to local broodstock using BMPs.*

   This action is funded and implemented by the LSRCP program office and WDFW. In 2015, the program continued at approximately the same production level as 48,711 Touchet River endemic brood-year 2014 hatchery stock steelhead were released.

   To date, RME data has indicated that the current supplementation program may not be supporting the native Touchet River population as intended. Hatchery co-managers and technical representatives are engaging in regional discussions for a potential change in the endemic program.

4. *For Upper Columbia Steelhead: For the Winthrop NFH steelhead program, implement measures to transition to local broodstock and to manage the number of Winthrop NFH-produced steelhead on the spawning grounds. Such broodstock and adult escapement reform measures, including capital construction, would be identified through development of an updated HGMP and ESA consultation. Implementation of reform measures is contingent on a finding, in consultation with NOAA Fisheries, that the measures are biologically and economically feasible and effective. Implementation of reforms will be prioritized and sequenced.*

The Winthrop NFH has now fully transitioned to local broodstock by collecting all brood from the Methow subbasin via hatchery volunteers (Winthrop NFH, Methow Fish Hatchery, and Twisp Weir), coordinated transfers between agencies, limited tangle netting, and angling. The last group of summer steelhead to be raised in a 1-year rearing cycle were released in 2015. Local broodstock collection in 2015 was successful to meet hatchery needs despite difficult high water conditions. The USFWS continued to manage returning Winthrop NFH-produced, Wells Hatchery, and unknown hatchery-origin steelhead on the spawning grounds in 2015. All hatchery-produced steelhead collected at the hatchery or via angling were removed from the naturally spawning population.

These efforts were previously defined through Reclamation's Value Planning Process with Methow subbasin stakeholders. In 2015, per the recommendation from the team, Reclamation continued to provide funding to USFWS to continue local broodstock collection, enhance returning hatchery fish management, and monitor these efforts.

RPA Action 41 – Implement Safety Net Programs to Preserve Genetic Resources and Reduce Short-term Extinction Risk

The Action Agencies will continue to fund the operation of on-going "safety net" programs that are providing benefits to ESA-listed stocks at high risk of extinction by increasing genetic resources and will identify and plan for additional safety-net programs, as needed.

1. *For Snake River sockeye: Continue to fund the safety net program to achieve the interim goal of annual releases of 150,000 smolts while also continuing to implement other release strategies in nursery lakes such as fry and parr releases, eyed-egg incubation boxes, and adult releases for volitional spawning (see Action 42 for expansion of the program for building genetic resources and assisting in promoting recovery).*

   BPA continued to fund BPA Project 2007-402-00 (Snake River Sockeye Salmon Captive Broodstock) to preserve this species. The program has produced hundreds of thousands of progeny from remnants of the wild stock. Since 1999, 6,310 adults from the program have returned to Stanley basin in Idaho. In 2015, over 420,000 brood-year 2013 smolts were released into Redfish Lake Creek.

2. *For Snake River Spring/Summer Chinook: For the Tucannon River spring/summer Chinook safety-net supplementation program fund capital construction, operation and monitoring and evaluation costs to implement a program that builds genetic diversity using local broodstock and a sliding scale for managing the composition of natural spawners comprised of hatchery-origin fish.*

   BPA Project 2000-019-00 (Tucannon River Spring Chinook Captive Brood), a one-generation safety-net program, was completed as planned in 2010. BPA, through the LSRCP Direct Funding Agreement, continues to fund an integrated conservation hatchery program for Tucannon River spring/summer Chinook salmon with an annual production goal of 225,000 yearling smolts. Approximately 240,000 brood-year 2013 smolts were released into the Curl Lake acclimation pond in 2015. Despite heavy avian predation losses in the pond, approximately 207,859 subsequently entered the Tucannon River. Hatchery managers are actively evaluating solutions to address the acclimation period predation issue In addition, to address recent pre-spawn mortalities in the Tucannon, efforts to hold returning adults and outplant them later in the season appears to have increased adult survival.

3. *For Snake River Spring/Summer Chinook: For the Upper Grande Ronde and Catherine Creek safety net supplementation programs fund capital construction, operation and monitoring and evaluation costs to implement a program that builds genetic diversity using local broodstock, and a sliding scale for managing the composition of natural spawners comprised of hatchery origin fish.*

   BPA continued to fund this safety-net program through BPA Project 2007-404-00 (Spring Chinook Captive Propagation—Oregon). The Catherine Creek and Lostine River have met adult return goals of 150 spawning adults in nature, therefore these two safety-net programs have now been phased out. Adult return goals have been met for the Upper Grande Ronde stock; and this safety-net work was phased out in 2015.

4. *For Snake River Spring/Summer Chinook: Fund the Johnson Creek/South Fork Salmon River safety net supplementation program, as described in the existing Section 10 permit.*

   BPA continued to fund implementation of this RPA action through BPA Project 1996-043-00 Johnson Creek Artificial Propagation Enhancement Project. This project does not have a captive broodstock component, but releases up to 110,000 spring/summer Chinook salmon smolts annually in Johnson Creek, Idaho. Only natural origin Johnson Creek fish are used for broodstock. Egg incubation and rearing occur at McCall Fish Hatchery.

5. *For Snake River Spring/Summer Chinook: Fund the experimental captive rearing program for East Fork and West Fork Yankee Fork Salmon River (until phased out by IDFG).*

   All captive rearing in this experimental program has ended and the last remaining brood year (2005) was released as mature adults to their natal waters in 2010. During 2015, the project continued to monitor the reproductive performance of captive-reared Chinook salmon released to spawn in natal streams through BPA Project No. 2007-403-00 (Idaho Snake River Spring Chinook Captive Propagation).

6. *For Snake River Steelhead, as a project to benefit primarily B-Run steelhead, the Action Agencies will work with NOAA Fisheries to develop a trigger for future artificial propagation safety-net planning or to identify populations for immediate safety-net planning.*

   The Action Agencies continued to fund collection of B-Run steelhead population viability data in order to inform development of a trigger (see also RPA Subaction 50.5). The 2014 NOAA Fisheries Supplemental BiOp stated that calculation of average A- and B-run populations is no longer valid and that initial monitoring results indicated that some populations assumed to be either A-run or B-run may instead support a mixture of the two life history strategies. Ongoing RME efforts and studies using adult PIT tag detections should allow for more improved population specific assessments in NOAA Fisheries' next 5-year status review expected in 2016. At that time, NOAA Fisheries and the Action Agencies will review the development of a trigger, as described above.

RPA Action 42 – Implement Conservation Programs to Build Genetic Resources and Assist in Promoting Recovery

The Action Agencies will implement conservation programs for ESA–listed stocks where the programs assist in recovery.

1. *For Upper Columbia Spring Chinook: Fund reintroduction of spring Chinook salmon into the Okanogan Basin consistent with the Upper Columbia Salmon Recovery Plan including capital construction, operation and monitoring and evaluation costs to implement a transition to local broodstock and a sliding scale for managing the composition of natural spawners composed of hatchery origin fish. Re-introduction will be coordinated with the restoration and improvement of spring Chinook habitat in the Okanogan Basin and will be contingent on the availability of within ESU broodstock from the Methow Basin.*

   This spring Chinook hatchery program is intended to create a non-essential, experimental population in the Okanogan Basin as authorized under 10(j) of the ESA. In October 2014, NOAA Fisheries issued Section 10(a)(1)(A) permit that authorizes the propogation of Methow Composite spring Chinook eyed eggs or juveniles at Winthrop NFH and the transfer of those fish to the Chief Joseph Hatchery Program for additional rearing and release of up to 200,000 smolts into the Okanogan River via the Tonasket Acclimation Pond.

2. *For Upper Columbia Steelhead: Fund a program to recondition natural origin kelts for the Entiat, Methow and Okanogan basin, including capital construction, operation and monitoring and evaluation costs.*

   BPA continued to fund this action through BPA project 2008-458-00. In 2015, Upper Columbia steelhead reconditioning efforts were promising; 58 natural origin steelhead kelts were obtained for reconditioning from various collection locations, including Winthrop NFH, Methow Salmon Hatchery and temporary weirs. Thirty of those kelts survived to be released in the fall of 2015. Improved physical condition, i.e. body weight and body fat percentage, was observed in all kelts released.

3. *For Upper Columbia Steelhead: Fund a program that builds genetic diversity using local broodstock and accelerates steelhead recovery in the Okanogan Basin as steelhead habitat is restored and improved, including capital construction, operation, and monitoring and evaluation costs.*

   This action is being pursued by the Confederated Tribes of the Colville Reservation through BPA Project 2007-212-00 (Locally Adapted Okanogan Steelhead Broodstock). A draft Master Plan was completed in September 2014 (Step 1 of the NPCC's Three-Step Process), however a definitive proposed action regarding production levels and release locations is still under consideration.

4. *For Middle Columbia Steelhead: Fund a program to recondition natural origin kelts in the Yakima River basin including capital construction, implementation and monitoring and evaluation costs.*

   BPA continued to fund this action through BPA Project 2007-401-00 (Kelt Reconditioning/Reproductive Success). The project collects steelhead kelts from middle Columbia DPS populations (e.g., Satus Creek, Toppenish Creek, and Naches River) at Prosser Dam on the Yakima River for reconditioning. In 2015, a total of 1098 kelts were collected for long-term reconditioning. Survival to release was 30 percent or 396 fish.

5. *For Snake River Steelhead: For the East Fork Salmon River, fund a small-scale program (no more than 50,000 smolts) including trapping locally returning steelhead in the East Fork Salmon River for broodstock, and follow BMPs for rearing, release, and adult management strategies. Fund capital construction, operation, and monitoring and evaluation costs to implement a program that builds genetic diversity using local broodstock and a sliding scale for managing the composition of natural spawners comprised of hatchery origin fish.*

   In 2015, is funded and implemented by the LSRCP. An HGMP for this program was submitted to NOAA Fisheries in 2011. However, the program has changed significantly since the 2011, including increasing goals from 50,000 to 60,000 smolts. Approximately 61,357 brood year 2014 smolts were released in 2015.

6. *For Snake River Spring/Summer Chinook Salmon: For the Lostine and Imnaha rivers, contingent on a NOAA Fisheries approved HGMP, fund these hatchery programs including capital construction, operation and monitoring and evaluation costs to implement supplementation programs using local broodstock and following a sliding scale for managing the composition of natural spawners composed of hatchery origin fish.*

   Supplementation programs using local broodstock for the Lostine and Imnaha rivers are being implemented by the Nez Perce Tribe through BPA Project 1998-007-02 and by ODFW through the LSRCP. HGMPs for the Lostine and Imnaha rivers supplementation programs were submitted to NOAA Fisheries for ESA consultation by the Newz Perce Tribe and ODFW in May 2011 and received sufficiency letters. In 2014, NOAA Fisheries began drafting a Biological Opinion for this consultation completed BiOp and Section 10 permits are expected summer of 2016. The USFWS is also nearing completion of their Biological Opinion for these HGMPs. The Imnaha weir was installed in the fall of 2015 which should greatly improve efforts to address sliding scale escapement levels for the upper river.

7. *For Snake River Sockeye: Fund further expansion of the sockeye program to increase total smolt releases to between 500,000 and 1 million fish.*

   Construction of the Springfield Sockeye Hatchery was completed in 2013 and this new facility, combined with existing facilities, enables the Snake River sockeye captive propagation program to achieve release goals consistent with this RPA Sub-action. The operation and maintenance of the new hatchery is funded under BPA Project 2007-402-00 (Snake River Sockeye Captive Broodstock). Approximately 211,000 brood-year 2013 smolts were released in May 2015. At the end of 2015 there are approximately 544,000 brood-year 2014 yearlings currently being reared at Springfield Hatchery.

8. *For Snake River Sockeye: The Action Agencies will work with appropriate parties to investigate feasibility and potentially develop a plan for ground transport of adult sockeye from LGR Dam to Sawtooth Valley lakes or artificial propagation facilities.*

   The Action Agencies, together with state and federal fishery agencies, implemented a pilot project in 2010 to evaluate feasibility of ground transport from the Lower Granite Dam adult trap to IDFG's Eagle Hatchery. Ground transport would be a feasible option if future river conditions and low return numbers warrant its use, and if NOAA Fisheries and the fishery co-managers, in coordination with the Action Agencies, decide to implement this option. In July 2015, as a result of Snake River water temperatures and flows, a trap-and-haul effort was initiated at Lower Granite Dam, with ground transport to the Eagle Hatchery. A total of 51 adults were collected at Lower Granite Dam. Of those 51, 35 (69 percent) were assigned as Snake River Sockeye. (3 of those were of natural origin, with the remaining 32 of hatchery origin.) The remaining 16 fish (31 percent) were determined to be from Wenatchee or Okanogan stocks.

9. *For Columbia River Chum: Fund a hatchery program to re-introduce chum salmon in Duncan Creek including capital construction, implementation and monitoring and evaluation costs as long as NOAA Fisheries considers it beneficial to recovery and necessary to reduce extinction risk of the target population.*

   This RPA Sub-action has been incorporated into the RPA Sub-action 42.10 below.

10. *For Columbia River Chum: Fund assessment of habitat potential, development of reintroduction strategies, and implementation of pilot supplementation projects in selected Lower Columbia River tributaries below Bonneville Dam.*

    BPA continued to fund BPA Project 2008-710-00 which addresses chum reintroduction and habitat assessment actions associated with RPA Sub-actions 42.9 and 42.10. BPA Project 2001-053-00, Reintroduction of Chum Salmon into Duncan Creek, associated with RPA Subaction 42.9, was merged into BPA Project 2008-710-00, Development of an Integrated Strategy for Chum Salmon Restoration in the Tributaries below Bonneville Dam. In 2015, this project continued to collect chum salmon broodstock to be used for suppplementing Duncan Creek and in artificial production programs, and continued monitoring and evaluation activities throughout the project area.

Predation Management Implementation Reports, RPA Actions 43 – 49

Table 17. Predation management strategy reporting.

RPA Action No.	Action	Comprehensive Evaluation Reporting
Predation Management Strategy 1		
43	Northern Pikeminnow Management Program (NPMP)	Comprehensive Evaluation Report will summarize NPMP actions taken.
44	Develop strategies to reduce non-indigenous fish	Comprehensive Evaluation Report will summarize actions taken as a result of the workshop.
Predation Management Strategy 2		
45	Caspian Tern	Comprehensive Evaluation Report will summarize the effects of redistribution of Caspian terns on salmonids in the Columbia River estuary.
46	Double-Crested Cormorant	Comprehensive Evaluation Report will summarize actions taken.
47	Inland Avian Predation	Comprehensive Evaluation Report will summarize actions taken.
48	Other Avian Deterrent Actions	Annual deterrent actions will not be reported.
Predation Management Strategy 3		
49	Marine Mammal Control Measures	Not applicable.

RPA Action 43 – Northern Pikeminnow Management Program*

**** The language below reflects changes made by the 2014 BiOp:***

The Action Agencies will continue to annually implement the base program and continue the general increase in the reward structure in the northern pikeminnow sport-reward fishery consistent with the increase that started in 2004.

1. *The Action Agencies will fund and update northern pikeminnow exploitation and consumption models using best available information including a range of estimated inter and intra-specific compensation, as needed, to more accurately estimate salmonid survival benefits of the NPMP.*

   The NOAA Fisheries 2010 FCRPS Supplemental BiOp called for BPA to increase tagging efforts to boost the number of tagged northern pikeminnow to better inform and increase the statistical significance of the biological evaluation of pikeminnow removals. The evaluation component of the NPMP uses tag recoveries in sponsored fisheries to quantitatively measure the benefit of removals within the year and cumulatively. Evaluation indicates that, as a result of the program, pikeminnow predation on juvenile salmon has declined 40 percent, saving 3 to 5 million juvenile salmon annually that would otherwise have been eaten by this predator. In 2015, researchers continued to maintain the higher tagging effort. The general increase in tagging and resultant improvement in estimation is consistent with NOAA Fisheries 2008 FCRPS BiOp and with recommendations of the Independent Scientific Advisory Board (ISAB) (Hankin and Richards 2000).

In 2015, the exploitation rate on northern pikeminnow was 17.2 percent, within the program objective based on the hypothesis that a 10 to 20 percent exploitation rate (on northern pikeminnow 9 inches or longer) could achieve up to a 50 percent reduction in predation mortality (Rieman and Beamesderfer 1990). The exploitation rate was based on a numerical catch of 207,807 from the sport reward and dam angling fisheries.

2. *The Action Agencies will evaluate the feasibility of using improved electrofishing methods to meet the current monitoring goals while reduce take of ESA-listed salmonids.*

   Changes made to the electrofishing methods involve measures instituted to minimize interactions specifically with Pacific salmon or sturgeon. Upon encountering these taxa, delivery of the electric current is ceased immediately and the boat is moved out of the area (i.e., downstream) before the electrical field is reestablished. Sampling typically is conducted in areas where water depth is between one and two meters (i.e., near shore). In the event Pacific salmon or sturgeon are encountered continuously as sampling progresses downstream, electrofishing activities are relocated to deeper water, off shore, for the remainder of the sampling event. Finally, a threshold of 500 encounters with juvenile salmonids has been established for a given sampling event. If this number is met at any point during an electrofishing run, sampling is discontinued in that area. Interactions with Pacific salmon have varied among field seasons throughout the past ten years of the program. The measures described above have been implemented to minimize these encounters while maintaining sampling efficiencies.

3. *The Action Agencies will evaluate the effectiveness of focused removals of northern pikeminnow at Columbia and Snake River Dams to investigate the cost and benefits of dam angling in increasing juvenile salmonid survival.*

   As part of the ongoing annual evaluation of the NPMP, managers determined that continued implementation of the dam angling program component is warranted based on the 2015 catch of 7,693 from the forebays and tailraces of The Dalles and John Day Dams. This represents a 19.7-percent increase in catch from 2014.

RPA Action 44 – Develop Strategies to reduce non-indigenous Fish

The Action Agencies will work with NOAA Fisheries, states and tribes to coordinate to review, evaluate, and develop strategies to reduce non-indigenous piscivorous predation. The formation of a workshop will be an initial step in the process.

In 2013, the Action Agencies funded the last year of a study to address the prioritized non-native fish predation issues resulting from a series of workshops in 2009. The study objectives were to evaluate the physiological condition of smallmouth bass, walleye and channel catfish as they head into the over-wintering time-period, and to determine whether American shad, as a prey item, may be contributing to an enhanced physiological condition of non-native predators. Generally, the study concluded that predators that ate mostly fish were in better condition than those that ate mostly crustaceans or other items, and the notion that consumption of American shad may be significantly enhancing the condition of nonnative predators, and perhaps improving their overwinter survival and making them more effective predators on juvenile salmonids, was inconclusive. There has been no further action since 2013.

RPA Action 45 – Reduce Caspian Terns on East Sand Island in the Columbia River Estuary

The FCRPS Action Agencies will implement the Caspian Tern Management Plan. East Sand Island tern habitat will be reduced from 6.5 to 1.5 to 2 acres. It is predicted that the target acreage on East Sand Island will be achieved in approximately 2010.

In November 2006, the USFWS and Corps signed separate records of decision adopting the Caspian Tern Management Plan. NOAA Fisheries completed the BiOp for the proposed action on February 16, 2006. In 2008, the Corps began the implementation of the Caspian Tern Management Plan with the construction of a one-acre island in Fern Ridge Reservoir. Since then, the Corps has constructed a total of eleven sites, but one site (Dutchy Island) was later removed. In 2015, a total of 8.64 acres was available to terns nesting in southern Oregon and California. These sites are listed in Table 18, below. Due to the number of alternative nest sites made available in interior Oregon and California, in 2015 the area made available for tern nesting at East Sand Island was limited to 1 acre, less than the 1.55 acres available in 2014. Construction of additional tern nesting habitat in the Don Edwards National Wildlife Refuge in San Francisco Bay began in late 2014 and was completed in early 2015.

The Caspian tern colony on East Sand Island in the Columbia River estuary, the largest of its kind in the world, was estimated at 6,240 pairs (95 percent c.i. = 6,000 - 6,460 pairs) in 2015. This is nearly identical to the estimate of 6,270 pairs in 2014 and the smallest Caspian tern colony size recorded at East Sand Island since the initiation of reductions in tern nesting habitat on the island in 2008, as part of the Caspian Tern Management Plan. This represents a decline of about 41 percent in the size of the Caspian tern colony on East Sand Island from its peak in 2008 (about 10,670 breeding pairs); but remains above the goal set forth in the Caspian Tern Management Final Environmental Impact Statement, 3,125–4,375 breeding pairs. In 2015, the tern colony area was reduced to 1.0 acre, 50 percent smaller than in 2014. This restriction resulted in an average nesting density of 1.32 nests/m2 within the 1-acre core of prepared colony area in 2015. The value in 2015 is the highest nesting density ever recorded for Caspian terns on East Sand Island and substantially higher than in 2014 (1.06 nests/m^2) (Roby et al. 2016a).

The average proportion of juvenile salmonids in the diet of Caspian terns during the 2015 nesting season was 33 percent, similar to the average observed over the previous eight nesting seasons. The estimated total smolt consumption by Caspian terns nesting at East Sand Island in 2014 was 4.5 million (95 percent c.i. = 3.9–5.1 million), not significantly different from total annual smolt consumption during 2011, 2012, and 2013. Predation rates on specific populations of salmonids (ESUs/DPSs) by Caspian terns in 2015 were similar to those observed during 2011–2014, but were generally lower than those observed during the period 2007–2010. Similar to previous years, Caspian tern predation rates were 5-10 times higher on populations of steelhead smolts (8.6–11.4 percent, depending on DPS) compared with populations of salmon (0.9–1.6 percent, depending on ESU).

Table 18. Status of Caspian tern nesting islands for the 2015 breeding season (Collis et al. 2015).

Location	Acres Available in 2015	Completion Date	Social Attraction	Watered
Fern Ridge Reservoir (OR)	1.0	Feb 2008	Yes	Yes
Crump Lake (OR)	1.0	Mar 2008	No	Yes
East Link Unit, Summer Lake Wildlife Area (OR)	0.5	Dec 2008	Yes	Yes
Dutchy Lake, Summer Lake Wildlife Area (OR) *	0.0	Feb 2009	NA	NA
Sump 1B, Tule Lake NWR (CA)	2.0	Aug 2009	Yes	Yes
Gold Dike Unit, Summer Lake Wildlife Area (OR)	0.5	Sep 2009	Yes	Yes
Orems Unit, Lower Klamath NWR (CA)	0.0	Sep 2009	No	No
Sheepy Lake, Lower Klamath NWR, (CA)	0.8	Feb 2010	No	Yes
Malheur Lake, NWR (OR)	1.0	Feb 2012	Yes	Yes
Don Edwards NWR, San Francisco Bay (CA)	1.83	Feb 2015	Yes	Yes
*Island removed in 2012. No management or monitoring in 2014.				

RPA Action 46 – Double-Crested Cormorants*

**** The language below reflects changes made by the 2014 BiOp:***

The FCRPS Action Agencies will develop a cormorant management plan (including necessary monitoring and research) and implement warranted actions to reduce cormorant predation in the estuary to Base Period levels (no more than 5,380 to 5,939 nesting pairs on East Sand Island).

East Sand Island is home to the largest Double-crested cormorant colony in western North America and is the largest known breeding colony of the species world-wide. In 2014, all of East Sand Island was available to Double-crested cormorants.

In 2015, the colony consisted of about 12,150 breeding pairs, down from the 14,916 pairs recorded in 2013, and 13,626 pairs in 2014, but higher than the average annual estimate of 10,776 for 1997–2013. Predation rate results indicated that impacts by Double-crested cormorants on ESA-listed juvenile salmonids in 2015 were some of the highest ever recorded, with estimates of 14.5 percent (95 percent c.i. = 10.5–22.4) and 12.8 percent (95 percent c.i. = 9.3–19.6) for Snake River spring/summer Chinook salmon and Snake River steelhead, respectively. Impacts on salmon ESUs were comparable to those of steelhead DPSs in 2015, although the lowest rates were observed on two salmon populations (Snake River sockeye salmon and upper Willamette River spring Chinook salmon, with less than 2.5 percent of available fish consumed by cormorants in 2015). Analysis suggests that Double-crested cormorants consume juvenile salmonids in relative proportion to their availability on an annual basis.

On February 6, 2015 the Final EIS was published and on March 19, 2015 a Record of Decision was signed by the Corps' Brig. Gen John Kem. Final EIS alternative C-1 was selected as the recommended management plan. On March 2015 the Corps applied for a depredation permit from U.S. Fish and Wildlife Service and received a one-year depredation permit on April 13, 2015 for Double-crested cormorant culling and egg oiling. The Corps completed the first year of implementation of the Cormorant Management Plan in 2015 which resulted in 2,346 individual adult Double-crested Cormorants culled and 5,089 nests oiled.

RPA Action 47 – Inland Avian Predation

The FCRPS Action Agencies will develop an avian management plan (for Double-Crested Cormorants, Caspian Terns, and other avian species as determined by RME) for Corps-owned lands and associated shallow water habitat.

In 2015, the Action Agencies continued implementation of the Inland Avian Predation Management Plan (IAPMP). The final IAPMP was released in January 2014 with the Corps signing a Finding of No Significant Impact (FONSI) January 23, 2014 and Reclamation signing a FONSI January 24, 2014. Implementation of Phase 1 components of the IAPMP subsequently began in January 2014 including dissuasion of Caspian terns from Goose Island during the 2014 nesting season and development of construction plans for Caspian tern habitat at Don Edwards National Wildlife Refuge (south San Francisco Bay). The Corps and Reclamation completed construction of Caspian tern habitat at Don Edwards National Wildlife Refuge in the south San Francisco Bay in February 2015. Upon completion of construction efforts at Don Edwards NWR, the Corps and Reclamation dissuaded Caspian terns from both Goose and Crescent Islands during the 2015 nesting season. Management efforts in 2015 reduced the Goose Island predation rate on Upper Columbia River steelhead from a 2007-2013 average of 15.7 percent to approximately 1.5 percent and the predation rate on listed Upper Columbia River Spring Chinook from a 2007-2013 average of 2.6 percent to 0.1 percent in 2015 (Collis et al. 2016). Management efforts in 2015 reduced Crescent Island predation rates to less than 0.1 percent per ESU as no terns nested on Crescent Island during the 2015 season (Collis et al. 2016). However, during the 2015 nesting season, the historically small Caspian tern colony within the Blalock Islands Complex (near Boardman, Oregon, in John Day Dam reservoir) increased in size. Caspian tern predation rates by the colony at the Blalock Islands Complex increased from a historical 2007-2014 average of 0.6 percent or less per ESU to 8.0 percent and 8.2 percent on Snake River and Upper Columbia River steelhead respectively (Roby et al. 2016b). 2015 Goose Island and Crescent Island predation rates were based on historical, per capita (per bird) predation rate estimates and not empirically-derived PIT tag data from 2015.

The IAPMP is a habitat based management plan primarily addressing Caspian tern predation within the Columbia River basin upstream of Bonneville Dam. The Corps' avian deterrent program at the 8 lower Columbia and Snake River hydroelectric facilities continued to be addressed through the Fish Passage Operations and Maintenance (FPOM) group and has been included in the Fish Passage Plan (FPP) per RPA Action 48.

RPA Action 48 – Other Avian Deterrent Actions*

**** The language below reflects changes made by the 2014 BiOp:***

The Corps will monitor avian predator (terns, cormorants, and gulls) activity and continue to implement and improve avian deterrent programs at all lower Snake and Columbia River dams. This program will be coordinated through the Fish Passage Operations and Maintenance Team and included in the Fish Passage Plan.

Avian deterrent actions, such as long-term hazing and wire arrays, were implemented in consultation with FPOM and in accordance with the FPP (ACOE 2015a), as called for by RPA Action 48.

RPA Action 49 – Marine Mammal Control Measures

The Corps will install and improve, as needed, sea lion excluder gates at all main adult fish ladder entrances at Bonneville Dam annually. In addition, the Corps will continue to support land and water based harassment efforts by Oregon Department of Fish and Wildlife (ODFW), Washington Department of Fish and Wildlife (WDFW), and Columbia River Inter-Tribal Fish Commission (CRITFC) to keep sea lions away from the area immediately downstream of Bonneville Dam.

In 2015, the Corps again implemented and evaluated a variety of sea lion deterrents, from physical barriers to non-lethal harassment (Fish Field Unit 2016). Sea lion exclusion devices (SLEDs) were installed at Powerhouse II on February 24, at the Cascades Island ladder entrances on March 1, at B-branch ladder entrances on March 4, and at Powerhouse I entrances on March 4. The SLEDs feature 15.38-inch (39.05-centimeter) gaps that are designed to allow fish passage. Floating orifice gates were also equipped with SLED-like barriers. Removal of the SLEDS began on July 8 and was completed on July 20.

Since 2006, the Corps has contracted with the U.S. Department of Agriculture (USDA) Wildlife Services to harass sea lions away from fishways and other dam structures. In 2015, dam-based harassment by USDA agents began on March 18 and continued seven days per week through the end of May. Dam-based harassment involved a combination of acoustic, visual, and tactile non-lethal deterrents, including above-water pyrotechnics (cracker shells), and rubber buckshot from shotguns.

CRITFC conducted boat-based harassment on 31 separate days between March 6 and May 14. While boats were granted access to the Bonneville Dam tailrace boat restricted zone, they could not operate within 30 meters of dam structures or within 50 meters of fishway entrances. To minimize the impact to fish, the use of “seal bomb” deterrents was prohibited within 100 meters of fishways, collection channels, or fish outfalls for the Powerhouse II corner collector and smolt monitoring facility. Boat crews ceased use of seal bombs after adult salmonid passage exceeded 1,000 fish per day.

Corps biologists coordinated with USDA agents and boat-based crew from CRITFC on all sea lion harassment activities at Bonneville Dam to ensure safety and increase the effectiveness of harassment efforts. SLEDs and orifice gates continued to be effective at keeping sea lions out of the fishways. Non-lethal hazing with pyrotechnics from both the dam face and by boat continued to have limited effectiveness; pinnipeds swim away from an area when hazed, but return soon thereafter.

RME Implementation Reports, RPA Actions 50–73

The 2014 NOAA Fisheries Supplemental BiOp includes a large, comprehensive research and monitoring program covering status monitoring, action effectiveness research, and critical uncertainties research in the areas of fish population status, hydro, tributary habitat, estuary/ocean, harvest, hatchery, and predation (Table 19). This program includes numerous individual projects, many of which have been collecting needed data for multiple years. The following sections list the individual projects that support each RME RPA subaction and include computer links to find detailed, information through access to the Project technical and annual reports. These reports are the products of the contracted agency and/or tribal staff and do not necessarily represent the scientific or policy interpretation of any entity including the Action Agencies or NOAA Fisheries.

In 2015, many RME projects collected additional data as part of a multiyear study design. Summaries of the results of these research and monitoring efforts can be found in Section 1 of this Annual Progress Report under RME.

For all BPA-funded RME actions in RPA Actions 50-73, individual project information can be found at: http://www.cbfish.org/BiologicalOpinionAction.mvc/Index/2015/BiOpRpaStatus

A 2015 compilation of annual reports for these projects can be found at https://www.cbfish.org/FileResource.mvc/DownloadPdfFileResource/a646e04f-17f6-429c-968c-d633d8c38ba4

Individual Corps of Engineers project information and research reports are available upon request.

Table 19. RME strategy reporting.

RPA Action No.	Action	Comprehensive Evaluation Reporting
RME Strategy 1		
50	Fish Population Status Monitoring	The evaluation of fish population status information will be included.
51	Collaboration Regarding Fish Population Status Monitoring	Progress on collaboration will be reported.
RME Strategy 2		
52	Monitor and Evaluate Fish Performance within the FCRPS	The evaluation will include information from these actions.
53	Monitor and Evaluate Migration Characteristics and River Condition	The evaluation will include information from these actions.
54	Monitor and Evaluate Effects of Configuration and Operation Actions	The evaluation will include information from these actions.
55	Investigate Hydro Critical Uncertainties and Investigate New Technologies	The evaluation will include information from these actions.

RPA Action No.	Action	Comprehensive Evaluation Reporting
RME Strategy 3		
56	Monitor and Evaluate Tributary Habitat Conditions and Limiting Factors	The evaluation will include information from these actions.
57	Evaluate the Effectiveness of Tributary Habitat Actions	The evaluation will include information from these actions.
RME Strategy 4		
58	Monitor and Evaluate Fish Performance in the Estuary and Plume	The evaluation will include information from these actions.
59	Monitor and Evaluate Migration Characteristics and Estuary/Ocean Conditions	The evaluation will include information from these actions.
60	Monitor and Evaluate Habitat Actions in the Estuary	The evaluation will include information from these actions.
61	Investigate Estuary/Ocean Critical Uncertainties	The evaluation will include information from these actions.
RME Strategy 5		
62	Fund Selected Harvest Investigations	The evaluation will include information from these actions.
RME Strategy 6		
63	Monitor Hatchery Effectiveness	The evaluation will include information from these actions.
64	Investigate Hatchery Critical Uncertainties	The evaluation will include information from these actions.
65	Investigate Hatchery Critical Uncertainties	The evaluation will include information from these actions.
RME Strategy 7		
66	Monitor and Evaluate the Caspian Tern Population in the Columbia River Estuary	The evaluation will include information from these actions.
67	Monitor and Evaluate the Double-Crested Cormorant Population in the Columbia River Estuary	The evaluation will include information from these actions.
68	Monitor and Evaluate Inland Avian Predators	The evaluation will include information from these actions.
69	Monitoring Related to Marine Mammal Predation	The evaluation will include information from these actions.
70	Monitoring Related to Piscivorous (Fish) Predation	The evaluation will include information from these actions.

RPA Action No.	Action	Comprehensive Evaluation Reporting
RME Strategy 8		
71	Coordination	The evaluation will include a report on coordination efforts, projects and associated products and how the Action Agencies have incorporated those products into their RME and data management projects.
72	Data Management	The evaluation will include a report on data management projects.
RME Strategy 9		
73	Implementation and Compliance Monitoring	The Action Agencies will use the project-level detail contained in the Action Agencies' Biological Opinion databases to track results and assess our progress in meeting programmatic level performance targets. This performance tracking will be reported through annual progress reports and the 2013 and 2016 comprehensive reports.

RPA Action 50 – Fish Population Status Monitoring

The Action Agencies will enhance existing fish population status monitoring performed by fish management agencies through the specific actions listed below. In addition, ancillary population status and trend information is being obtained through several ongoing habitat and hatchery improvement projects.

1. *Implement and maintain the Columbia River Basin passive integrated transponder (PIT)-Tag Information System (annually).*

   BPA Project 1990-080-00 (Columbia Basin PIT Tag Information) covered the PTAGIS which is operated and maintained at http://www.ptagis.org. PIT tags are primarily used for hydro system and tributary survival assessments, as well as tributary assessments of population adult return abundance and diversity to help assess viable salmon population attributes of spawner abundance, adult productivity, spatial distribution, and diversity.

   BPA Project 2003-017-00, Integrated Status and Effectiveness Monitoring Program (ISEMP) is a collaborative effort between the ISEMP project and Columbia River Basin PIT Tag Information project. Management of PIT Tag Array operational data is maintained for tributary PIT Arrays, which supports rapid reduction of PIT tag data to support assessment of adult returns in the tributaries.

2. *Monitor adult returns at mainstem hydroelectric dams using both visual counts and the PIT Tag detection system (annually). (See Hydrosystem section).*

   This RPA calls for the continued monitoring of adult returns at key dams in the FCRPS. Visual counts occur at all sites. PIT tag detection systems are now installed at adult ladders at Bonneville, The Dalles, McNary, Lower Monumental, Little Goose and Lower Granite dams.

   BPA Project 2005-002-00 (Lower Granite Dam Adult Trap Operations) utilized an adult trap at Lower Granite Dam for broodstock collection, sampling, genetic stock identification (GSI), and PIT tag status monitoring of wild adult steelhead and wild adult Chinook. In 2015, BPA and the Corps started funding design work for an adult ladder PIT tag detection system, to be installed at John Day Dam in 2016.

In 2015, the Corps implemented its adult fish count program as described in the Fish Passage Plan (ACOE 2015a). Results are available in the 2015 Annual Fish Passage Report: Columbia and Snake Rivers (ACOE 2016).

3. *Monitor juvenile fish migrations at mainstem hydroelectric dams using smolt monitoring and the PIT Tag detection system (annually). (See Hydrosystem section)*

BPA Project 1987-127-00 (Smolt Monitoring Program) is a long-term effort involving multiple agencies to gather data on abundance, passage timing, system travel time and survival, and physical condition of smolts moving out of tributaries and past Snake and Columbia River hydro projects.

BPA Project 1989-107-00 (Statistical Support for Salmon) has provided guidance and technical assistance in mark-recapture study design and data analysis to multiple tribal, state, and federal agencies. A set of software programs for mark-recapture model parameter estimation and PIT detection analysis are available for public use: http://www.cbr.washington.edu/analysis.

BPA Project 1990-055-00 (Idaho Steelhead Monitoring and Evaluation Studies (ISMES)) conducted additional tagging of hatchery populations to improve the resolution of watershed estimates of juvenile hydrosystem survival and wild steelhead populations in the Clearwater River and upper reaches of the Snake River. Efforts were coordinated with the Genetic Stock Identification (2010-026-00) and the Parental Based Tagging (2010-031-00) projects. Major Population Group (MPG) composition was estimated based on the 10 genetic reporting groups.

BPA Project 1991-029-00 (RME of emerging issues and measures to recover the Snake River fall Chinook salmon ESU) conducted wild and hatchery origin fall Chinook tagging with a special focus on investigating passage timing of the “reservoir-type” yearling life history type and the ‘ocean-type’ subyearling migrants observed among fall Chinook above Lower Granite Dam. Total juvenile passage abundance at Lower Granite dam was 1.3 million wild fall Chinook subyearlings and 2.8 million hatchery fall Chinook subyearlings (the highest estimates recorded in 1992-2015), but the low flow conditions in 2015 may have biased these estimates upwards.

BPA Project 1994-033-00 (Fish Passage Center) provided technical analysis, data summaries, graphic representations for the state, federal and tribal fishery managers’ use in developing their recommendations for fish passage management to the federal operators and regulators and the National Marine Fisheries Service. The Fish Passage Center (FPC) designs and oversees the implementation of the Smolt Monitoring Program (SMP), including the dissolved gas trauma monitoring, and distributes the data daily to public and private entities in the region.

BPA Project 1996-020-00 (Comparative Survival Study (CSS)) built a long-term database monitoring smolt-to-adult return rates and passage characteristics of specific wild and hatchery groups of spring/summer Chinook and steelhead throughout the Columbia River Basin. CSS conducted additional tagging of hatchery populations to improve the resolution of watershed estimates of juvenile survival. Marked fish utilized in the analysis may be from groups PIT tagged specifically for this program and from groups marked for other research studies.

BPA Project 1993-029-00 (Survival Estimate for Passage through Snake and Columbia River Dams) NOAA Fisheries completed their twenty-third year of an annual survival study monitoring survival, travel time, and transported fraction of yearling spring migrants of Chinook, steelhead and sockeye salmon over major FCRPS reaches using PIT-tagged hatchery and wild groups. In addition, some upper Columbia stocks and Snake River coho are monitored. Length and condition was recorded for all fish tagged for the study at Lower Granite Dam juvenile fish facility. Reach conversion rates of returning adults tagged for the study is monitored at ladders in the mainstem. In 2015, NOAA continued development of towed antenna to be used in the estuary trawl. This 2.4 by 6.1 m flexible antenna is capable of detecting 12 mm full-duplex PIT tags. These antennas were versatile in application given their large size and ease of handling and had relatively low construction costs compared to traditional PVC antennas. Modifications tested in 2015 improved deployment logistics, system hydrodynamics, and electronic performance. Sampling during system development yielded 124 detections of various species and runs in 54 hours of sampling.

BPA Project 2007-083-00 (Grande Ronde Supplementation Monitoring and Evaluation on Catherine Creek/Upper Grande Ronde River) conducted additional tagging of wild steelhead populations to improve the resolution of watershed estimates of juvenile hydrosystem survival. Wild outmigrant abundance was estimated based on screw trap data.

4. *Fund status and trend monitoring as a component of the pilot studies in the Wenatchee, Methow, and Entiat river basins in the Upper Columbia River, the Lemhi and South Fork Salmon river basins, and the John Day River Basin to further advance the methods and information needed for assessing the status of fish populations. (Initiate in FY 2007-2009 Project Funding, review and modify annually to ensure that these projects continue to provide a means of evaluating the effectiveness of tributary mitigation actions).*

BPA Project 1991-073-00 (Idaho Natural Production Monitoring and Evaluation) monitored and evaluated the status of wild Snake River spring-summer Chinook salmon and summer steelhead populations in the Salmon and Clearwater River subbasins, including the Lemhi and South Fork Salmon Rivers. The Idaho Natural Production Monitoring and Evaluation Project study is to determine effectiveness of habitat mitigation for steelhead and spring/summer Chinook salmon in Idaho. The project continues to refine methods to estimate natural origin spawner abundance, proportion hatchery origin spawners (pHOS), and population level productivity (adult to adult recruits/spawner).

BPA Project 1996-020-00 – (Comparative Survival Study (CSS)). The CSS contributed to the implementation of RPA 50.4 in 2015 by providing 30,000 PIT tags for wild Chinook salmon and wild steelhead marking at the Chiwawa Trap and the Lower Wenatchee Trap both on the Wenatchee River, the Entiat River trap site and the Methow River trap site. The CSS also utilizes other Columbia River PIT tag mark groups generated from other tagging efforts, in addition to CSS specific tagging efforts.

BPA Project 1997-030-00 – (Secesh Chinook & Joseph Creek steelhead abundance monitoring): this project supports the ISEMP Study in the South Fork Clearwater. The ISEMP study design relies on this project to contribute population spatial scale escapement data for comparison of methods (PIT tag array vs DIDSON vs redd count expansions) and spatial scale assessments (subpopulation (Lake Creek), population (Secesh River), and Major Population Group (South Fork Salmon River).

BPA Project 1998-016-00 (Escapement and Productivity of Spring Chinook and Steelhead) initially provided basin-wide status and trend data for anadromous salmonids in the John Day River Basin, but has been refocused to IMW study in the Middle Fork John Day and South Fork John Day populations. To accomplish this, researchers estimate out-migrant abundance of summer steelhead, physical characteristics of outmigrant salmonids, SARs for summer steelhead, summer steelhead life-history patterns, and productivity of summer steelhead populations.

BPA Project 2003-017-00 (ISEMP) implemented status and trend monitoring fish and watershed-level action effectiveness monitoring in five Intensively Monitored Watersheds (IMWs) throughout the Columbia River Basin. The IMWs continued in the Entiat River, Bridge Creek, and Lemhi River watersheds, while status and trend monitoring is implemented in the Wenatchee, John Day, and Secesh River watersheds. Monitoring included operation of instream PIT tag detection arrays (IPTDS) for adult spawner abundance estimates, as well as juvenile abundance monitoring with rotary screw traps and tributary parr mark recapture surveys.

BPA Project 2010-034-00 (Upper Columbia Spring Chinook and Steelhead Juvenile and Adult Abundance, Productivity and Spatial Structure Monitoring) evaluated precision and accuracy of the smolt monitoring methodology for both steelhead and spring Chinook; estimated the proportion of hatchery steelhead in each primary population; estimated the precision of redd counts for both steelhead and spring Chinook; and evaluated the accuracy of the steelhead spawning ground survey design supporting the Upper Columbia pilot studies. Through this project WDFW has developed a new methodology of estimating steelhead run escapement. WDFW intends to conduct a second year of the radio telemetry study and finalize analysis before adopting the new methodology.

5. *Provide additional status monitoring to ensure a majority of Snake River B-Run steelhead populations are being monitored for population productivity and abundance. (Initiate by FY 2009, then annually.)*

BPA Project 1983-350-03 (Nez Perce Tribal Hatchery Monitoring and Evaluation) monitored and evaluated hatchery and natural fish through PIT tagging, weir operation and/or spawning ground surveys, screw trapping, habitat surveys, genetic analysis, and harvest monitoring. Estimating fish-out (juvenile production) in Lolo Creek is joint effort between this project and 2010-057-00.

BPA Project 1989-098-00 (The Salmon Studies in Idaho Rivers- IDFG (ISS)) supported smolt trap infrastructure used to monitor B-Run Steelhead in coordination with the ISEMP project. This project was completed with an annual report and ongoing required field monitoring will be integrated into 1990-055-00 (ISMES) and 1991-073-00 (Idaho Natural Production Monitoring and Evaluation Project) in 2015.

BPA Project 1990-055-00 Idaho Steelhead Monitoring and Evaluation (M&E) Studies (ISMES) continued to operate temporary weirs to estimate escapement in Fish Creek (Lochsa River), Rapid River (Little Salmon River), and Big Creek (lower Middle Fork Salmon River). Wild fish were sampled further; scales were collected, and a small portion of the anal fin was removed for a genetics tissue sample. This project works cooperatively with Genetic Stock Identification Program (GSI; 2010-026-00), and the

Parental Based Tagging Program (2010-031-00) and has implemented a sampling program at Lower Granite Dam (LGR) to annually estimate abundance of all wild steelhead (adults and smolts) in the Snake River basin (including wild B run steelhead) by Major Population Group (MPG) or finer scale.

BPA Project 1991-073-00 (Idaho Natural Production Monitoring and Evaluation Project (INPM) is a long-term monitoring and research project to determine the effectiveness of habitat mitigation for Idaho steelhead and spring/summer Chinook through assessments of population characteristics, survival, and productivity. It conducts the biological sampling at Lower Granite Dam to annually estimate wild steelhead abundance (adult and smolt) by Major Population Group, age, and sex for the Snake River ESU upstream from Lower Granite Dam.

BPA Project 2003-017-00 (ISEMP) implemented status and trend monitoring fish and watershed-level action effectiveness monitoring. Monitoring included operation of instream PIT tag detection arrays (IPTDS) for adult spawner abundance estimates, in multiple populations in Salmon and Clearwater MPG as well as juvenile abundance monitoring with rotary screw traps and tributary parr mark recapture surveys in the Lemhi and Secesh rivers. The ISEMP project directly estimates sex and age-structured escapement for 13 of the 25 populations of Snake River steelhead identified by the Interior Columbia Basin Technical Recovery Team, including 5 of the 7 populations known to support B-run steelhead

BPA Project 2005-002-00 (Lower Granite Dam Adult Trap Operations) supported PIT tagging of adult steelhead returns for adult escapement assessments and parental-based tagging for GSI. Ongoing discussions with NOAA Fisheries, the Action Agencies and the sponsors are underway to ensure increased trapping does not increase ESA take and that the study design for representational marking is not compromised.

BPA Project 2009-005-00 (Influence of Environment and Landscape on Salmonid Genetics) builds on related studies by our group to identify steelhead stocks in the Columbia and Snake river basins, and supported single nucleotide polymorphism genetic analysis of steelhead samples from other projects. The project focuses on information, combined with length measurements, provides the opportunity to scrutinize the proportion of specific stocks that are actually maturing after two years in the ocean and reach the length criteria established for A- and B-run steelhead. Further, we are addressing heritability and genetic basis for the phenotypic characteristics of A- and B-run steelhead.

BPA Project 2010-026-00 (Chinook and Steelhead Genotyping for GSI at Lower Granite Dam) has improved the evolutionary and biological understanding of A-run versus B-Run life history designations in the Snake River basin. In collaboration with projects 1990-055-00, 1991-073-00 and 2010-031-00, this project also annually estimates the abundance of all wild steelhead in the Snake River DPS (including wild B-run steelhead) by Major Population Group (MPG) or finer scale. Also in collaboration with projects 1990-055-00, 1991-073-00 and 2010-031-00, this project provides annual estimates of spawning escapement and run-timing of wild and hatchery steelhead returning to the Snake River basin.

BPA Project 2010-031-00 (Snake River Chinook and Steelhead Parental Based Tagging) continued development and evaluation of a new genetic technology called Parentage Based Tagging (PBT). PBT can serve as a versatile tool for the genetic tagging steelhead and Chinook salmon in the Snake River Basin. To support this RPA, creation of genetic parental databases, serves as a major component of the RPA strategy.

BPA Project 2010-038-00 (Lolo Creek Permanent Weir Construction) was closed in 2014 because it is believed the existing PIT tag infrastructure and analysis methods may support the fish in and fish out needs for the Clearwater MPG. Additionally, other populations in the Clearwater are a higher priority and more representative of the MPG to monitor to inform recovery and this RPA action.

BPA Project 2010-057-00 (B-Run steelhead supplementation effectiveness research) continued to support additional marking and tagging of fish and supported infrastructure used to monitor B-Run Steelhead in the Clearwater River: Lolo Creek and South Fork Clearwater River populations. Fish-in (adult escapement) estimates are provided by the Integrated Status and Effectiveness Monitoring Project (ISEMP; 2003-017-00). Estimating fish-out (juvenile production) in Lolo Creek is joint effort between this project and Nez Perce Tribal Hatchery Monitoring and Evaluation (1983-035-03).

6. *Review and modify existing Action Agencies' fish population status monitoring projects to improve their compliance with regional standards and protocols, and ensure they are prioritized and effectively focused on critical performance measures and populations.*

BPA Project 1983-350-03 (Nez Perce Tribal Hatchery Monitoring and Evaluation) monitored and evaluated hatchery and natural fish through PIT tagging, weir operation and/or spawning ground surveys, screw trapping, habitat surveys, genetic analysis, and harvest monitoring. Specially it: lead collaborative run-reconstruction estimation of adult returns (natural and hatchery) to and upstream of Lower Granite Dam; conducted redd counts in the Imnaha, Salmon, Grande Ronde, Clearwater subbasins; assessed juvenile production indices, emigration timing, and survival for both Nez Perce Tribal Hatchery and the Fall Chinook Acclimation Project (FCAP) and natural production in the Clearwater subbasin; and marking (fin clips, CWT, and PIT tagging) of Nez Perce Tribal Hatchery spring and fall Chinook salmon and mark retention checks on NPTH and FCAP production.

BPA Project 1988-022-00 (Umatilla Fish Passage Operations) continued to collect data during adult trapping operations includes date, number of fish trapped, species, age and sex composition, marks and disposition.

BPA Project 1988-053-03 (Hood River Production Monitoring and Evaluation (M&E)-Warm Springs)) implemented, monitored, and evaluated actions for Chinook salmon in the Hood River Master Plans for consistency with Hood River Production Plan (HRPP) goals. This project provided all data collected to ODFW for analysis under BPA project 1988-053-04

BPA Project 1988-053-04 (Hood River Production Monitoring and Evaluation-ODFW) monitored and evaluated estimates adult escapement and natural production spring Chinook salmon in the Hood River subbasin. Monitors non-tribal harvest, seasonal stream discharge, and estimates adult escapement and natural production of Lower Columbia River DPS summer and winter steelhead, Lower Columbia River ESU Coho, Columbia River DPS Bull Trout, spring Chinook salmon, and cutthroat trout in the Hood River subbasin. Data will be used to develop, and refine, management objectives for the HRPP.

BPA Project 1988-053-08 (Hood River Production Operation and Maintenance and Powerdale) funded capturing all upstream migrant juvenile Chinook salmon escaping to East Fork Hood River, West Fork Hood River, and Neal Creek Fish Traps.

BPA Project 1989-024-01 (Evaluate Umatilla Juvenile Salmon and Steelhead Outmigration) was requested by the Oregon Department of Fish and Wildlife (ODFW) and the Confederated Tribes of the Umatilla Indian Reservation (CTUIR) based on both a local and regional high priority need for information on life history characteristics, survival, and success of hatchery- and naturally-reared salmon and steelhead in the Umatilla River and provides estimates of smolt abundance, migration timing and survival, life history characteristics and productivity status and trends for all anadromous salmonid species in the Umatilla River basin.

BPA Project 1990-005-00 (Umatilla Hatchery Monitoring and Evaluation) funds the Umatilla Fish Hatchery which was constructed to supplement summer steelhead in the Umatilla River. The Umatilla Hatchery Monitoring and Evaluation project began in 1991 to evaluate hatchery rearing techniques and juvenile and adult production goals, but now also supports evaluation of Hatchery spawners on the spawning grounds.

BPA Project 1990-005-01 (Umatilla Basin Natural Production Monitoring and Evaluation Project) provided information to tribal, state and federal fisheries managers by monitoring the status and trends in the abundance, distribution, movement and survival of summer steelhead during adult migration, spawning, rearing and juvenile migration in the Umatilla River drainage.

BPA Project 1990-055-00 (Idaho Steelhead Monitoring and Evaluation Studies) continued to operate temporary weirs to estimate escapement in Fish Creek (Lochsa River), Rapid River (Little Salmon River), and Big Creek (lower Middle Fork Salmon River). Wild fish were sampled further; scales were collected, and a small portion of the anal fin was removed for a genetics tissue sample. ISMES project produced steelhead productivity data both at the index area and MPG level for the 5-year ESA status review in 2015.

BPA Project 1991-028-00 (PIT Tagging Wild Chinook) assessed the migrational characteristics and estimate parr-to-smolt survival for Snake River wild spring/summer Chinook salmon smolts at Lower Granite Dam. Characterize parr and smolt survival and movement out of natal rearing areas of selected streams and examine the relationships between fish movement, environmental conditions within the streams, and weather and climate data.

BPA Project 1991-029-00 (Research, Monitoring, and Evaluation of Emerging Issues and Measures to Recover the Snake River Fall Chinook Salmon ESU) continued to calculate catch-per-unit effort (CPUE) during March 24-June 24, 2015, as an index of natural fall Chinook salmon subyearling abundance along the Snake River upper and lower reaches (Hells Canyon Dam to Salmon River; Salmon River to upper end of Lower Granite Reservoir) that support two of the four major spawning aggregates of the Snake River fall Chinook salmon ESU. CPUE was also calculated for those two reaches during 1992-2014.

BPA Project 1991-073-00 (Idaho Natural Production Monitoring and Evaluation) has been responsible for updating the Viable Salmonid Population metrics associated with listed Snake River spring/summer Chinook salmon populations in Idaho and those data used every 5 years in NOAA's status assessment of Snake River listed Chinook salmon and steelhead, including in 2015. IDFG staff have been collaborating with Nez Perce Tribe and Shoshone Bannock Tribe Fisheries personnel to review and update the existing VSP data sets for listed populations. Through the update, we are also collaboratively working to review the methods and data available for each population. Data are submitted annually to NOAA for incorporation into the Salmonid Population Summary (SPS) Database.

BPA Project 1992-026-04 (Grand Ronde Early Life History of Spring Chinook and Steelhead) monitors the VSP element Juvenile Migrant Abundance for Snake River Spring/Summer Chinook Salmon in the Catherine Creek, Grande Ronde Upper Mainstem, Minam River, and Wallowa-Lostine River MPG populations and for Snake River Steelhead in Catherine Creek and upper Grande Ronde River in the Upper Grande Ronde River MPG population and in Lostine River and Minam River in the Wallowa River MPG population.

BPA Project 1994-033-00 (Fish Passage Center) contributed to the implementation of RPA 50.6 by managing the implementation, reporting, data management and analyses for the Smolt Monitoring Program Project and the Comparative Survival Study Project. The Fish Passage Center Project, the Comparative Survival Study (CSS) project and the Smolt Monitoring Program (SMP) project are completely integrated with each other and they are implemented and overseen by the Fish Passage Center. In 2015 and in previous years, the FPC has managed PIT tag mark groups to progress towards the objective of collection of smolt monitoring and life-cycle monitoring data on the Major Population Group (MPG) level.

BPA Project 1995-063-25 (Yakima River Monitoring and Evaluation-Yakima/Klickitat Fisheries Project) monitored and evaluated steelhead abundance for the Yakima River MPG populations in collaboration with project 2010-030-00.

BPA Project 1995-063-35 (Klickitat River Monitoring and Evaluation-Yakima/Klickitat Fisheries Project) monitors adult abundance, spatial distribution, genetic diversity, productivity, survival, and habitat conditions of Middle Columbia River steelhead in the Klickitat River subbasin. Estimates of adult escapement at Lyle Falls on the lower Klickitat River occur via mark-recapture estimation; spawner abundance and distribution is also monitored via spawning ground surveys. Productivity metrics are being monitored via adult return estimation, scale age analysis, and PIT tagging.

BPA Project 1996-019-00 (Data Access in Real Time) maintains the DART tools which support assessments of multiple fish populations for this RPA through compilation of data. They also create ad host software to analyze PIT tag data systems. Without this customized software, sponsors would have a difficult time synthesizing PIT tag data for adult escapement for key fish-in and fish-out populations.

BPA Project 1996-035-01 (Yakama Reservation Watershed Project) works with project 1995-063-25 conducting biological monitoring including spawning ground surveys, snorkel surveys, and smolt trapping for populations in the Yakima Steelhead MPG.

BPA Project 1996-043-00 (Johnson Creek Artificial Propagation Enhancement) assessed the status and trends of the both natural-origin and hatchery-origin spring/summer Chinook salmon in Johnson Creek. Johnson Creek is the primary spawning and production area for spring/summer Chinook salmon population in the

East Fork South Fork Salmon River (South Fork Salmon River MPG in the Snake River ESU).

BPA Project 1997-015-01 (Imnaha River Smolt Monitoring) provided the FPC's Smolt Monitoring Project with tributary specific emigration data from the Imnaha River. It continues to collect a time series of juvenile Chinook salmon and steelhead data.

BPA Project 1997-030-00 (Secesh Chinook & Joseph Creek Steelhead Abundance Monitoring) quantifies adult spring/summer Chinook salmon returns to the Secesh River within the South Fork Salmon MPG in the Snake River ESU. Monitoring of escapement and migration timing utilized Dual Frequency Identification Sonar (DIDSON). Monitoring has been conducted annually since 2004. The project also operates a resistance board floating weir to quantify adult steelhead in Joseph Creek within the Grande Ronde MPG in the Snake River DPS. Monitoring has been conducted annually since 2011.

BPA Project 1998-007-02 (Grand Ronde Supplementation Operation and Maintenance, and Monitoring and Evaluation on Lostine River) Monitoring and evaluations quantify VSP (viable salmon population) metrics for both natural-origin and hatchery-origin fish for Lostine River, steelhead and the Wallowa/Lostine population Snake River spring Chinook salmon.

BPA Project 1998-007-03 (Grand Ronde Supplementation Operation and Maintenance on Catherine Creek/Upper Grande Ronde River) preserves the genetic variability and enhance the population size of the depressed spring Chinook salmon populations in Catherine Creek and the Upper Grande Ronde River using a hatchery program based on the indigenous stock.

BPA Project 1998-010-04 (Monitor and Evaluate (M&E) Performance of Juvenile Snake River Fall Chinook Salmon from Fall Chinook Acclimation Project) closed in 2014; ongoing monitoring of fall Chinook continued in other projects.

BPA Project 1998-016-00 (Escapement and Productivity of Spring Chinook and Steelhead) continued monitoring of Middle Columbia DPS spring Chinook salmon and summer steelhead in the John Day River basin. During 2015, they evaluated adult and juvenile steelhead in the South Fork, Upper Mainstem, and Middle Fork of the John Day River.

BPA Project 1998-019-00 (Wind River Watershed) is a collaborative effort to restore wild steelhead in the Wind River, and to measure, track and document adult and juvenile steelhead population status , life histories, and interactions, and to share information across agency and non-agency boundaries.

BPA Project 1999-020-00 (Analyze Persistence and Dynamics in Chinook Redds) addressed long-term status and trends of wild Chinook salmon populations in the Middle Fork Salmon River MPG.

BPA Project 2002-053-00 (Asotin Creek Salmon Population Assessment) estimated adult spawning escapement, juvenile outmigration and productivity for the Asotin Creek steelhead population, within the lower Snake River Steelhead MPG. This project monitored adult escapement in Asotin Creek, and George Creek, in addition to the following independent Snake River tributaries Alpowa Creek and Tenmile Creek. Additionally, a rotary smolt trap operated on Asotin Creek provided juvenile emigrant estimates. The sum of the data collected allowed for the estimation and calculation of critical viability metrics for the mainstem of Asotin Creek and George Creek.

BPA Project 2003-017-00 (ISEMP) contributed to status monitoring in IMW basins by: by operating IPTDS or supplying sufficient PIT tag recoveries to generate population abundance estimates; operation of rotary screw traps; conducted population-level pre-emigration abundance and survival estimation; assessed natural-origin adult spring/summer Chinook salmon and steelhead escapement above Lower Granite Dam (LGR) using PIT tag interrogation in the Salmon subbasin; conducted steelhead redd surveys in the Entiat River subbasin; and operated the adult weir in the John Day.

BPA Project 2003-022-00 (Okanogan Basin Monitoring and Evaluation Program) continued to monitor and assess adult and juvenile steelhead status for the Okanogan basin with mark recapture studies using PIT tags and other methods.

BPA Project 2007-083-00 (Grand Ronde Supplementation Monitoring and Evaluation on Catherine Creek/Upper Grande Ronde River) monitored adult abundance of the Upper Grande Ronde River and Catherine Creek populations and evaluated the effectiveness of supplementation in recovering spring Chinook salmon populations.

BPA Project 2007-402-00 (Snake River Sockeye Captive Propagation) Idaho Department of Fish and Game (IDFG), the National Marine Fisheries Service (NOAA Fisheries), the Shoshone-Bannock Tribes, the Oregon Department of Fish and Wildlife (ODFW), and the University of Idaho monitored the abundance of Snake River Sockeye.

BPA Project 2009-004-00 (Monitoring Recovery Trends in Key Spring Chinook Habitat Variable and Validation of Population Viability Indicators) focused on monitoring Upper Grande Ronde Chinook salmon recovery trends through identifying areas that have depressed populations creating a baseline and future modeling.

BPA Project 2010-026-00 (Chinook and Steelhead Genotyping for Genetic Stock Identification (GSI) at Lower Granite Dam) in collaboration with projects 1990-055-00, 1991-073-00 and 2010-031-00, provides annual estimates of spawning escapement and migration timing of wild and hatchery steelhead and Chinook salmon returning to various major population groups or specific drainages in the Snake River basin. The sampling of adult and juvenile Chinook salmon and steelhead at Lower Granite Dam allow the annual reporting of three viable salmonid population (VSP) criteria (abundance, productivity, and diversity) for the Snake River ESU. This project has reviewed and modified the monitoring program at Lower Granite Dam to implement GSI, and estimate abundance and biological parameters for wild steelhead and Chinook salmon stocks (both juveniles and adults) at Lower Granite Dam.

BPA Project 2010-028-00 (Estimate Adult Steelhead Abundance in Small Streams Associated with Tucannon & Asotin Populations) continued to assess adult abundance associated with Tucannon and Asotin Chinook and steelhead populations.

BPA Project 2010-030-00 (Viable Salmonid Population Estimates for Yakima Steelhead MPG) assessed spawner abundance and productively of Yakima River MPG populations with distributions and abundance is the primary focus of this project improved tracking of the Upper Yakima and Naches population.

BPA Project 2010-032-00 (Imnaha River Steelhead Status Monitoring) quantifies adult steelhead adult escapement into the Imnaha River subbasin and described the population's spatial distribution within the subbasin. A properly monitored Imnaha steelhead population will contribute towards understanding the status and viability of the entire Snake River ESU and informed management decisions. This project has not delivered BPA a report since the last CE to update the status.

BPA Project 2010-034-00 (Upper Columbia Spring Chinook and Steelhead Juvenile and Adult Abundance, Productivity and Spatial Structure Monitoring) objectives are: (1) evaluate precision and accuracy of the smolt monitoring methodology for both steelhead and spring Chinook; (2) estimate the proportion of hatchery steelhead in each primary population; (3) estimate the precision of redd counts for both steelhead and spring Chinook; (4) and evaluate the accuracy of the steelhead spawning ground survey design.

BPA Project 2010-035-00 (Abundance, Productivity and Life History of Fifteen Mile Creek Winter Steelhead) funded ODFW to establish a comprehensive monitoring and evaluation program for abundance, productivity, and life history of steelhead in the Fifteen Mile Creek population, which is ESA-listed as a component of the Mid-Columbia steelhead DPS. Results show that this is conclusively not a winter steelhead population, which could change the relative importance of the population in delisting decisions and priorities for monitoring.

BPA Project 2010-038-00 (Lolo Creek Permanent Weir Construction) was closed because it is believed the existing PIT tag infrastructure and analysis methods may support the fish-in and fish-out needs for the Clearwater MPG.

BPA Project 2010-042-00 (Tucannon Expanded PIT Tagging) was integrated into project 2010-028-00.

BPA Project 2012-013-00 (Snake River Fall Chinook Monitoring and Evaluation) expands monitoring of Snake River fall Chinook adult distribution and informs estimates of percent Hatchery Origin Spawners (pHOS) for specific spawning aggregates within the Snake River Basin. Data for the study will be collected through 2017 with the annual field activities (data collection) occurring from August 18th to mid-December.

7. *Fund marking of hatchery releases from Action Agencies funded facilities to enable monitoring of hatchery-origin fish in natural spawning areas and the assessment of status of wild populations (annually).*

In 2015, BPA continued to support and fund a policy of 100 percent mark of all hatchery fish to meet viable salmonid population, hatchery, and habitat action effectiveness evaluation needs identified under several RPAs and regional recovery plans. However, while mark rates achieve this goal for the majority of hatcheries, there are some programs that still do not mark 100 percent of their fish releases and document marking percentages and types to improve accuracy of Natural Origin Spawner Abundance (NOSA) reporting.

BPA continued to work through 16 projects and with regional agencies on the importance of high, known mark rates, and to require better reporting of hatchery fish mark rates to better assess where there may be deficiencies or issues that need to be addressed.

8. *Report available information on population viability metrics in annual and comprehensive evaluation reports. (Initiate in FY 2008).*

   The Action Agencies continued to support the reporting of available population viability metrics through the Coordinated Assessments lead by StreamNet and PNAMP project data collection and transfer to the NOAA Fisheries Salmon Population Summary database to facilitate population viability assessments (http://q.streamnet.org/Request.cfm?cmd=BuildPicklist&NewQuery=BuildCriteria&PicklistItem=DataCategory). Status of the project is tracked at http://www.streamnet.org/ca-priority-data/ In addition to the StreamNet project and the multiple monitoring projects listed above under the RPA 50 subactions that support population viability assessments, BPA participated in and supported the Coordinated Assessments Project. The Coordinated Assessments Project is a collaborative effort working with fishery management co-managers and NOAA Fisheries to develop data exchange templates to facilitate assessments for viable salmonid population indicators such as adult spawner abundance, spawner to adult ratios, and recruit per spawner relationships for ESA-listed populations. BPA also developed guidelines and templates for RME reporting to facilitate more consistent and timely reporting of monitoring results and actively supported the development and required use of a monitoring protocol documentation tool and other coordination tools under the Pacific Northwest Aquatic Monitoring Partnership to help further advance coordination, data sharing, evaluation, and reporting of population viability metrics.

RPA Action 51 – Collaboration Regarding Fish Population Status Monitoring

The Action Agencies will enhance existing fish populations status monitoring performed by fish management agencies through the following collaboration commitments:

1. *Support the coordination, data management, and annual synthesis of fish population metrics through Regional Data Repositories and reports (Annually).*

   BPA Project 1988-108-04 (StreamNet – Coordinated Information System/Northwest Environmental Database (NED)) managed by Pacific States marine Fishery Commission (PSMFC) continued to support the implementation of the Coordinated Assessments Projects with, StreamNet and WDFW EPA grant Management to develop standard data exchange templates across the Northwest for the indicators of adult spawner abundance and juvenile salmonid out-migrant production.

   BPA Project 1989-098-00 (Salmon Studies in Idaho Rivers-IDFG) helped determine the utility of supplementation as a potential recovery tool for imperiled stocks of spring and summer Chinook salmon in Idaho, using both freshwater and saltwater smolt/adult rearing environments. In their final reports they related experimental concerns with limitations related to the design. However, the overall findings confirmed the benefits of supplementation to support viability of the demographically imperiled populations that were studied.

BPA Project 1994-033-00 (Fish Passage Center) as a regional data repository and has contributed by providing all of the Smolt Monitoring Program project data and analyses, and the Comparative Survival Study data and analyses to the public through the Fish Passage Center web site at http://www.fpc.org. In 2015, the FPC continued to develop and implemented structural map based data and queries, for ESA listed salmon and steelhead geographical data at adult and juvenile life stages at the Major Population Group (MPG) level. Future opportunities for collaboration with the Coordinated Assessments hatchery indicators was identified to continue into the future.

BPA Project 1996-019-00 (Data Access in Real Time (DART)) DART's extensive data integration and synthesis of region-wide publically available datasets permits the development and presentation of analysis tools providing user selected summaries and reports on basin and subbasin salmonids populations for survival and detection probabilities, travel times, adult upstream conversion rate, migration timing, and repeat spawners. DART works in cooperation with the Upper Columbia PUDs and tribes to publish historical and real-time adult passage data. DART's Valid Tag List reporting provides a foundation for spawning population estimates above Lower Granite Dam. DART's extensive filtering of PTAGIS data into ESU categories and life stages allows for analysis of specific life stages and endangered populations. The separation of PIT-tag observations into specific life stages further enhances the value of specific life-stage reports. DART's Conversion Rate analysis provides estimates of adult upstream migrations survivals through the mainstem and allows for the integration of PTAGIS interrogation, recapture, and mortality datasets in the analyses.

BPA Project 1997-030-00 (Chinook Salmon Adult Abundance Monitoring) field tests electronic data capture software and reports data to regional databases, including the LSRCP's Fish Inventory System (FINS) database housed at PSMFC and the Salmonid Population Summary (SPS) database for regional population viability analysis conducted by NOAA Fisheries.

BPA Project 2003-017-00 (ISEMP) has developed several data repositories intended to hold or report data, both in the raw, unsummarized form, or in metrics/indicators. The databases are used to feed data to regional databases, such as PTAGIS, or to feed data to regional data query systems such as Data Access in Real-Time (DART). Additionally, the project has coordinated closely with PTAGIS and DART to provide a consistent storage of raw data and associated meta-data required for effective use of fish tagging information. ISEMP project personnel also participate in regional forums and committees. ISEMP also compiles, parses, and reports all ISEMP interrogation data from In-Stream PIT tag Detections Systems (IPTDS) to PTAGIS.

BPA Project 2004-002-00 (Pacific Northwest Aquatic Monitoring Program Coordination) provided a forum for coordination of aquatic monitoring and data management efforts in the region to promote consistency in monitoring approaches and protocols; follow a scientific foundation; support monitoring policy and management objectives; and collect and present information in a manner that can be shared. Ongoing work in development of the tools at http://www.monitoringresources.org have allowed BPA and the Coordinated Assessment efforts to improve metadata documentation and exchanges to improve data discovery.

BPA Project 2008-507-00 (CRITFC's Tribal Data Network Accord Project) demonstrated implementation of coordination and standardization tools though evaluation and application of handheld technologies for data capture (e.g., the Digital Pen). More recent work was oriented to facilitate Coordinated Assessment data exchanges.

2. *Facilitate and participate in an ongoing collaboration process to develop a regional strategy for status and trend monitoring for key ESA fish populations. (Initiate in FY 2008).*

   The intent of this RPA was met through completion of the ASMS strategy in 2010 and finalization and publication of the Coordinated Assessment state and tribal strategies in 2011. With a 5-year work plan drafted in 2015. BPA identified that reevaluation of the strategy using PNAMP's Integrated Status and Trend Monitoring (ISTM), may occur to find efficiencies but that the regional strategy will continue to be supported through the existing collaboration. In addition BPA Project 2010-026-00 (Chinook and Steelhead Genotyping for GSI at Lower Granite Dam) confirmed the feasibility of the genetic and PIT tag monitoring strategy to monitoring Snake River Steelhead

3. *Provide cost-shared funding support and staff participation in regional coordination forums such as the Pacific Northwest Aquatic Monitoring Partnership fish population monitoring workgroup and the Northwest Environmental Data Network to advance regional standards and coordination for more efficient and robust monitoring and information management (annually).*

   The intent of this RPA sub action has been met by BPA who has over time increased funding to BPA project 2004-002-00, Pacific Northwest Aquatic Monitoring Program Coordination (PNAMP), to maintain staffing for coordination efforts. PNAMP provides a forum for coordination of aquatic monitoring efforts in the region to promote consistency in monitoring approaches and protocols; follow a scientific foundation; support monitoring policy and management objectives; and collect and present information in a manner that can be shared. PNAMP provides staff time to plan and host regional coordination forums, as well as attend other forums that are relevant to our work. In addition, PNAMP provides cost-shared funding support for travel costs to get to and from these meetings and workshops. PNAMP provides staff time to set up travel arrangements for participants outside of USGS who request travel support to attend regional meetings and workshops. For those participants unable to attend events in person, PNAMP dedicates a portion of its annual operating costs to online meeting software, such as WebEx. Documents distributed at meetings are efficiently distributed ahead of time to remote participants via the PNAMP website (http://www.pnamp.org), which is also supported via cost share funds from PNAMP partners.

RPA Action 52 – Monitor and Evaluate Fish Performance within the FCRPS

The Action Agencies will monitor the following biological responses and/or environmental attributes involved in passage through the hydrosystem, and report these estimates on an annual basis:

1. *Monitor and evaluate salmonid dam survival rates for a subset of FCRPS projects.*

   In 2015, the Corps did not carry out any studies to evaluate compliance with the Juvenile Salmon Dam Passage Performance Standards.

   BPA Project 1987-127-00 (Smolt Monitoring Program) gathered data on abundance, passage timing, system travel time and survival, and physical condition of smolts moving out of tributaries and past Snake and Columbia River hydro projects. All SMP data for 2015 are presently posted on the Fish Passage Center web site at http://www.fpc.org.

BPA Project 1989-107-00 (Statistical Support for Salmon) funded the University of Washington to provide software, technical assistance and guidance in mark-recapture study design and data analysis to tribal, state, and federal agencies. Between 2010 and 2014, a total of 29 compliance studies have been performed at six FCRPS hydro projects on three different fish stocks (yearling and subyearling Chinook salmon, steelhead). Additional studies are planned through at least 2017. In 2015, at the request of the U.S. Army Corps of Engineers, expertise from this project was used to provide guidance for tagging studies in the Willamette Valley. In 2015, this project posted on DART the reach survivals of over 25 hatchery and wild trapped stocks. The project has also calculated and posted SARs for over 322 hatchery–release location combinations within the FCRPS.

BPA Project 1991-051-00 (Modeling and Evaluation Statistical Support for Lifecycle Studies) assisted other projects in statistical analysis of tag detection data. In 2015, this project posted on DART the reach survivals and travel times of over 74 hatchery and wild trapped stocks. The project has also calculated and posted SARs for over 322 hatchery–release location combinations within the FCRPS.

BPA Project 1997-015-01 (Imnaha River Smolt Monitoring) tagged and monitored steelhead and Chinook smolts during outmigration from the Imnaha River.

2. *Monitor and evaluate juvenile salmonid in-river and system survival through the FCRPS, including estimates of differential post-Bonneville survival of transported fish relative to in-river fish (D-value), as needed. Monitor and evaluate adult salmonid system survival upstream through the FCRPS.*

The 2008 FCRPS BiOp established a methodology to annually estimate system survival rates of listed adult salmonids through defined hydrosystem reaches based on PIT-tagged fish detections at Bonneville, McNary, and Lower Granite Dams with corrections for harvest and straying.

Long-term adult system survival performance is evaluated for five stocks using a 5-year rolling average of annual system survival estimates. Snake River spring/summer Chinook and Snake River steelhead are used as surrogates for Snake River sockeye and mid-Columbia steelhead. Results are reported in Section 1.

BPA Project 1993-029-00 (Survival Estimate for Passage through Snake and Columbia River Dams) NOAA Fisheries completed their twenty-third year of an annual survival study monitoring survival, travel time, and transported fraction of yearling spring migrants of Chinook, steelhead and sockeye salmon over the Lower Granite Dam – Bonneville Dam and McNary Dam – Bonneville Dam, and above Lower Granite Dam reaches using PIT-tagged hatchery and wild groups. In addition, some upper Columbia stocks and Snake River coho are monitored. Length and condition was recorded for all fish tagged for the study at Lower Granite Dam juvenile fish facility. Reach conversion rates of returning adults tagged for the study are monitored at ladders in the mainstem.

BPA Project 1994-033-00 (Fish Passage Center) provided technical analysis, data summaries, graphic representations of fish survival and abundance data for state, federal and tribal fishery managers. It also provides technical oversight for implementation of the Smolt Monitoring Project and CSS. All of the metadata, data, estimation methods and survival estimates are available to the public at http://www.fpc.org/survival/smp_multiyearsurvival_query.html

BPA Project 1996-020-00 (Comparative Survival Study (CSS)) estimated travel time and survival of in-river and transported fish, and smolt-to-adult survival indices for both yearling and subyearling migrant Chinook and summer steelhead, and sockeye mostly originating above Lower Granite Dam. All CSS data, survival estimates, travel time, instantaneous mortality, analyses and reports are available to the public at http://www.fpc.org.

3. *Monitor and evaluate adult salmonid system survival upstream through the FCRPS.*

In 2015, a PIT detection system was designed for the ladder exit tunnel and on weir 648 near the ladder junction pool at Lower Granite Dam. That system was installed during the winter of 2015/2016, and its performance is exceeding design expectations. The detection system will improve estimates of adult conversion rates, reascension, and passage timing.

The second year of a two year of adult salmon and steelhead upstream migration study was conducted in 2014. Objectives included estimating conversion rates from Bonneville to McNary Dam, assessing the effects of lamprey passage improvements on adult passage behavior at Bonneville Dam, an assessment of The Dalles spillwall on adult passage, and an evaluation of the John Day North ladder improvements.

For BPA Project 1991-051-00 (Modeling and Evaluation Statistical Support for Lifecycle Studies), the University of Washington used their program ROSTER to analyze lifecycle data (including estimation of D and transport/in-river ratios) of spring and fall Chinook and steelhead sorted by brood year, and hatchery and wild release groups. In 2015, the project began an investigation of adult steelhead straying rates, overshoot rates, and fallback rates for 14 different subbasin populations from 2005 to 2015. The investigations expanded to include the biological, geographical, and operational factors that may influence the rates of fallback and eventual successful migration to natal spawning stream. This steelhead fallback study will continue into 2016.

BPA Project 2008-908-00 (FCRPS Water Studies & Passage of Adult Salmon & Steelhead) investigated factors influencing adult fish mortality in the lower Columbia River, and explored whether mortality rates vary by source population. Their multiyear analysis of steelhead survival through the lower Columbia suggests that Snake origin populations experience an average conversion rate 5 percent higher than upper Columbia origin populations, however the difference between Snake and upper Columbia groups has decreased since implementation of the BiOp. In contrast, while upper Columbia origin spring Chinook displayed lower average conversion rates than Snake origin Chinook during 2002-2009, Snake origin Chinook displayed lower conversion rates in the period 2010-2015. It has not been possible to identify a mechanism explaining the observed survival differences but timing of adult migrations may have contributed to the pattern.

4. *Provide additional PIT Tag marking of Upper Columbia River populations to provide ESU specific estimates of juvenile and adult survival through the Federal mainstem dams.*

BPA Project 1987-127-00 (Smolt Monitoring Program) gathered data on abundance, passage timing, system travel time and survival, and physical condition of smolts moving out of tributaries and past Snake and Columbia River hydro projects. The SMP estimated survival for the Upper Columbia populations of Chinook, steelhead, and sockeye juveniles marked at Rock Island Dam and Leavenworth hatchery. Data is available at http://www.fpc.org/smolt/SMP_queries.html.

BPA Project 1994-033-00 (Fish Passage Center) provided technical analysis, data summaries, graphic representations of fish movement and survival for state, federal and tribal fishery managers. The FPC is responsible for development of data entry software, hardware, data summaries, bootstrap confidence interval calculation, analyses, data management, data storage and data analyses and data distribution and public access for SMP and CSS data and analyses.

BPA Project 1996-020-00 (Comparative Survival Study (CSS)) helped fund additional tagging of 30,000 Chinook, sockeye and steelhead juveniles from Entiat, Methow, Chiwawa, and Wenatchee tributaries, and hatchery Chinook from Leavenworth NFH. The study estimated in-river survival in the mainstem Columbia and smolt-to-adult survival indices.

BPA Project 1993-029-00 (Survival Estimate for Passage through Snake and Columbia River Dams) funded NOAA Fisheries to produce annual survival estimates for yearling spring migrants McNary Dam – Bonneville Dam reaches using PIT-tagged hatchery and wild groups. While NOAA does not tag any juveniles in the upper Columbia, it does estimate lower Columbia survival rates among fish tagged in other projects. In 2015, NOAA estimated survival individually for seven spring Chinook stocks and two steelhead stocks originating at Upper Columbia River hatcheries

BPA Project 2003-017-00 (Integrated Status and Effectiveness Monitoring Program (ISEMP)) implemented both status and trend monitoring (fish and habitat) and watershed-level action effectiveness monitoring in five IMWs throughout the Columbia River Basin. ISEMP has continued to implant Upper Columbia River Spring-Run Chinook ESU and Upper Columbia River steelhead DPS juveniles with PIT tags in 2015 in the Little Wenatchee, at up to 18 sites in the Entiat River subbasins, at 20 sites along the Entiat mainstem under the IMW sampling, and at the rotary screw trap at the mouth of the Entiat River.

5. *Assess the feasibility of PIT Tag marking of juvenile Snake River Sockeye Salmon for specific survival tracking of this ESU from the Stanley Basin to Lower Granite Dam and through the mainstem FCRPS projects.*

BPA Project 2010-076-00 (Characterizing migration and survival for juvenile Snake River sockeye salmon between the upper Salmon River basin and Lower Granite Dam) used PIT tags and radio telemetry to determine locations of mortality between upper Salmon River and Lower Granite Dam for smolts tagged at Sawtooth and Oxbow fish hatcheries. On-the-ground work ended in 2014, while the final report was prepared in 2015.

BPA Project 1994-033-00 (Fish Passage Center) provided technical analysis, data summaries, graphic representations of fish survival and movement for the state, federal and tribal fishery managers. All juvenile sockeye data and analyses from mark groups included in the Comparative Survival Study are available to the public at http://www.fpc.org/survival/smp_multiyearsurvival_query.html

BPA Project 1996-020-00 (Comparative Survival Study (CSS)) has tagged Snake River sockeye from the Sawtooth/Springfield hatchery program since 2013, and has estimated sockeye in-river survival and smolt-to-adult survival indices since 2009. 64,200 hatchery sockeye were tagged by CSS in 2015. In addition, Skaha Lake and Wenatchee River sockeye mark groups were recently added in a pilot study for the upper Columbia for comparison with the Snake River population.

6. *Develop an action plan for conducting hydrosystem status monitoring (analytical approaches, tagging needs, methods, and protocols) in ongoing collaboration with the State and Federal fishery agencies and Tribes. This will be done in coordination with status monitoring needs and strategies being developed for estuary/ocean, habitat, hatcheries, and harvest. (Initiate in FY2009).*

The Action Agencies and NOAA Fisheries developed the report "The Status and Needs of the Columbia Basin PIT Tag Information System as Related to FCRPS BiOp RME Requirement" (BPA et al. 2013). This Action Agency and NOAA document addresses needs of the PIT tag information system associated with the FCRPS BiOp and its assorted RME studies. The report provides a review of the status and needs of PIT tagging and detection capabilities and identifies proposed assessments aimed at optimizing the use of PIT tags that are central to several hydro FCRPS BiOp RPA actions, and an assortment of habitat, hatchery and population monitoring efforts. Some proposed assessments involve analytical exercises, while others require the formation of, and participation in, tagging coordination forums.

The PIT Tag Forecaster (PTF) was formulated in response to PIT tag planning needs identified in the status report developed in association with RPA action 52.6. The database system for anadromous salmonids was launched by PSMFC in 2015. Fishery agency representatives populated the database by early 2015 and will update it annually. In 2015, three-year projections (2016-2018) for future PIT tag use across all Columbia Basin subbasins were available for query by any party using the online PTF tool, which is located on the PTAGIS website.

Another PIT tag assessment has been conducted- "Determine the extent to which proposed detector installations or alternative tagging strategies can improve the precision of system survival estimates, and provide rationale for how such improvements will affect management decisions regarding system survival." In 2015, preliminary results were compiled by University of Washington and BioAnalysts staff and vetted with the Action Agencies and NOAA. That assessment will likely be finalized in 2016 and provide input to next Biological Opinion.

7. *Cooperate with NOAA Fisheries, US v Oregon parties, Confederated Tribes of the Colville Reservation, and other co-managers to (1) review relevant information and identify factors (migration timing, spatial distribution, etc.) that might explain the differential conversion rates (BON to MCN) observed for Upper Columbia River steelhead and spring Chinook salmon compared to Snake River steelhead and spring/summer Chinook salmon (see RPA Table 7 and **SCA - Adult Survival Estimates Appendix); (2) develop a monitoring plan to determine the most likely cause of these differential losses (considering the potential use of flat plate PIT Tag detectors in tributaries or fishery areas, additional adult detectors at The Dalles and John Day fishways, etc., to provide improved estimates of harvest or stray rates for improved conversion rate estimates in the future); and (3) implement the monitoring plan.*

BPA Project 2008-908-00 (FCRPS Water Studies & Passage of Adult Salmon & Steelhead) investigated factors influencing adult fish mortality in the lower Columbia River, and explored whether mortality rates vary by source population. Their multiyear analysis of steelhead survival through the lower Columbia suggests that Snake origin populations experience an average conversion rate 5 percent higher than upper Columbia origin populations, however the difference between Snake and upper Columbia groups has decreased since implementation of the BiOp. In contrast, while upper Columbia origin spring Chinook displayed lower average conversion rates than Snake origin Chinook during 2002-2009, Snake origin Chinook displayed lower conversion rates in the period 2010-2015. It has not been possible to identify a mechanism explaining the observed survival differences but timing of adult migrations may have contributed to the pattern.

BPA Project 1994-033-00 (Fish Passage Center) provided technical analysis, data summaries, graphic representations of fish survival and movement for state, federal and tribal fishery managers.

8. *Monitoring adult passage counts is a cornerstone monitoring activity that must be performed on an annual basis. Adult fish counting is typically performed 16 hours per day, during daylight hours, by either video or visual counting methods, at all of the Corps projects that pass fish. Adult fish counting will continue at a minimum on the schedule presented in Table 8.*

Adult fish counts were conducted as called for in Table 8 of the RPA with the following exceptions:

- At The Dalles, John Day, McNary and Ice Harbor Dams, adult fish were counted from April 1 through October 31, 2015.
- At Lower Granite, 24-hour counts were conducted from June 15 through September 30, 2015, rather than through August 31, 2015.

All changes were fully coordinated during development of the FPP and through the FPOM workgroup process. Results are available in the 2015 Annual Fish Passage Report (ACOE 2016).

RPA Action 53 – Monitor and Evaluate Migration Characteristics and River Condition

The Action Agencies will monitor and evaluate the following biological and physical attributes of anadromous fish species migrating through the FCRPS on an annual basis.

1. *Monitor and estimate the abundance of smolts passing index dams.*

BPA Project 1987-127-00 (Smolt Monitoring Program - SMP) gathered data on abundance, passage timing, system travel time and survival, and physical condition of smolts (daily descaling, condition, fish injury, gas bubble trauma) moving out of tributaries and past Snake and Columbia River hydro projects. In addition the project records flow, spill, water temperature, project operations, studies, and research that occurred and that may have affected passage conditions. All SMP data for 2015 are presently posted on the Fish Passage Center web site at http://www.fpc.org.

BPA Project 1991-051-00 (Modeling and Evaluation Statistical Support for Lifecycle Studies) estimated smolt passage indices at all FCRPS dams, plus Rocky Reach and Rock Island dams. For each index count location and fish stock, daily in-season passage counts are reported. The monitoring also includes the historical trend in smolt passage indices over the years. The data is posted daily in a tool on the DART database, allowing visualization of the in season and historical trends, and can be instantaneously correlated with within-year and between-year annual measures of environmental indicators and system operations.

BPA Project 1994-033-00 (Fish Passage Center) provided technical analysis, data summaries, graphic representations for the state, federal and tribal fishery managers.

BPA Project 1991-029-00 (Research, monitoring, and evaluation of emerging issues and measures to recover the Snake River fall Chinook salmon ESU) estimated daily passage abundances and timing distribution at Lower Granite Dam for natural and hatchery subyearling fall Chinook salmon. Natural origin subyearling smolts have displayed a more protracted outmigration than hatchery origin smolts which peak in late May and early June.

2. *Monitor and describe the migration timing of smolts at index dams, identify potential problems, and evaluate implemented solutions.*

BPA Project 1987-127-00 (Smolt Monitoring Program) gathered data on abundance, passage timing, system travel time and survival, and physical condition of smolts moving out of tributaries and past Snake and Columbia River hydro projects. All historic data and current year data is available at http://www.fpc.org/smolt/SMP_queries.html.

BPA Project 1994-033-00 (Fish Passage Center) provided technical analysis, data summaries, graphic representations for the state, federal and tribal fishery managers. 2015 fish passage indices calculated by the project suggested that higher flow and higher spill for fish passage result in faster juvenile fish travel times.

BPA Project 1996-020-00 (Comparative Survival Study (CSS)) estimated smolt-to-adult survival indices for spring-, summer- and fall-run Chinook, sockeye, and summer steelhead. Most tag groups originate above Lower Granite Dam, but several upper Columbia ESUs are monitored and the project recently added two upper Columbia sockeye populations. Juvenile survival and passage metrics are available at http://www.fpc.org.

BPA Project 1993-029-00 (Survival Estimate for Passage through Snake and Columbia River Dams) funded NOAA Fisheries to produce annual survival and run timing estimates for PIT-tagged yearling spring migrants using PIT-tagged hatchery and wild groups of Chinook, steelhead and sockeye salmon. The project tagged thousands of Chinook and steelhead at Lower Granite Dam to help produce broad reach estimates for the Lower Granite Dam – Bonneville Dam, and McNary Dam – Bonneville Dam river sections. The project also estimates survival/timing to Lower Granite for juveniles tagged above-Lower Granite Dam at hatcheries and wild traps. PIT-tagged fish can currently be detected at juvenile bypasses at each dam between Lower Granite and Bonneville with the exception of The Dalles, and at ladders at each dam except for John Day. NOAA compared current year patterns with previous years, and made the data available for use in the COMPASS model.

BPA Project 1991-051-00 (Modeling and Evaluation Statistical Support for Lifecycle Studies) used their RealTime program to forecast and monitor percent run to date, and date to specified percentiles for 24 PIT tagged stocks of wild Chinook, sockeye and steelhead ESU/DPSs and the 25 Fish Passage Center indexed runs at large. The data was published daily on the DART website. Online run-timing predictions are provided via the internet at http://www.cbr.washington.edu/inseason to the fisheries community and public throughout the smolt outmigration.

3. *Monitor and document the condition (e.g., descaling and injury) of smolts at all dams with juvenile bypass systems, identify potential problems, and evaluate implemented solutions.*

The Corps conducted hydraulic modeling and field flow measurements within the gatewells at Bonneville's Second Powerhouse in an effort to identify and design modifications aimed at reducing mortality and injury for fish using the juvenile bypass system. A flow-control device was selected, installed, and hydraulic modeling results were verified at the project. A biological evaluation of fish condition and survival using the flow-control device is planned for the 2015 outmigration.

The Corps continued design and construction activities associated with improvements to the Lower Granite Lock and Dam Juvenile Bypass System (JBS). Construction of improvements to the upstream portions of the JBS began in late 2014 and are anticipated to be completed in March 2018. Design of a new outfall structure continued through the FFRDWG process in 2015 with subsequent completion of construction anticipated by March 2018.

BPA Project 1987-127-00 (Smolt Monitoring Program) gathered data on abundance, passage timing, system travel time and survival, and physical condition of smolts moving out of tributaries and past Snake and Columbia River hydro projects. Fish condition monitoring for sites with juvenile bypass systems in 2015 plus historical data is available to the public at http://www.fpc.org/smolt/SMP_queries.html.

BPA Project 1994-033-00 (Fish Passage Center) provided coordination, technical analysis, data summaries, graphic representations for the state, federal and tribal fishery managers.

4. *Monitor and enumerate adult salmonids passing through fishways in the FCRPS, identify potential problems, evaluate implemented solutions.*

In 2015, the Corps again implemented its adult fish count program as detailed in the FPP. Results are available in the 2015 Annual Fish Passage Report (ACOE 2016).

Fishways were monitored on a regular basis, as per FPP specifications. Results are discussed in an annual Fishway Inspection Report prepared for each project. Fishways were also inspected by representatives from NOAA Fisheries and other agencies. Results of those inspections are available at http://www.fpc.org/documents/Fishway_Inspection_Reports.html. See also the discussion of adult passage improvements under RPA Action 28 above.

In 2015, the Corps completed analysis of data from a two-year study evaluating the effects of modifications at dams on adult salmon passage. One of the topics was the effect of the new spillwall at The Dalles Dam on use of the north shore ladder. The study found that at high flows the proportion of adult salmon using the north ladder decreased, but this did not appear to result in a delay in passage (Frick et al. 2015).

In 2014 and 2015, in response to high temperature differentials in the adult fishway at Lower Granite Dam and resulting passage delays, three temporary pumps were used to add cooler water from deeper in the forebay directly to the front of diffuser 14 inlet. In addition, spill and turbine operations were varied to minimize passage delay. During the winter of 2015-2016 permanent modifications were made to the auxiliary ladder pump intakes and discharge routing to cool the Lower Granite Dam adult fish ladder. These improvements will be evaluated during the 2016 fish passage season.

5. *In addition to current operations (generally April 10 - August 31), evaluate operation of the Bonneville (second powerhouse) PH2 corner collector from March 1 through start of spill as a potential means to provide a safer downstream passage route for steelhead kelts, and implement, if warranted.*

From 2008 through 2012, the Corps evaluated operation of the corner collector as a means to provide safe passage for downstream-migrating steelhead. Based on these past evaluations, and in consultation with the Fish Passage Operations and Maintenance subcommittee, operation of the corner collector was determined to provide a benefit. Annual operation of the corner collector has been incorporated into the Fish Passage Plan.

In 2015, the Bonneville corner collector was opened for steelhead kelt passage on March 10, 2015. Normal spill operations began on April 10, 2015. This provided 31 additional days of downstream passage for steelhead kelts.

RPA Action 54 – Monitor and Evaluate Effects of Configuration and Operation Actions

The following will be conducted at specific projects for specific years as operations or configurations change, or new problems are identified.

1. *Monitor and evaluate the effects of existing spillways, modifications, and operations on smolt survival.*

During the spring of 2015 a Direct Injury and Sensor Fish evaluation of the new chute and deflector for the spillway weir at Ice Harbor Dam was completed. Results indicated a significantly improved route of passage for this spillway weir bay (Deng et al. 2015; Normandeau 2015).

BPA Project 1989-107-00 (Statistical Support for Salmon) funded the University of Washington to contribute skills and technology to the 2008 BiOp compliance studies used to quantity smolt passage rates and survival through the spillways, weirs, turbines, and juvenile bypass systems. For each of the 28 compliance survival studies conducted between 2010 and 2014, route-specific passage survival and proportions have been estimated at each hydro dam under investigation. The information is being used by NOAA Fisheries to refine their COMPASS model.

2. *Monitor and evaluate the effectiveness of traditional juvenile bypass systems and modifications to such, on smolt survival and condition.*

The Corps used hydraulic modeling and flow measurements to evaluate gatewell hydraulic conditions at Bonneville's Second Powerhouse in an effort to identify and design modifications aimed at reducing mortality and injury for fish using the juvenile bypass system. In 2014, the recommended alternative, a gatewell flow reduction device, was installed in a single Powerhouse II turbine unit gatewell and hydraulic conditions were evaluated. Results indicated that the prototype modifications improved flow conditions within the gatewell. In 2015, fish condition and survival for tagged fish passing through modified gatewells were compared to fish passing through an unmodified (current condition) gatewell. Tests were conducted at varying flow within the 1 percent peak efficiency range. A hydraulic evaluation followed in the fully modified unit that compared pre- and post-modification conditions. The results from the biological and hydraulic evaluation suggest that the objectives have been met to improve hydraulic conditions and juvenile fish survival in modified gatewells when operating in the upper 1 percent peak efficiency range.

Efforts are underway to fully implement the gatewell modification across all main units at Powerhouse II in late 2016 and early 2017. Unmodified Powerhouse II turbine units continue to be operated at the mid to lower end of the 1 percent peak efficiency range, as coordinated through FPOM. While both the modification and the interim operation reduce flow into the gatewells, thereby reducing the injury to fish passing into the juvenile bypass system, the reduction in fish guidance efficiency (FGE) is expected to be minimal. Once modifications are complete, Powerhouse II turbine unit operation is expected to return to the full 1 percent range, and the effectiveness of the modifications will be evaluated again.

Juvenile Bypass systems at John Day and McNary dams were evaluated in 2014 as part of the Juvenile Salmon Dam Passage Performance Standard compliance studies (Skalski et al. 2015a; 2015b). An assessment of why the survival target for summer migrants at John Day and McNary dams in 2014 was not met is currently being analyzed.

The Corps continued design and construction activities associated with improvements to the Lower Granite Lock and Dam Juvenile Bypass System (JBS). Construction of improvements to the upstream portions of the JBS began in late 2014 and are anticipated to be completed in March 2018. Design of a new tailrace outfall structure continued through the FFDRWG process in 2015 with subsequent completion of construction anticipated by March 2018.

BPA Project 1993-029-00 (Survival Estimate for Passage through Snake and Columbia River Dams) funded NOAA Fisheries to produce annual survival estimates for yearling spring migrants over the Lower Granite Dam to Bonneville Dam reach. Each Chinook and steelhead smolt tagged at Lower Granite Dam routinely has fish length and condition information recorded. The fish condition data were used in the multiyear Corps sponsored bypass selectivity study, carried out by NOAA.

BPA Project 1989-107-00 (Statistical Support for Salmon) funded the University of Washington to contribute skills and technology to the 2008 BiOp compliance studies used to quantity smolt passage rates and survival through the spillways, weirs, turbines, and juvenile bypass systems. Also generated are estimates of fish passage efficiency (FPE), spill passage efficiency (SPE), forebay residence times, and tailrace egress times. In 2015, this project consulted on the potential study designs for future compliance studies at Ice Harbor and Bonneville dams.

3. *Monitor and evaluate the effectiveness of surface bypass structures and modifications on smolt survival and condition.*

Surface passage and surface water hydraulic contribution to tailwater temperatures at Little Goose and Lower Granite dams was evaluated throughout summer 2015 as part of the temperature management to improve adult sockeye and summer Chinook passage.

4. *Monitor and evaluate the effectiveness of turbine operations and modifications on smolt survival and condition.*

Post-hoc analysis of passage data collected at Bonneville during 2010-2012 performance testing was conducted in 2013 and 2014. Objectives included estimating and comparing juvenile fish survival within and above the one percent peak efficiency range at Powerhouse I and Powerhouse II. At both powerhouses results indicate that there is no measureable difference in turbine passage survival based on turbine operation. In addition to analyzing fish survival data, work continued in 2014 to determine the safest operating range for fish passing through existing FCRPS turbines. Physical model studies and numerical model studies were conducted to further this understanding.

A Turbine Survival Program Phase II report was completed in 2013 which identifies the best target operating range for each project. The recommended target operating ranges are based on maximizing turbine passage survival.

In preparation for studies evaluating the new turbine runners at Ice Harbor Dam the vertical distribution of spring and summer migrating juvenile salmonids were evaluated for fish passing through existing intake 1B in 2015 using split-beam hydroacoustics. The vertical distribution of smolts passing intake 1B was estimated both downstream of the trashracks and downstream of the STS's and included estimates of FGE for spring and summer.

Additionally, sensor fish data were collected in Turbine Unit 1B at Ice Harbor dam at four operating points (lower 1 percent, peak, best operating point, and upper 1 percent) at 3 release elevations to collect baseline data that will be used to compare the turbine environment hydraulic conditions when the new unit runners are installed (beginning in 2017).

The Turbine Survival Program continued to develop a biological index test through computational fluid dynamics modeling and physical modeling at the Corps' Engineer Research and Development Center.

BPA Project 1989-107-00 (Statistical Support for Salmon) funded the University of Washington to contribute skills and technology to the 2008 BiOp compliance studies used to quantity smolt passage rates and survival through the spillways, weirs, turbines, and juvenile bypass systems.

5. *Monitor and evaluate overall dam passage with respect to modifications at projects (including forebay delay and survival).*

Juvenile fish performance standard testing was not conducted in 2015, but is being planned for 2018 in the Lower Snake River.

BPA Project 1987-127-00 (Smolt Monitoring Program) gathered data on abundance, passage timing, system travel time and survival, and physical condition of smolts moving out of tributaries and past Snake and Columbia River hydro projects. SMP data provides indications of passage timing differences that may be affected by hydro system project operations such as spill and flow project configurations, as well as changes in hatchery production programs.

BPA Project 1994-033-00 (Fish Passage Center) provided technical review of dam performance testing study designs, analyses, and draft reports. http://www.fpc.org/documents/FPC_memos.html

6. *Monitor and evaluate the effectiveness of the juvenile fish transportation program and modifications to operations.*

In 2015, the Action Agencies continued to monitor and evaluate the effectiveness of the juvenile fish transportation program; this effort included seven BPA projects. Information resulting from the 2015 RME will enable further progress in identifying the benefits of transportation and supporting adaptive management actions. Significant 2015 RME are as follows:

Spring Migrants: The Action Agencies continued research to determine the potential of transportation to increase adult returns of anadromous salmon. A PIT tag study to evaluate weekly SARs for spring Chinook salmon and steelhead transported from Lower Granite Dam continued in 2015. More precise temporal transportation data should help clarify effects of transportation and relationships to environmental variables. Overall, ratio of SARs of transported to in-river migrating fish reported by NOAA Fisheries show that transport is a benefit throughout most of the season for spring migrants. The greatest transport benefit for wild Chinook salmon usually occurs after May 1, but in most years transport is beneficial by the third week of April. Another trend observed in the data is that SARs for in-river migrants tend to decrease throughout the season. This is consistent with the observation that while transport may be beneficial early in the migration season, it usually becomes even more beneficial later in the season.

Summer Migrants: In 2013-2015, the Action Agencies continued implementing the 2007 fall Chinook salmon consensus proposal and long-term framework developed collaboratively with regional fish management agencies and Tribes. This intensive RME effort for subyearling fall Chinook salmon will help determine the appropriate management strategy to optimize adult returns. In 2014, NOAA Fisheries and USFWS completed an analysis report and analyzed two years of complete adult returns (2006 and 2008). The report was distributed for regional review and comment in 2015. Analysis and reporting of adults returning in 2016 (from juveniles tagged in 2012) will complete the full evaluation.

BPA Project 1994-033-00 (Fish Passage Center) provided technical analysis, data summaries, graphic representations of the juvenile fish transportation program and modifications to operations for state, federal and tribal fishery managers. They maintained a dam count database at their website: http://www.fpc.org.

BPA Project 1996-020-00 (Comparative Survival Study (CSS)) estimated smolt-to-adult survival indices for transported and non-transported spring-, summer-, and fall-run Chinook, sockeye, and summer steelhead, mostly originating above Lower Granite Dam. SAR and TIR for monitored stocks are reported in the annual report http://www.fpc.org/documents/CSS.html

BPA Project 1993-029-00 (Survival Estimate for Passage through Snake and Columbia River Dams) funded NOAA Fisheries to produce annual survival estimates for yearling spring migrants over the Lower Granite Dam – Bonneville Dam and McNary Dam – Bonneville Dam, and above-Lower Granite Dam reaches using PIT-tagged hatchery and wild groups. Estimated percentages of non-tagged spring/summer Chinook salmon transported during the entire 2015 season were 11.4 percent for wild and 13.6 percent for hatchery smolts. For non-tagged steelhead, estimated percentages transported were 12.4 percent for wild and 13.6 percent for hatchery smolts. These transported fractions are the lowest on record since monitoring started in 1993.

7. *Monitor and evaluate the effects of environmental conditions affecting juvenile fish survival.*

BPA Project 1987-127-00 (Smolt Monitoring Program) gathered data on abundance, passage timing, system travel time and survival, and physical condition of smolts moving out of tributaries and past Snake and Columbia River hydro projects.

BPA Project 1993-029-00 (Survival Estimate for Passage through Snake and Columbia River Dams) funded NOAA Fisheries to produce annual survival estimates for yearling spring migrants over major reaches of the FCRPS using PIT-tagged hatchery and wild groups. They compared daily measures of flow, temperature, and spill at Snake dams with the daily smolt index and survival. They also continued experimentation with an alternative towed mobile antenna in the estuary. Conditions in 2015 were relatively unique, with record spill percentages and high water temperatures. In prior years of low flow such as 2001 and 2005, spill was curtailed in order to maximize transportation. Hydrosystem survival was below the 18-year average for both Chinook and steelhead, but was higher than similar low flow years in the record.

BPA Project 1994-033-00 (Fish Passage Center) provided technical analysis, data summaries, graphic representations of fish movement and survival for state, federal and tribal fishery managers.

BPA Project 1996-020-00 (Comparative Survival Study (CSS)) estimated smolt-to-adult survival indices for spring-, summer-, and fall-run Chinook, sockeye, and summer steelhead, mostly originating above Lower Granite Dam, and continued their work investigating correlations between survival and river and operational factors. Potential mechanisms for the pattern of increasing mortality rates over the migration season and with water temperature could include (1) declining smolt energy reserves or physiological condition over the migration season and with water temperature, (2) increasing predation rates on smolts over the migration season and with water temperature, (3) increases in disease susceptibility or disease-related mortality over the migration season and with water temperature, or (4) some combination of these often interrelated mechanisms. Potential mechanisms for lower mortality rates with increasing spill levels include reduced forebay and tailrace predation levels as spill levels increase and increased spillway passage route proportions and reduced turbine passage route proportions with increased spill levels.

BPA Project 2003-041-00 (Evaluate Delayed (Extra) Mortality Associated with Passage of Yearling Chinook Salmon through Snake River Dams) completed a seven year experiment (2005-2011) comparing survival of yearling Chinook transported and released at McNary Reservoir with their cohort traveling through four lower Snake dams.

BPA Project 1989-108-00 (Modeling and Evaluation Support/Columbia River Integrated Statistical Program) conducted data analyses to identify environmental factors influencing the performance of the Comprehensive Fish Passage (COMPASS) model in predicting juvenile timing and survival during outmigration, and the influence of fish size and condition on hydrosystem survival and smolt-to-adult survival. They modeled the relationship between growth patterns in early life history, smolt length, and smolt-to-adult return.

8. *Monitor and evaluate the effectiveness of reducing predation toward improving juvenile fish survival.*

BPA Project 1990-077-00 (Development of System-wide Predator Control) continued the Northern Pikeminnow Management Program to reduce predation on juvenile salmonids by harvesting pikeminnow in FCRPS reservoirs and estuary. In 2015, a mark recapture experiment produced an estimate of 17.2 percent systemwide exploitation for northern pikeminnow >250 mm.

The Action Agencies continue to implement habitat and dam-based actions to reduce predation on juvenile and adult salmonids. See also RPA Actions 43 through 49 and 66 through 70 for detailed information on related activities.

9. *Investigate, evaluate and deploy alternative technologies and methodologies for fish passage and the RME Action.*

The Corps continued design and construction activities associated with improvements to the Lower Granite Lock and Dam Juvenile Bypass System (JBS). Construction of improvements to the upstream portions of the JBS began in late 2014 and are anticipated to be completed in March 2018. Design of a new tailrace outfall structure continued through the FFDRWG process in 2015 with subsequent completion of construction anticipated by March 2018.

BPA Project 1983-319-00 (New Marking and Monitoring Technologies) funded NOAA Fisheries to develop new designs for fish tags and tag detection systems, including a prototype for spillway PIT tag detection. In 2015, NOAA tested read ranges of a new multiplexing in-stream transceiver and master controller system.

10. *Determine if actions directed at benefiting juveniles have an unintended effect on migrating adults (e.g., certain spill operations).*

Surface passage and surface water hydraulic contribution to tailwater temperatures at Little Goose and Lower Granite dams was evaluated throughout summer 2015 as part of the temperature management to improve adult sockeye and summer Chinook passage.

The Corps continued physical model studies to evaluate Lower Granite, Little Goose, and Ice Harbor dam spill patterns. Objectives of this work included identifying pattern adjustments for low flow periods that minimize adult salmon delays associated with spillway weir operation and elevated water temperatures.

In 2015, the Corps finalized a two-year study to evaluate the effects of modifications at The Dalles and John Day dams on adult salmon passage (Frick et al. 2015). Specific juvenile passage modifications being evaluated include The Dalles Dam Spillwall and the spillway weirs and new spill pattern at John Day Dam. Results are discussed under RPA actions 28.2 and 28.3, above.

11. *Install and maintain adult PIT Tag detectors in fish ladders at key dams in the FCRPS and evaluate adult survival (conversion rates).*

PIT tag detectors were designed in 2015 for installation in winter 2015/2016 in the adult ladder exit tunnel and weir 648 near the junction pool in bottom of the ladder at Lower Granite Dam.

BPA Project 1983-319-00 (New Marking and Monitoring Technologies) designed a PIT tag detection system for the John Day ladder to be installed in 2016.

12. *Monitor and evaluate the effects of fish ladder operations and configurations on adult passage rates.*

The Lower Granite Dam ladder temperature differential effects to adult passage delay that occurred during the 2013 low flow and high water temperature regime also occurred during 2015, with an earlier onset of warm water temperatures that began in early- to mid-June 2015. The operation was managed through operation of the auxiliary forebay pumps and an additional submerged pump system supplying >60 feet deep sourced water into the diffuser 14 intake. This operation was successful at reducing ladder temperature differentials by 1–4 degrees C and allowing season-wide operation of the adult trapping and PIT sort-by-code loop. Successful trapping and transport of 51 adult sockeye salmon to Eagle Hatchery by IDFG and NOAA was possible, confirming the feasibility of successful emergency operations for trapping and transporting adult sockeye salmon when water temperatures exceed 20°C.

In addition to the temperature effects monitoring and in-season management for adult passage the Corps funded the first of a two year study designed to elucidate effects to adult Chinook and sockeye salmon behavior due to noise and vibration generated by JFF Upgrade construction activities at Lower Granite Dam. The new PIT tag detectors were a critical requirement for this study.

Newly-installed lamprey passage entrance structure, installed in the McNary Dam south shore fishway entrance, was monitored in 2014-2015 for negative impacts on salmon passage using a combination of optical, video and acoustic imaging.

BPA Project 1994-033-00 (Fish Passage Center) organizes and oversees monthly fishway inspections:
http://www.fpc.org/documents/Fishway_Inspection_Reports.html.

13. *In addition to the current sluiceway operation (generally April 1–November 30), evaluate operation of The Dalles Dam sluiceway from March 1–March 31 and from December 1–December 15 as a potential means to provide a safer fallback passage route for overwintering steelhead and kelts, implement if warranted.*

Results from two years of evaluations of downstream passage through The Dalles Dam sluiceway by overwintering summer steelhead and outmigrating steelhead kelts indicated that there are large enough benefits (0.9 percent of a 6 percent target for Snake River B-run steelhead) to justify operating this route early and to keep this surface route open later, March 1 to 15 December (Tackley and Clugston 2011). In 2015, the sluiceway was operated March 1–31 and December 1–15 to provide safer passage conditions for overwintering steelhead and steelhead kelts.

14. Investigate surface-flow outlets during wintertime to provide safer fallback opportunity for over wintering steelhead (need will be determined by results of further research).

A winter Spillway Weir passage efficiency study was conducted in the winter 2014-2015. This study compared the turbine and spillway weir (10 kcfs) passage efficiency for adult steelhead at McNary Dam during the November–February time frame. Passage efficiency was compared between spillway weir on and spillway weir off as well as powerhouse passage and total passage with the spillway weir in operation (Ham et al. 2015).

RPA Action 55 – Investigate Hydro Critical Uncertainties and Investigate New Technologies

The Action Agencies will fund selected research directed at resolving critical uncertainties that are pivotal in lifecycle model analyses. Specific actions include:

1. Investigate and quantify delayed differential effects (D-value) associated with the transportation of smolts in the FCRPS, as needed. (Initiate in FY 2007–2009 Projects).

The Corps held a regional workshop on the potential selectivity of juvenile bypass systems in June 2013 and several presenters provided data and associated analyses addressing the question of whether bypass systems are selective for specific traits (e.g., length). Overall, there appeared to be evidence of selectivity in bypass systems from multiple researchers and some presented information suggesting there was either no selectivity or the selectivity was not thought to be biologically meaningful. At the conclusion of the workshop broad consensus was that this issue deserved more attention and that it is a critical uncertainty in the operation of the FCRPS.

Several multiyear research studies continue to assess and estimate differential delayed effects associated with the transportation of juvenile salmon and steelhead. The parameter D is the ratio of post-Bonneville survival of barged and in-river migrants. Other indices of transportation benefit provide more direct and readily interpretable results, including various transport-to-in-river migrant ratios such as TIR and ratio of smolt to adult return of transported to in river migrating fish indices.

Under BPA Project 1989-108-00 (Columbia River Integrated Statistical Program), University of Washington developed a model to evaluate hypotheses that seasonal timing of arrival of transported juveniles to the estuary, and thermal stress of migrating in-river may influence seasonal patterns of transport related delayed mortality for Chinook salmon. They further explored the relationship of seasonal patterns of D with timing of transportation and physiological maturity and bioenergetics condition of juveniles.

BPA Project 1994-033-00 (Fish Passage Center) provided technical analysis, data summaries, graphic representations of fish movement and survival for state, federal and tribal fishery managers. The FPC manages the implementation, reporting, data management and analyses for the Smolt Monitoring Program Project and the Comparative Survival Study Project. The project calculates juvenile survival, smolt-to-adult return rates, TIR and D for all PIT tag groups utilized in CSS analyses. http://www.fpc.org/survival/smolttoadult_queries.html

BPA Project 1996-020-00 (Comparative Survival Study (CSS)) estimated smolt-to-adult survival indices including D and TIR for spring-, summer-, and fall-run Chinook, sockeye, and summer steelhead, mostly originating above Lower Granite Dam. They also explored the relationship between spill rates, flow, and D. A model estimate with input from migration years 1997-2013 predicts that the TIR ratio will be less than 1.0 when juvenile Chinook survival is 55 percent or higher and juvenile steelhead survival is 71 percent or higher.

BPA Project 1991-028-00 (PIT Tagging Wild Chinook) estimated parr-to-smolt survival for wild Snake River spring/summer Chinook above Lower Granite Dam.

BPA Project 1989-098-00 (Salmon Studies in Idaho Rivers) studied hatchery supplementation as a recovery tool for threatened stocks of spring/summer Chinook in Idaho rivers.

2. *Investigate the post-Bonneville mortality effect of changes in fish arrival timing and transportation to below Bonneville. (Initiate in FY 2007-2009).*

BPA Project 2003-041-00 (Evaluate Delayed (Extra) Mortality Associated with Passage of Yearling Chinook Salmon through Snake River Dams) completed a seven year experiment (2005–2011) comparing survival of yearling Chinook transported from Lower Granite Dam and released at McNary Reservoir with their cohort traveling through four lower Snake dams.

BPA Project 1994-033-00 (Fish Passage Center) provided technical analysis, data summaries, graphic representations for the state, federal and tribal fishery managers, and coordinated the Comparative Survival Study and Smolt Monitoring Program

BPA Project 1993-029-00 (Survival Estimate for Passage through Snake and Columbia River Dams) funded NOAA Fisheries to produce annual survival estimates for yearling spring migrants over the Lower Granite Dam – Bonneville Dam. The project also operates the PIT trawl which detects both transported and in-river migrants, and estimates arrival timing and travel speeds of each group based on initial detections at Lower Granite Dam.

BPA Project 1987-127-00 (Smolt Monitoring Program) gathered data on abundance, passage timing, system travel time and survival, and physical condition of smolts moving out of tributaries and past Snake and Columbia River hydro projects. The PIT tag mark groups generated through the Smolt Monitoring Program are analyzed with PIT tag mark groups generated through the Comparative Survival Study to generate juvenile survivals, smolt to adult return rates, estimates of transport in-river ratios and estimates of post-Bonneville mortality "D".

3. *Conduct a workshop every other year with members of the Independent Scientific Advisory Board (ISAB) to review current research and monitoring approaches on post Bonneville mortality for transported and non-transported fish. (Initiate in FY 2009).*

The Corps commissioned a synopsis and literature review of differential delayed mortality, identified critical uncertainties, and sponsored the Snake River Basin Differential Delayed Mortality Workshop in May 2011. A draft report was produced and sent to regional fish managers for review and comment. Results from the synopsis were presented at the Corps Annual AFEP review in December 2011. The final report (Anderson et al. 2012) was sent to the ISAB for review in the spring of 2012. A workshop has not been conducted since, as relatively little new information has become available since the 2011 workshop.

4. *Investigate, describe and quantify key characteristics of the early life history of Snake River Fall Chinook Salmon in the mainstem Snake, Columbia, and Clearwater rivers. (Initiate in FY 2007-2009 Project).*

BPA Project 2002-032-00 (Snake River Fall Chinook Salmon Life History Investigations) used adult otolith microchemistry to estimate the fraction of returning adults which entered the ocean as subyearlings and yearlings, and their site of spawning. Of the 125 presumably natural-origin adults sampled, most (90 percent) entered the ocean as subyearlings and remainder entered as yearlings. The majority (about 75 percent) of returning adults originated and reared in the lower Snake River (from mouth of the Grande Ronde River to below Ice Harbor Dam) followed by 16 percent originating and rearing in the upper reach of the Snake River (above the mouth of the Salmon River). Most juveniles that overwintered in freshwater did so in the lower Snake River.

BPA Project 1991-029-00 (Research, monitoring and evaluation of emerging issues and measures to recover the Snake River fall Chinook salmon ESU) monitored weight, length, abundance, and timing of fry and parr stage fall Chinook as they appeared in Lower Granite Reservoir and upper reaches of the Snake. Fry emergence timing has generally been earlier in the relatively warmer Snake River upper reach than in the relatively cooler Snake River lower reach in most years. The median date of parr presence along both Snake River reaches generally became earlier as density along the shorelines increased as can be seen by examining the means of the median dates of parr presence for the periods of low (1992–1999) and high (2000–2015) abundance. Adding the 2015 data to the data set collected on timing of parr presence, size, growth, and dispersal timing into the reservoir provided further evidence for density-dependent phenotypic change in Chinook salmon subyearlings. Natural parr and smolts have begun to regain the movement timing and size phenotypes expressed by their historical counterparts under similarly high abundances.

BPA Project 1987-127-00 (Smolt Monitoring Program) gathered data on abundance, passage timing, system travel time and survival, and physical condition of smolts moving out of tributaries and past Snake and Columbia River hydro projects.

BPA Project 1996-020-00 (Comparative Survival Study (CSS)) conducted a simulation to assess the potential for bias in SAR estimates for fall Chinook based on detection rates of migrants passing Lower Granite during winter or holding over until spring.

BPA Project 1989-107-00 (Statistical Support for Salmon) provided software, technical assistance and guidance in mark-recapture study design and data analysis to tribal, state, and federal agencies. In 2015, the program "Branch" was completed to analyze tributary PIT tag detection data beyond the capabilities of the program "TribPit" (http://www.cbr.washington.edu/analysis/apps/branch). It is capable of analyzing movement and survival of species such as fall Chinook which may outmigrate at different age classes. In addition, a new software program "Basin TribPit" was initiated to expand on the capabilities of TribPit (http://www.cbr.washington.edu/analysis/apps/tribPit/) at the request of state and tribal biologists. This will allow multiple releases of juvenile tagged fish to be analyzed simultaneously within a tributary system. It is capable of analyzing movement and survival of species such as fall Chinook which may outmigrate at different age classes.

5. *Complete analysis and reporting of a multi-year (2000–2007) investigation on the effects of adult passage experience in the FCRPS on pre-spawning mortality (2008). Following reporting, SRWG will review the results and provide a recommendation on the need and nature of future research. Future research will be coordinated through the Regional Forum.*

   This action was completed in 2008.

6. *Continue development of state-of-the-art turbine units to obtain improved fish passage survival through turbines with the goal of using these new units in all future turbine rehabilitation or replacement programs.*

   The Ice Harbor test turbine project will replace Units 1–3. A fixed blade runner will be installed in unit 2 and an adjustable blade runner will be installed in units 1 and 3. Reducing strike, turbulence, and nadir pressure were the driving design criteria (Trumbo et al. 2014). Installation of the unit 2 runner is scheduled to begin in spring of 2016 and be completed in 2017.

   Work continues for design of state-of-the-art turbines for improved fish survivability at John Day and McNary Dams.

7. *Investigate feasibility of developing PIT Tag detectors for spillways and turbines.*

   In 2015, the Corps continued developing a prototype spillway PIT tag monitoring project. The Corps is working with NOAA Fisheries and other regional resource management offices in technology development and testing.

   BPA project 1983-319-00 (New Marking and Monitoring Technologies) funded NOAA Fisheries continued development of a prototype spillway ogee detection system, which is expected to be installed at Lower Granite Dam in 2017. In 2015, the project updated the firmware and exciter modules of the FS3001 ogee transceiver and tested read ranges of the transceiver on direct power supply and 24V batteries. Improved shielding and grounding improved the read range from previous tests of synchronization.

8. *Evaluate new tagging technologies for use in improving the accuracy and assessing delayed or indirect hydro effects on juvenile or adult fish.*

   BPA Project 1983-319-00 (New Marking and Monitoring Technologies) funded NOAA Fisheries to develop new designs for fish tags and tag detection systems. In 2014, they did not evaluate any new tagging technologies. The project continued development of a spillway ogee detection system, and tested detection rates of 32 m/sec vs. 16 m/sec tags of both 9 mm and 12 mm lengths with prototype antennas at the Pasco Research Station.

   BPA Project 1989-107-00 (Statistical Support for Salmon) worked with several agencies to investigate several new technologies for tagging studies. These include:
   - Micro-injectable acoustic tags for smaller salmonids.
   - Backpack or saddleback acoustic tags to avoid barotrauma during turbine passage.

- Suture technologies to find the best approach to retain acoustic tags and prevent post-surgical problems.
- Design and analysis of bioassays to assess tag effects and identify minimum tagging sizes for fish.

9. *Assess the feasibility of developing PIT Tag detectors for use in natal streams and tributaries, or other locations, as appropriate to support more comprehensive and integrated All-H monitoring designs and assessments of stray rates.*

   BPA Project 1983-319-00 (NOAA Fisheries- New Marking and Monitoring Technologies) completed design and development work on a multiplexing transceiver system, and installed the system in several tributary locations in the John Day River. Testing indicated that the PIT tag read range was significantly reduced when antenna cables were run in the water instead of in the air. Several approaches were attempted to reduce noise, which were partially successful but the project will continue to try to improve the read range during the next year. NOAA is also designing an improved configuration for multiple antennas with a single master controller which will allow the system to continue operation if individual components become damaged.

   BPA Project 1989-107-00 (Statistical Support for Salmon). University of Washington project staff designed the program BRANCH to analyze mark-recapture statistical studies involving complex, bidirectional movement through tributaries and mainstem river systems. In 2015, they used the program to analyze steelhead overshoot and fallback rates through FCRPS and PUD dams. The steelhead investigations indicate barged steelhead smolts have higher rates of overshoot and lower rates of successful fallback than do in-river migrants. Similarly, hatchery stocks have higher rates of overshoot and lower rates of successful fallback than do naturally reared stocks. Overshoot rates also appear to be related to the proximity of the natal streams to upriver hydroprojects.

RPA Action 56 – Monitor and Evaluate Tributary Habitat Conditions and Limiting Factors

The Action Agencies will:

1. *Implement research in select areas of the pilot study basins (Wenatchee, Methow and Entiat river basins in the Upper Columbia River, the Lemhi and South Fork Salmon river basins, and the John Day River Basin) to quantify the relationships between habitat conditions and fish productivity (limiting factors) to improve the development and parameterization of models used in the planning and implementation of habitat projects. These studies will be coordinated with the influence of hatchery programs in these habitat areas.*

   Reclamation Project R14-PG-49 (Integrative Data Modeling, Analyst and Management Activities) with USGS developed a model to evaluate the food web as it relates to fish productivity in the middle Methow reach. This project funded the collection of food web data and post-floodplain treatment fish production data to help parameterize the model and further develop relationships between habitat and fish productivity, (see e.g., Bellmore and Baxter 2013; Bellmore et al. 2013, 2014, 2015; Benjamin and Bellmore, 2016; Benjamin et al. 2013, 2016; Mejia et al. 2016; Romine et al. 2013).

BPA Project 1989-098-00 (Salmon Studies in Idaho Rivers-Idaho Department of Fish and Game (IDFG)) assessed the use of hatchery Chinook salmon to restore or augment natural populations, and to evaluate the effects of supplementation on the survival and fitness of existing natural populations. The program has collected data from 30 streams throughout Idaho.

BPA Project 1990-055-00 (Idaho Steelhead Monitoring and Evaluation Studies) monitored and evaluated the status of wild steelhead populations in the Clearwater and Salmon River drainages.

BPA Project 1998-016-00 (Escapement and Productivity of Spring Chinook and Steelhead) provided basin-wide status and trend data for steelhead and spring Chinook in the John Day River Basin. Analyses completed in 2015 on previously collected data illustrate relationships in the Middle Fork Chinook population where productivity increases as summer minimum discharge increases; suggesting that restoration actions that increase summer discharge will likely increase Chinook salmon population productivity.

BPA Project 2003-017-00 (Integrated Status and Effectiveness Monitoring Program (ISEMP)) implemented both status and trend monitoring (fish and habitat) and watershed-level action effectiveness monitoring in five IMWs throughout the Columbia River Basin. The IMWs continued in the Entiat River, Bridge Creek, and Lemhi River watersheds, while status and trend monitoring is implemented in the Wenatchee, John Day, and Lemhi river watersheds. Efforts to further develop both the Habitat Suitability Index (HSI) and Net Rate of Energy Intake (NREI) models continued in 2015. HSI models for adult and juvenile Chinook and Steelhead are in production in most CHaMP sites to date and is actively used for restoration planning in the Entiat IMW. Work with ISEMP's quantile regression forest model (QRF) also continued in 2015, identifying 12 habitat metrics to predict Chinook parr carrying capacity. Initial results from QRF capacity estimates in a subset of watershed matched nicely with Beverton-Holt carrying capacity estimates. Life Cycle Models (LCM) have been developed and are operational for the Lemhi, Middle Fork John Day populations for use in restoration planning. A LCM has been developed for the spring Chinook Entiat population as well, with the Secesh under way.

BPA Project 2008-471-00 (Upper Columbia Nutrient Supplementation) quantified and evaluated nutrient status and availability in the Twisp River, a tributary to the Methow River.

BPA Project 2010-034-00 (Upper Columbia Spring Chinook and Steelhead Juvenile and Adult Abundance, Productivity and Spatial Structure Monitoring) evaluated precision and accuracy of smolt monitoring and the precision of redd counts for both steelhead and spring Chinook, estimate the proportion of hatchery steelhead, and evaluate the accuracy of the steelhead spawning ground survey design in Upper Columbia Rivers.

BPA Project 2011-006-00 (Columbia Habitat and Monitoring Program (CHaMP)) developed and implemented a standardized habitat monitoring program covering at least one population per MPG for habitat status and trend to support habitat and fish relationship development used in limiting factor assessments and for planning and evaluation of habitat actions. Efforts to further develop both the Habitat Suitability Index (HSI) and Net Rate of Energy Intake (NREI) models continued in 2015. HSI models for adult and juvenile Chinook and Steelhead are in production in most

CHaMP sites to date and is actively used for restoration planning in the Entiat IMW. Partnered work with ISEMP's quantile regression forest model (QRF) also continued in 2015, identifying 12 habitat metrics to predict Chinook parr carrying capacity. Initial results from QRF capacity estimates in a subset of watershed matched nicely with Beverton-Holt carrying capacity estimates. Life Cycle Models (LCM) have been developed and are operational for the Lemhi, Middle Fork John Day populations for use in restoration planning. A LCM has been developed for the spring Chinook Entiat population as well, with the Secesh under way.

2. *Implement habitat status and trend monitoring as a component of the pilot studies in the Wenatchee, Methow and Entiat river basins in the Upper Columbia River, the Lemhi and South Fork Salmon river basins, and the John Day River Basin. (Initiate in FY 2007-2009 Projects, annually review and modify annually to ensure that these projects continue to provide a means of evaluating the effectiveness of tributary mitigation actions.)*

   BPA Project 2003-017-00 (Integrated Status and Effectiveness Monitoring Program) (ISEMP)) continued to support habitat status and trend monitoring through watershed-level action effectiveness studies (IMWs) in the John Day (Bridge Creek), Entiat, and Lemhi and ongoing habitat status and trends monitoring in the Wenatchee.

   BPA Project 2008-471-00 (Upper Columbia Nutrient Supplementation) quantified and evaluated nutrient status and availability in the Twisp River, a tributary to the Methow River. This project monitors and tracks nutrients and food within a watershed in the Methow River Basin and will contribute, along with CHaMP and Reclamation data, to habitat status and trend monitoring within the Methow River Basin.

   BPA Project 2011-006-00 (Columbia Habitat and Monitoring Program) developed and implemented a standardized habitat monitoring program for habitat status and trend (including the 6 basins identified in this RPA subaction) to support habitat and fish relationship development used in limiting factor assessments and for planning and evaluation of habitat actions. In 2015, CHaMP completed its fifth year of monitoring, with crews applying standardized habitat monitoring protocols at 408 sites in 15 watersheds across the interior Columbia River Basin. Coordination with BPA Action Effectiveness Programmatic in a subset of watersheds continued in 2015, enabling both programs to leverage data from status and trend and effectiveness monitoring sites and produce sampling efficiencies. Data and results from CHaMP watersheds continue to contribute to the ISEMP IMW pilot studies in the Wenatchee, Methow, Entiat, Lemhi and John Day River basin.

3. *Facilitate and participate in an ongoing collaboration process to develop a regional strategy for limited habitat status and trend monitoring for key ESA fish populations. This monitoring strategy will be coordinated with the status monitoring needs and strategies being developed for hydropower, habitat, hatchery, harvest, and estuary/ocean.*

   BPA Project 2003-017-00 (Integrated Status and Effectiveness Monitoring Program) (ISEMP)) continued to work collaboratively with the region on the development of protocols and new technologies, indicators, sample designs, analytical, data management and communication tools and skills, and restoration experiments that support the development of a region-wide Research, Monitoring and Evaluation (RME) strategy to assess the status of anadromous salmonid populations, their tributary habitat and restoration and management actions.

BPA Project 2003-022-00 (Okanogan Basin Monitoring & Evaluation Program) (OBMEP) measured habitat conditions and steelhead natural production in the Okanogan River Basin. The project also consolidated information related to sockeye and Chinook salmon. Okanogan Basin Monitoring and Evaluation Program data are used to help identify limiting factors, support adaptive management, prioritize and select restoration actions, manage local fisheries, and develop new restoration actions. In 2015, continued integration of OBMEP data into the EDT-3 (Ecosystem Diagnostic Tool version 3) provided improvements in data quality and results for OBMEP's Okanogan River basin Chinook salmon and steelhead status and trend reports and report cards. These updated reports and report cards have been shared regionally as potential tools for expansion across the Columbia River Basin.

BPA Project 2004-002-00 (Pacific Northwest Aquatic Monitoring Program Coordination) funded the Pacific Northwest Aquatic Monitoring Program to provide a forum for coordination of aquatic monitoring efforts in the region to promote consistency in monitoring approaches and protocols; follow a scientific foundation; support monitoring policy and management objectives; and collect and present information in a manner that can be shared. Partnership, scoping and coordination with regional entities including the Northwest Power and Conservation Council in 2015 have led to the development of two initiatives to be completed in 2016 focusing on regional habitat indicators and intensively monitored watersheds.

BPA Project 2009-004-00 (Monitoring Recovery Trends in Key Spring Chinook Habitat Variables and Validation of Population Viability Indicators) assessed the status and trend of stream habitat conditions in the upper Grande Ronde River, Catherine Creek and Minam Creek to evaluate the potential of freshwater habitat restoration in aggregate, applied in a spatially diffused manner to these basins, to improve the viability of spring Chinook salmon populations. In 2015, this project continued coordination with various regional efforts including CHaMP, the Grande Ronde ATLAS, and Expert Panel execution.

BPA Project 2011-006-00 (Columbia Habitat and Monitoring Program) continued to develop and implement a standardized habitat monitoring program for habitat status and trend (consistent with the Anadromous Salmonid Monitoring Strategy (ASMS) regional collaborative strategy and ISRP review) to support habitat and fish relationship development used in limiting factor assessments and for planning and evaluation of habitat actions.

RPA Action 57 – Evaluate the Effectiveness of Tributary Habitat Actions

The Action Agencies will evaluate the effectiveness of habitat actions through RME projects that support the testing and further development of relationships and models used for estimating habitat benefits. These evaluations will be coordinated with hatchery effectiveness studies.

1. *Action effectiveness pilot studies in the Entiat River Basin to study treatments to improve channel complexity and fish productivity.*

   BPA Project 2003-017-00 (Integrated Status and Effectiveness Monitoring Program) (ISEMP) determined the effectiveness of restoration at improving Chinook and steelhead freshwater productivity for the Entiat River IMW. The primary restoration action to be tested is active instream modification via engineered structures that increase habitat complexity and diversity by creating large pools and off-channel areas. ISEMP implemented CHaMP protocols at over 35 mainstem and 6 side channel sites in the Entiat in 2015 to continue to evaluate the effect of restoration actions on instream complexity. Fish sampling at the mouth, mainstem and side channels of the Entiat occurred at over 30 sites, monitoring summer and winter juvenile abundance, survival and growth. Presently, 3 years of post-treatment data for phase one actions and 1 year of post-treatment data for phase two actions have been collected. Analysis of the effectiveness of all actions completed to date are anticipated in the 2015 combined ISEMP/CHaMP Annual Report.

BPA Project 2010-034-00 (Upper Columbia Spring Chinook and Steelhead Juvenile and Adult Abundance, Productivity and Spatial Structure Monitoring) evaluated precision and accuracy of smolt monitoring and the precision of red counts for both Entiat River steelhead and spring Chinook, estimated the proportion of hatchery steelhead, and evaluated the accuracy of the steelhead spawning ground survey design in Upper Columbia Rivers.

BPA Project 2011-006-00 (Columbia Habitat and Monitoring Program) developed preliminary summaries of habitat quality indices for the Entiat River Basin. See RPA Subactions 56.1, 56.2, and 56.3 for further descriptions of CHaMP. ISEMP implemented CHaMP protocols at over 35 mainstem and 6 side channel sites in the Entiat in 2015 to continue to evaluate the effect of restoration actions on instream complexity. Fish sampling at the mouth, mainstem and side channels of the Entiat occurred at over 30 sites, monitoring summer and winter juvenile abundance, survival and growth. Presently, 3 years of post-treatment data for phase one actions and 1 year of post-treatment data for phase two actions have been collected. Analysis of the effectiveness of all actions completed to date are anticipated in the 2015 combined ISEMP/CHaMP Annual Report.

2. *Pilot study in the Lemhi River Basin to study treatments to reduce entrainment and provide better fish passage flow conditions.*

BPA Project 2003-017-00 (Integrated Status and Effectiveness Monitoring Program) (ISEMP) evaluated the effectiveness of reconnecting numerous small tributaries to the mainstem Lemhi River for the Lemhi IMW. While tributary reconnections are the major restoration focus, the Lemhi River IMW also evaluates additional habitat actions including channel modifications, riparian fencing, diversion removals and screening, and side-channel development. Potential restoration scenarios and actions that would meet or exceed survival targets in the basin for spring/summer Chinook salmon continued to be explored using the ISEMP-developed life cycle model in 2015. 2016 marks the transition from Phase I evaluation to Phase II implementation in the Lemhi where restoration practitioners will implement actions to achieve the 7 percent survival improvement target identified for spring/summer Chinook salmon.

BPA Project 2011-006-00 (Columbia Habitat and Monitoring Program) developed and continued to implement a standardized habitat monitoring program for habitat status and trend data that included the Lemhi River. This work was partnered work with ISEMP for the Lemhi IMW (see project description above).

3. *Action effectiveness pilot studies in Bridge Creek of the John Day River Basin to study treatments of channel incision and its effects on passage, channel complexity, and consequentially fish productivity.*

   BPA Project 1998-016-00 (Escapement and Productivity of Spring Chinook and Steelhead) provided basin-wide status and trend data for anadromous salmonids in the John Day River Basin. In 2015, the project estimated adult steelhead escapement and freshwater productivity for the South Fork John Day River population. Results from 2015 indicate escapement has exceeded the recovery goal in 8 of the 10 past years for the South Fork steelhead population.

   BPA Project 2003-017-00 (Integrated Status and Effectiveness Monitoring Program) examined the effects of restoration actions on aggrading incised stream channels and restoring floodplain connectivity on steelhead growth, survival, abundance, and production. Restoration is aimed at causing aggradation of the incised stream channels by installing a series of instream beaver dam support structures, (vertical wood post driven into the stream bottom) designed to assist beaver in the construction of stable, longer-lasting dams. Results to date show that the total number of beaver dams are on average four-times more abundant than pre-restoration. Substantial increases in natural beaver dam construction are attributed to restoration actions creating a source of beavers. Both natural and artificial beaver structures have raised the water, created upstream dam pools and downstream plunge pools as well as caused aggradation with formation of new channels. Temperatures remained constant or decreased in reaches with extensive beaver dams while temperatures increased in reaches without. Within four years of restoration, results are showing a 175 percent increase in juvenile fish production in Bridge Creek relative to its control Murderer's Creek.

   BPA Project 2011-006-00 (Columbia Habitat and Monitoring Program) developed and implemented a standardized habitat monitoring program for habitat status and trend to support habitat and fish relationship development used in limiting factor assessments and for planning and evaluation of habitat actions. CHaMP partnered with ISEMP to examine the effects of restoration actions on aggrading incised stream channels and restoring floodplain connectivity on steelhead growth, survival, abundance, and production in Bridge Creek. Restoration is aimed at causing aggradation of the incised stream channels by installing a series of instream beaver dam support structures designed to assist beaver in the construction of stable, longer-lasting dams. Results to date show that the total number of beaver dams is on average four-times more abundant than pre-restoration. Substantial increases in natural beaver dam construction are attributed to restoration actions creating a source of beavers. Both natural and artificial beaver structures have raised the water, created upstream dam pools and downstream plunge pools as well as caused aggradation with formation of new channels. Temperatures remained constant or decreased in reaches with extensive beaver dams while temperatures increased in reaches without. Within four years of restoration, results are showing a 175 percent increase in juvenile fish production in Bridge Creek relative to its control Murderer's Creek.

4. *Project and watershed level assessments of habitat, habitat restoration and fish productivity in the Wenatchee, Methow, and John Day basins.*

   Reclamation Project R14 PG 49 (Integrative Data Modeling, Analyst and Management Activities) with USGS developed a model to assess the effectiveness of habitat treatments in the Methow River Basin. In addition, a Chinook salmon life-cycle model constructed in 2014 and 2015 is being used to evaluate longer-term population trajectories following habitat improvements. Preliminary simulation modeling suggests an increase in local fish productivity associated with habitat improvements. On-the-ground efforts continued to collect data to compare with pre-project data (Martens and Connolly 2014), and earlier studies documented the benefits of barrier removal (Martens and Connolly 2010; Weigel et al. 2013a; 2013b; USGS 2014a; 2014b). Tributary habitat project implementers are testing whether the aquatic tropic model can help prioritize project alternatives at the design stage.

Reclamation Project R15 AC 00020 provides monitoring support for Methow River tributary habitat improvement projects, especially data gathering related to project effectiveness for the Whitefish Island and the 3R projects.

BPA Project 1998-016-00 (Escapement and Productivity of Spring Chinook and Steelhead) provided basin-wide status and trend data for anadromous salmonids in the John Day River Basin. These long term escapement and productivity estimates generated from this project can be used to evaluate the influence of habitat restoration on population productivity for populations in the South fork, Upper Mainstem and Middle Fork John Day River.

BPA Project 2003-017-00 (Integrated Status and Effectiveness Monitoring Program) examined the effects of restoration actions on aggrading incised stream channels and restoring floodplain connectivity on steelhead growth, survival, abundance, and production in Bridge Creek, John Day Basin. Restoration is aimed at causing aggradation of the incised stream channels by installing a series of instream beaver dam support structures, (vertical wood post driven into the stream bottom) designed to assist beaver in the construction of stable, longer-lasting dams. Results to date show that the total number of beaver dams are on average four-times more abundant than pre-restoration. Substantial increases in natural beaver dam construction are attributed to restoration actions creating a source of beavers. Both natural and artificial beaver structures have raised the water, created upstream dam pools and downstream plunge pools as well as caused aggradation with formation of new channels. Temperatures remained constant or decreased in reaches with extensive beaver dams while temperatures increased in reaches without. Within four years of restoration, results are showing a 175 percent increase in juvenile fish production in Bridge Creek relative to its control Murderer's Creek.

BPA Project 2010-034-00 (Upper Columbia Spring Chinook and Steelhead Juvenile and Adult Abundance, Productivity and Spatial Structure Monitoring) evaluated precision and accuracy of smolt monitoring and the precision of redd counts for both Methow River and Entiat River steelhead and spring Chinook, estimated the proportion of hatchery steelhead, and evaluated the accuracy of the steelhead spawning ground survey design in Upper Columbia Rivers. The application of fish monitoring protocols/methods in the Wenatchee and Methow benefit directly from this project.

BPA Project 2011-006-00 (Columbia Habitat and Monitoring Program) developed and implemented a standardized habitat monitoring program for habitat status and trend to support habitat and fish relationship development used in limiting factor assessments and for planning and evaluation of habitat. Watershed-level assessments of habitat continued in 2015 in both the Wenatchee and Methow River subbasins. Partnered work with ISEMP in the Bridge Creek John Day IMW also continued. 2015 results can be found in the ISEMP 2003-017-00 project description above.

5. *Action Agencies will convene a regional technical group to develop an initial set of relationships in FY 2008, and then annually convene the group to expand and refine models relating habitat actions to ecosystem function and salmon survival by incorporating research and monitoring results and other relevant information.*

   BPA Project 2004-002-00 (Pacific Northwest Aquatic Monitoring Program Coordination) funded the Pacific Northwest Aquatic Monitoring Program providing a forum for coordination of aquatic monitoring efforts in the region to promote consistency in monitoring approaches and protocols; follow a scientific foundation; support monitoring policy and management objectives; and collect and present information in a manner that can be shared. Reclamation's Interagency Agreement with USGS (IA R13-PG-10-428) also provides funding for PNAMP. PNAMP work supported development of modeling approaches through products that provided more accessible data and standardized metadata.

   BPA Project 2009-004-00 (Monitoring Recovery Trends in Key Spring Chinook Habitat Variables and Validation of Population Viability Indicators) continued to monitor status and trends in fish habitat characteristics (limiting factors) for spring Chinook populations, evaluate effectiveness of stream restoration actions on limiting factors and develop a life cycle model to link biotic responses of spring Chinook to projected changes in stream habitat conditions. In 2015, life cycle model analyses were completed for spring/summer Chinook salmon in the Grande Ronde basin (including Upper Grande Ronde, Catherine Creek and Minam populations). These analyses simulated the expected benefit to population recovery if habitat improvements increase survival, productivity and capacity. Fish-habitat relationships required to integrate the effects of habitat restoration into life cycle model efforts, including structural equation modeling and linear mixed effects modeling, were also further developed in 2015. These modeling efforts examined fish-habitat relationships among large woody debris, large pool frequencies and juvenile Chinook salmon rearing capacity as well as temperature scenario effects on juvenile Chinook salmon rearing densities.

   BPA Project 2003-017-00 (Integrated Status and Effectiveness Monitoring Program) participated in NOAA Fisheries Life Cycle Modeling workshops for the tributaries to discuss fish and habitat monitoring modeling approaches and data needs.

   BPA Project 2012-001-00 (AMIP Salmonid Life Cycle Model Support) collaboratively worked with several regional entities on fish and habitat relationships and associated life cycle modeling approaches. In 2015, modelers made progress gathering data to estimate relationships between habitat conditions and survival and spawner and parr capacity for populations across the Columbia River Basin.

RPA Action 58 – Monitor and Evaluate Fish Performance in the Estuary and Plume

The Action Agencies will monitor biological responses and/or environmental attributes, and report in the following areas:

1. *Monitor and evaluate smolt survival and/or fitness in select reaches from Bonneville Dam through the estuary.*

Corps Project EST-P-15-01 (Evaluating the Effectiveness of Habitat Restoration Actions in the Lower Columbia River and Estuary) initiated a study design and field investigations in 2015 to monitor and evaluate juvenile salmon growth/condition and performance in the Columbia River estuary. Factors of growth/condition include length and weight, liver glycogen, insulin growth factor, and liver somatic; and factors of performance include diet, gut fullness, trophically transmitted parasites, bioenergetics and early life history diversity. The above metrics are considered proxies to juvenile salmon fitness.

BPA Project 2003-007-00 (Lower Columbia River Estuary Ecosystem Monitoring) collected data on juvenile salmonid lipid content at monitoring sites throughout the LCRE during 2015. Lipid content can be an indicator of smolt fitness or condition.

2. *Develop an index and monitor and evaluate life history diversity of salmonid populations at representative locations in the estuary.*

Corps Project EST-P-15-01 (Evaluating the Effectiveness of Habitat Restoration Actions in the Lower Columbia River and Estuary) initiated a study design and field investigations in 2015 to investigate the importance of juvenile salmonid early life history diversity (ELHD) in tidal systems of the Columbia River estuary. Factors of life history diversity include species, genetic stock identification (ESU/DPS), fork length, weight, and time of capture; and incorporate fish abundance, richness, and evenness. The ELHD index can be applied to compare changes in life history diversity across time at the same locale (e.g., status and trends) or across space (e.g., different locales, or habitats). The ELHD index has application as a high-level indicator to track trends in metrics that influence the viability status of salmon and steelhead populations in the Columbia River basin. Weitkamp et al. (2015) showed that juvenile salmonid stocks within a single basin can differ in their size and timing at ocean entry, and differ in early marine growth and survival. These findings re-affirmed the Action Agencies approach to gather data and track juvenile salmonid early life history diversity expression by genetic stock identity in the Columbia River estuary.

3. *Monitor and evaluate juvenile salmonid growth rates and prey resources at representative locations in the estuary and plume.*

BPA Project 1998-014-00 (Ocean Survival of Salmonids) collected juvenile salmon, associated nekton, and physical metrics of the estuary, plume and nearshore ocean in May, June, and in September (in collaboration with NOAA's Southwest Fisheries Science Center). The diets, feeding intensity, and condition of yearling Chinook salmon caught in May and June of 2015 reflected a diet of warm ocean prey, a high proportion of empty stomachs, average stomach fullness in May and low fullness in June, and poor physical condition. Analysis of food availability and diets of juvenile salmon caught in the nearshore and coastal ocean indicate trophic mediated responses in both size of juveniles and potentially in their early ocean survival.

BPA Project 2003-007-00 (Lower Columbia River Estuary Ecosystem Monitoring) provided dissolved oxygen, temperature, pH, and conductivity data at habitat and fish monitoring locations and collected data on juvenile salmonid prey resources throughout the LCRE through the Estuary Partnership in conjunction with OHSU during 2015. Site-specific water quality data were collected at Ilwaco Slough at river kilometer (rkm) 6, Whites Island (rkm 72), Campbell Slough (rkm 149), and Franz Lake (rkm 221) continuously between April and August 2015. Continuous mainstem conditions data (temperature, conductivity, dissolved oxygen, turbidity, chlorophyll *a* concentration, nitrate concentration, and colored dissolved organic matter) were collected from January to December 2015 at river mile 122 at the Camas-Washougal marina. Juvenile salmonid prey resource data were collected monthly at Ilwaco Slough, lower Grays River, Welch Island (rkm 53), Whites Island, Campbell Slough, and Franz Lake between April and July 2015.

Corps Project EST-P-15-01 (Evaluating the Effectiveness of Habitat Restoration Actions in the Lower Columbia River and Estuary) collected juvenile salmon in the Columbia River estuary in fall and winter 2015. Juvenile salmonid condition (length and weight) were examined. Additionally, salmonid condition and growth (insulin growth factor, liver glycogen and liver somatic) were examined at the mainstem sites. Prey resources were collected at both. Hanson et al. (2015) presented data indicating that non-native reed canarygrass supports reduced macro invertebrate diversity compared to native vegetation. The action agencies are continuing to consider the effect of reed canarygrass on macroinvertebrate prey production, availability to juvenile salmon and subsequent dietary intake at restoration sites and implications for site design, construction, and maintenance.

4. *Monitor and evaluate temporal and spatial species composition, abundance, and foraging rates of juvenile salmonid predators at representative locations in the estuary and plume.*

BPA Project 1998-014-00 (Ocean Survival of Salmonids) In 2015, there was no new information regarding fish predators in the Columbia River plume and coastal ocean. However, investigation of ocean avian predation is continuing; seabird surveys took place during June 2015 and the analysis of those data is in progress.

Corps Project AVS-P-08-01 and AVS-P-08-02 (Avian Predation Research, Monitoring, and Evaluation) monitored predation impacts by Caspian terns in 2015 at East Sand Island by examining diet content (i.e., amount of juvenile salmon consumed by species). Predation impacts by Caspian terns and double-crested cormorants were also evaluated by recovery of PIT tags to estimate rate of predation by ESU/DPS (i.e., percent of those available that were consumed).

RPA Action 59 – Monitor and Evaluate Migration Characteristics and Estuary/Ocean Conditions

The Action Agencies will monitor and evaluate selected ecological attributes of the estuary, which include the following or equivalent:

1. *Map bathymetry and topography of the estuary as needed for RME.*

BPA Project 2003-007-00 (Lower Columbia River and Estuary Ecosystem Monitoring) contributed to developing a seamless elevation dataset for the LCRE. This dataset represents the most up-to-date, comprehensive, and highest resolution elevation dataset (including high-resolution light detection and ranging data) that has been generated for mapping bathymetry and topography in the LCRE. There has been no further action since 2013.

2. *Establish a hierarchical habitat classification system based on hydrogeomorphology, ground-truth it with vegetation cover monitoring data, and map existing habitats.*

BPA Project 2003-007-00 (Lower Columbia River and Estuary Ecosystem Monitoring) supports multiple efforts in the estuary by mapping ecosystem processes to specific locations in the estuary to better organize current efforts (habitat actions and RME). This effort also helps to better predict how the LCRE landscape will evolve over time. The Estuary Partnership assisted USGS with compiling the synthesis report in 2015.

3. *Develop an index of habitat connectivity and apply it to each of the eight reaches of the study area.*

BPA Project 2003-007-00 (Lower Columbia River and Estuary Ecosystem Monitoring). In 2015, the Estuary Partnership used a new version of the Corps' Hydrologic Engineering Center Ecosystem Functions Model (HEC-EFM) to develop statistical relationships between site hydrology as predicted by a HEC-RAS 2-D hydrodynamic model and ecological parameters. HEC-EFM coupled a 2-D hydrodynamic model output with vegetation data from reference sites and fish and wildlife habitat suitability data. The model can be used to map the seasonal timing and frequency of inundation under different restoration designs and to answer questions about how these changes can affect habitat for multiple species.

BPA Project 2002-077-00, (Estuary/Ocean Research and Evaluation) finalized the Area Time Inundation Index Model (ATIIM) in 2016. The ATIIM evaluates spatial and temporal inundation patterns; and integrates modeled or scenario-based hourly water-surface elevation data and terrain elevation data to evaluate habitat connectivity. Hydrological metrics include inundation frequency, duration, maximum area, and maximum frequency area. The model can inform evaluation of proposed restoration sites, e.g.: determine trade-offs between water-surface elevation and habitat opportunity, contrast alternative restoration designs, predict impacts of altered flow regimes, and estimate nutrient and biomass fluxes (Coleman et al. 2015).

4. *Evaluate migration through and use of a subset of various shallow-water habitats from Bonneville Dam to the mouth toward understanding specific habitat use and relative importance to juvenile salmonids.*

BPA Project 2003-007-00 (Lower Columbia River Estuary Ecosystem Monitoring) assessed annual trends in the presence and residency of juvenile salmonids at monitoring sites throughout the LCRE during 2015.

Corps Project EST-P-15-01 (Evaluating the Effectiveness of Habitat Restoration Actions in the Lower Columbia River and Estuary) evaluated juvenile salmon use of shallow water habitats in the Columbia River estuary in fall and winter 2015. Juvenile salmonid use was investigated to evaluate the ecological benefits of restoration actions for juvenile salmon in the lower Columbia River and estuary. Specific habitat attributes, such as water surface elevation, water temperature and channel cross-sections were examined at Sandy River Delta, and a study design to investigate other environmental attributes such as prey production and flux and relate those to juvenile salmonid growth, condition, and performance was a developed in 2015.

5. *Monitor habitat conditions periodically, including water surface elevation, vegetation cover, plant community structure, primary and secondary productivity, substrate characteristics, dissolved oxygen, temperature, and conductivity, at representative locations in the estuary as established through RME.*

BPA Project 2003-007-00 (Lower Columbia River Estuary Ecosystem Monitoring) assessed annual trends in habitat status at restoration and reference sites during 2015 and has been the primary contributor to habitat monitoring throughout the LCRE. Reference sites are used to inform restoration design and as a comparison for action effectiveness studies.

Corps Project EST-P-15-01 (Evaluating the Effectiveness of Habitat Restoration Actions in the Lower Columbia River and Estuary) monitored habitat condition at four sites in the Sandy River delta and eight shallow water habitat sites in the Columbia River estuary in fall and winter 2015. Environmental data includes water surface elevation, water temperature and channel cross-sections.

RPA Action 60 – Monitor and Evaluate Habitat Actions in the Estuary

The Action Agencies will monitor and evaluate the effects of a representative set of habitat projects in the estuary, as follows:

1. *Develop a limited number of reference sites for typical habitats (e.g., tidal swamp, marsh, island, and tributary delta to use in action effectiveness evaluations).*

   BPA Project 2003-007-00 (Lower Columbia River Estuary Ecosystem Monitoring) assessed annual trends in habitat status at restoration and reference sites in 2015 and has been the primary contributor to habitat monitoring throughout the LCRE. Reference sites are used to inform restoration design and as a comparison for action effectiveness studies.

   Corps Project EST-P-15-01 (Evaluating the Effectiveness of Habitat Restoration Actions in the Lower Columbia River and Estuary) established four reference sites in the Columbia River estuary in fall and winter 2015. Reference sites are paired to four restoration (treatment) sites in support of the before-after-reference-impact study design. Restoration and reference sites include off-channel habitats along the Oregon and Washington shorelines (e.g., Steamboat Slough, Dibble Point, Batwater and Karlson Island) and mid-channel island habitats (e.g., Crims, Welch, Fisher and Karlson Islands). Habitat strata surveyed include tidal channel, low to high marsh and shrub fringe.

2. *Evaluate the effects of selected individual habitat restoration actions at project sites relative to reference sites and evaluate post-restoration trajectories based on project-specific goals and objectives.*

   BPA Project 2003-011-00 (Lower Columbia River/Estuary Habitat Restoration) intensively monitored water surface elevation, bathymetry and topography, sediment accretion, vegetation composition and percent cover, and terrestrial and benthic macroinvertebrates at five habitat restoration sites during 2015. This project evaluates the effectiveness of restoration projects. This work was done per the CEERPs programmatic research and monitoring strategy for level 2 and 3 AEMR data collection. Based on the observed variability in the data collected thus far, the Action Agenciesare considering monitoring standard Level 3 metrics more frequently than one and five years post-restoration.

   Corps Project EST-P-15-01 (Evaluating the Effectiveness of Habitat Restoration Actions in the Lower Columbia River and Estuary) evaluated the effects of habitat restoration post-construction at Sandy River Delta and developed study designs and performed initial field reconnaissance at four restoration sites (Steamboat Slough, Dibblee Point, Batwater and Karlson Island) and four reference sites (Welch Island, Crims Island, Fisher Island and Karlson Island) in fall and winter 2015. Field reconnaissance included installation of water surface elevation and water temperature sensors; surveys of cross-sections at primary channel connections to the mainstem Columbia River; and sampling of prey community composition (e.g., stable isotopes, neuston, benthos, and fallout). These metrics along with material flux (prey, macrodetritus, nutrients, etc.) will be investigated in 2016. Howe and Simenstad (2015) investigated trophic dynamics in the Skokomish estuary (Puget Sound) and concluded that hydrologic reconnections promote detritus-based food-webs in estuaries. Results confirm the value of continuing to study the exchange of prey from restoring sites in the Columbia River estuary. In addition, because McNatt et al. (2015) has presented PIT tag detection data indicating that more up-river stocks use and migrate thru shallow water habitat than had been previously reported, the Action Agencies are considering deployment of more PIT arrays at restoring sites. This would be an additional method to assess direct benefits of habitat restoration to all stocks of juvenile salmonids.

The Action Agencies, as part of the ERTG Steering Committee, in coordination with ERTG and the project sponsors revisited 10 restored sites that the ERTG had previously scored. This tour provided an opportunity for the project sponsors, ERTG, and the Steering Committee to discuss lessons learned during project planning and implementation. The ERTG has concluded that more openings/levee breaches are better than few; bridges are preferred to culverts; and that lowering levees to reconnect the floodplain to the river is beneficial, even when complete removal is not possible. The Action Agencies will continue to host periodic site revisits and presented the CEERP Action Effectiveness Monitoring and Research Program to the ERTG in April 2016.

3. *Develop and implement a methodology to estimate the cumulative effects of habitat conservation and restoration projects in terms of cause-and-effect relationships between ecosystem and controlling factors, structures, and processes affecting salmon habitats and performance.*

Corps Project EST-P-12-01 (Synthesis and Evaluation of Research, Monitoring, and Restoration Project Data in the Lower Columbia River and Estuary) continued work on the development of a web-based, geospatial data management and analysis system (called “Oncor”) for research, monitoring and evaluation (RME) data. Work in 2015 included (1) coordination with agencies and regional stakeholders; (2) database construction; (3) analysis and synthesis of data (fish, vegetation, photo points, water surface elevation, water temperature, and sediment accretion); and (4) refinement of data reduction procedures and data exchange templates for 13 monitoring indicators.

BPA Project 2003-007-00 (Lower Columbia River Estuary Ecosystem Monitoring) continued to collect and aggregate both action effectiveness and ecosystem monitoring data. Findings have been presented at regional and national conferences, shared with regional stakeholders, and have been captured in the Action Agencies annual update of the Columbia Estuary Ecosystem Restoration Program (CEERP). CEERP provides critical guidance to regional managers, including action agencies and restoration practitioners; and was used to prioritize research and monitoring objectives, particularly action effectiveness evaluations. Together these programmatic work efforts provided a cumulative sum benefit to the CEERP by optimizing resource investments and focusing and adapting study designs on critical information gaps.

Corps Project EST-P-15-01 (Evaluating the Effectiveness of Habitat Restoration Actions in the Lower Columbia River and Estuary) initiated a study design and field investigations to evaluate the beneficial effects of habitat restoration on juvenile salmonids in the Columbia River estuary in fall and winter 2015. Beneficial effects of habitat restoration were investigated at four restoration (treatment) sites and four coincident reference sites (Objective 1). Juvenile salmon presence (species and genetic stock identification), condition (length and weight), performance (diet, gut fullness and trophically transmitted parasites (TTP)) were considered. Data from restoration and reference sites will also be compared to data collected at paired, in-river sampling locations (Objective 2) to evaluate the benefits of habitat restoration on juvenile salmon at the landscape scale. Work under objective 2 compares stock-specific indicators of juvenile salmonid growth/condition and fish performance at four transects of the estuary: (1) Bonneville, near Rkm 234; (2) tidal freshwater #1 at Rkm 100; (3) tidal freshwater #2 at Rkm 75; and (4) the mouth of the Columbia River at Rkm 15. In addition, Objective 2 evaluates the amount, composition, and timing of material flux (prey, macrodetritus, nutrients, etc.) from two reference sites and two restored sites, Steamboat Slough and Karlson Island respectively. This study (in whole) investigates the direct benefits of habitat restoration on juvenile salmonids that occupy the restored sites, but also investigates the indirect benefits of habitat restoration on juvenile salmon that may not occupy restored sites, but benefit from the restoration of those sites.

RPA Action 61 – Investigate Estuary/Ocean Critical Uncertainties

The Action Agencies will fund selected research direct at resolving critical uncertainties that are pivotal in understanding estuary and ocean effects.

1. *Continue work to define the ecological importance of the tidal freshwater, estuary, plume, and near shore ocean environments to the viability and recovery of listed salmonid populations in the Columbia River Basin.*

   Corps Project EST-P-15-01 (Evaluating the Effectiveness of Habitat Restoration Actions in the Lower Columbia River and Estuary) initiated a study design and field investigations in 2015 to better characterize the ecological importance of shallow water habitats to the viability of ESA-listed salmonids in the Columbia River Basin. Objective 1 evaluates the direct benefits of habitat restoration on juvenile salmon that occupy restoration sites, while Objective 2 evaluates the indirect benefits of habitat restoration on juvenile salmon that may not occupy restored sites, but benefit from the restoration of those sites. Juvenile salmonid growth/condition (e.g., length and weight) was examined. This, along with other growth/condition metrics (e.g., liver glycogen, insulin growth factor, and liver somatic), fish performance metrics (e.g., diet, gut fullness, TTP, bioenergetics and early life history diversity), and genetic stock identification will be examined at representative locations throughout the estuary, from Bonneville Dam down to the mouth of the Columbia River in 2016. Daly et al. (2015) concluded that ocean conditions affect prey availability, which, in turn, affects growth and survival in the ocean. BPA and Corps are considering application of a bioenergetics model as an additional method to relate water temperature, prey composition and quality, and fish diet and growth thru the estuary.

BPA Project 1989-108-00 (Modeling and Evaluation Support/Columbia River Integrated Statistical Program) explored the relationship of arrival timing at the estuary mouth with oceanic distribution of adult Chinook salmon (Bracis and Anderson 2013), environmental and geospatial ocean factors influencing juvenile Chinook distribution (Burke et al. 2013a), evaluated evidence for navigational sensory capabilities of yearling Chinook (Burke et al. 2013b), and inferred how coastal ocean dynamics influence yearling Chinook salmon marine growth and migration behaviors (Burke et al. 2016).

BPA Project 1998-014-00 (Ocean Survival of Salmonids) examined causal mechanisms affecting survival such as food-web structure and growth conditions in the plume and coastal ocean (not estuary) during June 2015. Overall, results indicate that a combination of physical and biological processes affect the early ocean survival of juvenile salmon, but the nature and strength of these relationships varies between species, ESUs, stock groups, and life history types.

BPA Project 2003-007-00 (Lower Columbia River Estuary Ecosystem Monitoring) monitored juvenile salmon use of shallow-water habitats in Reaches A-H during 2015. This project analyzed salmonid densities, fish community composition, salmonid age-size structure, genetic stock identity, salmon diet, residence times, spatial and temporal distribution, growth rates and habitat characteristics. In 2014 (field data collection) and 2015 (reporting), salmon prey availability and community structure, vegetation cover, and macrodetritus data were collected to examine the effects of aquatic invasive species (i.e., reed canarygrass) on food webs supporting juvenile salmon.

Corps Project EST-P-10-01 (The contribution of tidal fluvial habitats in the Columbia River Estuary to the recovery of diverse salmon ESUs) in 2014 analyzed and synthesized results from 2010–2013 estuary studies (Roegner et al. 2015). Summarized data for: salmon habitat use and genetic stock composition in reach F habitats; temporal variations in fish community structure and life history of out-migrant salmon near the estuary mouth; stock sources, travel times, and residency of PIT-tagged salmon entering selected wetland tidal channels in reaches B, C, and F; otolith-derived growth estimates for juvenile Chinook salmon collected at main-stem, back-water, and confluence habitats across the tidal fluvial estuary (Reaches C through H); Chinook salmon diet composition and instantaneous ration at main-stem and back-channel habitats in Reaches D and H (selected months March 2010 to September 2011); otolith-derived growth and survival estimates of adult spawning populations from two lower tributaries (Lewis River, Willamette River), two main-stem sites (Ives Island and Hanford Reach), and two upper Columbia River tributaries (Methow River and Wenatchee River); and shallow habitat opportunity modeling, including a new methodology based on depth criteria thresholds adjusted for bioenergetic (temperature), salinity, and velocity conditions.

2. *Continue work to define the causal mechanisms and migration/behavior characteristics affecting survival of juvenile salmon during their first weeks in the ocean.*

BPA Project 1998-014-00 (Ocean Survival of Salmonids) examined the spatial distribution of juvenile salmon in the coastal ocean and plume during their first spring and summer at sea, addressed migration behavior and stock-specific migration patterns, and evaluated the implications and consequences of stock-specific spatial distributions.

Corps Project EST-P-15-01 (Evaluating the Effectiveness of Habitat Restoration Actions in the Lower Columbia River and Estuary) initiated a study design and field investigations in 2015 to better characterize the causal mechanisms and migration/behavior characteristics affecting juvenile salmonid survival during the first weeks of ocean entry. The study team considers fish growth/condition and fish performance metrics to be proxies to survival. Key metrics of juvenile salmonid growth/condition include length and weight, liver glycogen, insulin growth factor, and liver somatic. Fish performance metrics include diet, gut fullness, trophically transmitted parasites, bioenergetics and early life history diversity. On the latter, McNatt et al. (2015) presented PIT tag detection data and concluded that more up-river stocks use and migrate thru shallow water habitat than had been previously reported. The Action Agencies are considering deployment of more PIT arrays as an additional method to characterize juvenile salmonid use by all stocks (timing and residence, or length of stay) in shallow water habitats.

3. *Investigate the importance of early life history of salmon populations in tidal freshwater of the lower Columbia River.*

   BPA Project 2003-007-00 (Lower Columbia River Estuary Ecosystem Monitoring) monitored salmonid density, fish community composition, salmonid age-size structure, genetic stock identity, residence times, spatial and temporal distribution, growth rates, and habitat characteristics throughout the LCRE in 2015 to further investigate the importance of early life history diversity.

   Corps Project EST-P-15-01 (Evaluating the Effectiveness of Habitat Restoration Actions in the Lower Columbia River and Estuary) initiated a study design and field investigations in 2015 to investigate the importance of juvenile salmonid early life history diversity in tidal systems of the Columbia River estuary. Factors of diversity include species, genetic stock identification, fork length, weight and time of capture; and incorporates fish abundance, richness, and evenness. This index can be applied to compare changes in life history diversity at the same locale, but across time (e.g., status and trends) or across space (e.g., different locales, or habitats). The ELHD index has application as a high-level indicator to track trends in the status of the recovery of salmon and steelhead populations in the Columbia River basin. These stock-specific metrics will be correlated with fish growth and condition metrics, and fish performance metrics respectively, including investigation of TTP at two restoration (treatment sites), two reference sites and two mainstem sites. Results will be related to TTP data collected per BPA Project 1998-014-00.

4. *Continue development of a hydrodynamic numerical model for the estuary and plume to support critical uncertainties investigations.*

   BPA Project 1998-014-00 (Ocean Survival of Salmonids) created a virtual representation of the circulation in the estuary and plume that allows extraction of salmon-relevant physical metrics of estuarine and plume conditions. While not specific to a particular salmonid stock or life stage, these simulations support stock-specific analyses.

   Corps Project EST-P-10-01 (The contribution of tidal fluvial habitats in the Columbia River Estuary to the recovery of diverse salmon ESUs) summarized modeling efforts from 2010 thru 2013. Results of this analysis in 2014 showed a strong influence of seasonal river flow and temperature criteria on habitat-opportunity for juvenile salmon in reach F. Modeling scenarios suggest that salmon habitat opportunities in the estuary could be sensitive to future sea-level rise because of increased salinity intrusion, particularly during summer and fall. Results are reported in Roegner et al. 2015.

RPA Action 62 – Fund Selected Harvest Investigations

The Action Agencies will fund selected harvest investigations linked to FCRPS interests:

1. *Evaluate the feasibility of obtaining PIT Tag recoveries between Bonneville and McNary dams to determine whether recoveries can help refine estimates of in-river harvest rates and stray rates used to assess adult survival rates.*

   BPA Project 2008-502-00 (Expanded Tribal Catch Sampling (CRITFC)) improved the monitoring and catch sampling of the Zone 6 tribal fisheries by increasing the collection of tribal catch data through increased sample rates and employing the use of additional data collection methods.

   BPA Project 2008-508-00 (Release Mortality Analysis) assessed rates of post-release mortality reported for non-retention and mark-selective fisheries in order to improve the accuracy of parameters used in harvest models.

2. *Evaluate methods to develop or expand use of selective fishing methods and gear.*

   BPA Project 2008-105-00 (Selective Gear Deployment (Colville Confederated Tribes)) continued use of selective fishing gear to harvest non-sensitive salmon species (hatchery-origin summer Chinook and natural-origin sockeye) for tribal utilization while simultaneously releasing ESA-listed sensitive salmon stocks (i.e., spring Chinook and summer steelhead) and natural origin summer Chinook. The project is a continuation of project 2007-249-00 Evaluate Live Capture Gear, which ended in 2011.

   BPA Project 1993-060-00 (Select Area Fisheries Enhancement (WDFW, ODFW, Clatsop Co.)) continued investigation and implementation of the use of off-channel terminal fishing locations in concert with hatchery rearing and acclimation protocols to offer harvest opportunities when conventional mainstem fisheries are constrained or eliminated because of ESA limitations.

3. *Evaluate post-release mortality rates for selected fisheries.*

   BPA Project 2008-105-00 (Deployment of Live Capture Gear) has ceased evaluating post-release mortality rates, and did not do so in 2015.

4. *Support coded-wire tagging and coded-wire tag recovery operations that inform survival, straying, and harvest rates of hatchery fish by stock, rearing facility, release treatment, and location.*

   BPA Project 1982-013-01 (Coded Wire Tag - Pacific States Marine Fisheries Commission (PSMFC)) covered operation of the regional Coded Wire Tag (CWT) database by PSMFC, and CWT extraction at the Clackamas lab. All ODFW and WDFW CWT recovery and analysis work is now covered under project 2010-036-00 or by NOAA Mitchell Act funding.

BPA Project 1982-013-03 (Coded Wire Tag-U.S. Fish & Wildlife Service (USFWS)) Conducted adipose fin clip and insertion of CWTs into spring Chinook and coho salmon for harvest management. Project will be discontinued after December, 2016.

BPA Project 1995-063-25 (Yakima River Monitoring and Evaluation-Yakima/Klickitat Fisheries Project (YKFP)) CWT marking of coho, spring Chinook, and early fall/summer Chinook has occurred under this project. Coho tagging has increased over this period from 550,000 to 800,000 smolts/year. Chinook tagging has been consistent at about 810,000 smolts/year for spring-run fish and 250,000 for late summer/early fall fish.

BPA Project 2002-060-00 (Nez Perce Harvest Monitoring on Snake and Clearwater Rivers) contributed to fish population status and trend monitoring in the South Fork Salmon River in by providing estimates of Nez Perce harvest of adult summer Chinook salmon. The adult harvest estimate has direct applicability to run reconstruction. For 2015, the estimated harvest of South Fork Clearwater River summer Chinook was 61 ±14 (95 percent c.i.). By conducting harvest monitoring and deriving Tribal harvest estimates with precision approaching those recommended in NOAA's monitoring guidance, this project contributes to population and trend monitoring relative to the South Fork Clearwater River.

BPA Project 2010-036-00 (Lower Columbia Coded Wire Tag Recovery Project (WDFW)) funded catch sampling and recovery of CWT and PIT tags from commercial and sport fisheries, spawning ground surveys, and spawning ground surveys and associated databases. Tag recovery and angler effort data was used for harvest management, escapement analysis, run forecasting, and informing *US v. Oregon*.

5. *Investigate the feasibility of genetic stock identification monitoring techniques.*

Genetic stock identification appears to be feasible. Multiple BPA projects have studied salmonid genetics to advance Chinook and steelhead stock identification so that any natural- or hatchery-origin Chinook or steelhead can be traced to its stock of origin. This approach can be used in sampling programs at dam or mainstem and in ocean fisheries. Parental based tagging (PBT) technologies have been developed to identify the specific hatchery stock and age of sampled hatchery fish. Additionally, Genetic Stock Identification (GSI) techniques using SNPs technology have been developed to segregate wild runs of Snake River Spring/Summer Chinook and Snake River Steelhead by stock of origin. Results from the projects associated with this RPA indicate that wild steelhead and Chinook salmon populations exhibit sufficient genetic structuring to monitor these species at the ESU and MPG level. These projects, in collaboration with BPA projects 2010-031-00 and 2008-907-00, use standardized genetic markers and integrated sampling programs at Bonneville and Lower Granite Dam and in Columbia River and Snake River mainstem fisheries to estimate the stock composition of steelhead and Chinook salmon. Project 2010-031-00 along with projects 2010-026-00 and 2008-907-00 are directly implementing RPA Action 62.5 for wild and hatchery stocks within the Snake River basin and throughout the Columbia River basin. The development of Parentage Based Tagging (PBT) technology for hatchery stocks, integrated with Genetic Stock Identification (GSI) for wild stocks, provides powerful tools to monitoring hatchery and wild stocks throughout the Columbia River basin and implement other RPA Actions of the BiOp. For example, these technologies will support implementation of RPA Action 50.5 (Provide additional status monitoring to ensure a majority of Snake River B-Run steelhead populations are being monitored for population productivity and abundance). In addition, these tools should allow better evaluation of the effectiveness of other RPA actions, and thus improve management and conservation of salmon and steelhead populations throughout the Columbia River basin affected by FCRPS operation.

Projects associated with RPA 62.5:

BPA Project 1983-350-03 (Nez Perce Tribal Hatchery Monitoring & Evaluation) monitored and evaluated for hatchery and natural fish through PIT tagging, weir operation and/or spawning ground surveys, screw trapping, habitat surveys, genetic analysis, and harvest monitoring.

BPA Project 1989-096-00 (Genetic Monitoring and Evaluation Program for Salmon and Steelhead (ODFW, NOAA Fisheries)) monitored genetic changes associated with hatchery propagation in multiple Snake River subbasins for Chinook salmon and steelhead and derives estimates of reproductive success for individual families and groups of fish.

BPA Project 1989-098-00 (Salmon Studies in Idaho Rivers-Idaho Department of Fish & Game (IDFG)) analyzed DNA from adult and juvenile Chinook salmon for parentage analysis and genetic monitoring.

BPA Project 1990-055-00 (Idaho Steelhead Monitoring and Evaluation (IDFG)) monitored and evaluated the status and trends of wild steelhead populations in Idaho.

BPA Project 1991-073-00 (Idaho Natural Production Monitoring and Evaluation (IDFG)) monitored trends in abundance, productivity, spatial structure, and diversity for spring/summer Chinook salmon and steelhead trout in the Salmon, Clearwater, and minor middle Snake tributaries in the Idaho portion of Hells Canyon, as well as for the Snake River spring/summer Chinook ESU.

BPA Project 1995-063-25 (Yakama River Monitoring and Evaluation-Yakima/Klickitat Fisheries Project (YKFP)) collected genetic data samples to detect significant genetic changes in extinction risk, within-stock genetic variability, between-stock genetic variability, and domestication selection.

BPA Project 1996-043-00 (Johnson Creek Artificial Propagation Enhancement (NPT)) quantified 38 key performance measures, which are being standardized throughout the Columbia River Basin, and contributed to regional RME efforts addressing six major categories: (1) abundance, (2) survival-productivity, (3) distribution, (4) genetic, (5) life history, and (6) habitat.

BPA Project 1997-015-01 (Imnaha River Smolt Monitoring (NPT)) tagged and monitored steelhead and Chinook smolts during outmigration from the Imnaha River.

BPA Project 1997-030-00 (Chinook Salmon Adult Abundance Monitoring (NPT)) monitored escapement of natural-origin spring/summer Chinook salmon (Snake River spring/summer Chinook ESU).

BPA Project 1997-038-00 (Listed Stock Chinook Salmon Gamete Preservation (NPT)) continued in a maintenance phase with no gamete collections in 2013. Samples stored at the Washington State University repository were monitored and securely maintained.

BPA Project 1998-007-02 (Grande Ronde Supplementation Operations and Maintenance and Monitoring and Evaluation on the Lostine River (NPT)) monitored and evaluated the Chinook salmon conventional hatchery program for the Lostine River.

BPA Project 1998-016-00 (Escapement and Productivity of Spring Chinook and Steelhead (ODFW)) provided basin-wide status and trend data for anadromous salmonids in the John Day River Basin.

BPA Project 2002-030-00 (Salmon and Steelhead Progeny Markers (CTUIR)) took fin clips from returning adult steelhead broodstock held at the Minthorn Springs facility and juveniles collected for otolith extraction. Genetic information gathered is used for determining maternal origins in validation of a transgenerational mark.

BPA Project 2002-053-00 (Asotin Creek Salmon Population Assessment (WDFW)) collected DNA samples from adult steelhead and adult Chinook salmon when captured incidentally.

BPA Project 2003-054-00 (Evaluate the Relative Reproductive Success of Hatchery-Origin and Wild-Origin Steelhead Spawning Naturally in the Hood River (Oregon State University)) used gene expression profiling to identify potential traits that differ genetically between hatchery and wild fish.

BPA Project 2003-063-00 (Natural Reproductive Success and Demographic Effects of Hatchery-Origin Steelhead in Abernathy Creek, Washington (WDFW)) evaluated relative reproductive success between hatchery-origin and natural-origin steelhead trout, simultaneously investigating methods of operating a conservation hatchery and the effectiveness of integrated artificial production programs toward supporting naturally spawning populations.

BPA Project 2007-404-00 (Spring Chinook Captive Propagation-Oregon (ODFW, NPT)) maintained captive broodstock and evaluated growth, health, survival to maturation, age and size at maturation, fecundity and other characteristics for individuals of each brood year and of each experimental treatment group (eggs vs. parr and fully vs. partially covered tanks).

BPA Project 2008-907-00 (Genetic Assessment of Columbia River Stocks (CRITFC)) combined four interrelated projects from the Accords that address Single Nucleotide Polymorphism Discovery, Genetic Baseline Expansion, GSI to Evaluate Catch, and GSI of fishes passing Bonneville Dam.

BPA Project 2009-005-00 (Influence of Environment and Landscape on Salmon and Steelhead Genetics (CRITFC)) determined correlation of watershed characteristics such as elevation, barriers, migration distance, and temperature to genetic structure of Chinook salmon and steelhead populations, and tests for association of single nucleotide polymorphisms and gene expression results with traits of interest that are related to recovery of steelhead populations.

BPA Project 2010-026-00 (Chinook and Steelhead Genotyping for GSI at Lower Granite Dam (IDFG)) developed and maintained Columbia River basin-wide single nucleotide polymorphism baselines for steelhead and Chinook salmon as well as develops and implements GSI techniques for Snake River steelhead and Chinook salmon monitoring.

BPA Project 2010-028-00 (Estimate Adult Steelhead Abundance in Small Streams Associated with Tucannon & Asotin Populations (WDFW)) collected tissue samples for inclusion in Snake Basin genetic characterization of steelhead for future run reconstruction estimates at Lower Granite Dam (coordinated with Project 2010-026-00).

BPA Project 2010-030-00 (Provide Viable Salmonid Population Estimates for Yakima Steelhead MPG (YN,WDFW)) conducted biological and DNA sampling at the Chandler juvenile, and Prosser and Roza adult monitoring facilities, as well as analysis of steelhead DNA samples to improve the genetic profile for all four populations in the MPG.

BPA Project 2010-031-00 (Snake River Chinook and Steelhead Parental Based Tagging (IDFG)) genotyped approximately 16,500 samples (annually) to create the first parental genetic baselines for hatchery steelhead and Chinook salmon in the Snake River basin.

BPA Project 2010-032-00 (Imnaha River Steelhead Monitoring (NPT)) collected tissue samples from adult to describe the genetic stock structure, gene flow between spawning aggregates, and determine effective population size.

RPA Action 63 – Monitor Hatchery Effectiveness

The Action Agencies will continue to fund selected monitoring and evaluation of the effectiveness of Hatchery Actions. The evaluation of hatchery projects will be coordinated with the Tributary Habitat monitoring and evaluation program.

1. *Determine the effect that safety-net and conservation hatchery programs have on the viability and recovery of the targeted populations of salmon and steelhead. (Initiate in FY 2007–2009 Projects).*

For this subaction, several projects continue to be funded to support RME for populations associated with the implementation of RPA Actions 41 and 42 (Implement Conservation Programs to Build Genetic Resources, Reduce Short-term Extinction Risk and Assist in Promoting Recovery), see tables 7 and 8 in the RPA.

Information needed to support this RPA subaction includes two categories of RME: 1) population status and trend and 2) hatchery effectiveness monitoring. Metrics such as abundance and productivity by origin (i.e. hatchery or natural), stray rates of hatchery-origin fish, and life history characteristics enable managers to understand how the hatchery program is affecting the VSP parameters that indicate viability, and ultimately recovery.

In the following four paragraphs, a summary of results from selected projects covering this RPA subaction are discussed:

Several studies indicate that reduced reproductive success of hatchery fish is consistent between our conventional gene frequency monitoring and parentage studies. Currently funded studies are evaluating some of the factors that contribute to reduced fitness of hatchery fish such as the work occurring in project 1989-096-00.

In four populations of Snake River spring/summer Chinook salmon there was a general reduction in smolts per spawner at higher spawner numbers, indicating a potential density dependent relationship (1992-026-04). This relationship is seen in the supplemented populations (Catherine Creek, Grande Ronde Upper Mainstem, and Lostine River), and the unsupplemented population (Minam River).

There was a net increase in total abundance (i.e., natural origin and supplementation origin combined) for each year associated with the supplementation program in Johnson Creek, and that the boost has been on an upward trajectory with each additional year of operation. This finding was also consistent with output from our simulation model. There was an upward trajectory with our natural abundance, albeit lower than that observed with total abundance (1996-043-00). The study established that hatchery rearing of wild fish resulted in more wild-born adults in the next two generations than if fish had been left to spawn naturally. The demographic boost provided by the hatchery (brood years 1998; 2000-2003) appears to be continued into the fifth generation. Results from the study suggest that the use of management practices similar to those utilized by the JCAPE project (e.g., using 100 percent local, wild-origin brood stock) can provide a boost to the population size with minimal fitness impacts in Johnson Creek (1996-043-00).

Hatchery releases increased fish distribution and abundance in vacant or under-seeded habitat total abundance in the Lostine River and adult outplants into Bear Creek and Wallowa River. There is some evidence to suggest that hatchery production fish may have altered life-history characteristics when compared to natural production in the Grand Ronde River. Hatchery fish age-at-return was biased to more jacks than naturally produced fish. Juvenile out-migration was earlier for hatchery smolts than natural smolts, and natural juveniles have more diverse out-migration strategies and timing (1998-007-02).

Snake River Spring/Summer Chinook ESU and Steelhead DPS

BPA Project 1989-096-00 (Genetic Monitoring and Evaluation Program for Salmon and Steelhead) provides gene frequency monitoring for Snake River Basin Chinook and steelhead, and has quantified and described genetic diversity in natural populations and hatchery brood stocks. This project also investigates the structure of populations, genetic relationships between populations, and documented the stability of those connectivity patterns in the presence of various levels of hatchery straying as well as changes in overall abundance through time. Reproductive success of some of the Chinook and steelhead populations is also measured through this project.

BPA Project 1989-098-00 (Salmon Studies in Idaho Rivers-Idaho Department of Fish and Game) focused on collecting information on the Snake River Chinook ESU (Salmon River, which are listed under ESA and Clearwater River Chinook, which are not listed) to determine the benefits and risks of hatchery supplementation.

BPA Project 1996-043-00 (Johnson Creek Artificial Propagation Enhancement) has been ongoing since 1996 to evaluate the life cycle of natural- and hatchery-origin supplementation spring/summer Chinook salmon from Johnson Creek (part of the

Snake River spring/summer Chinook ESU) to quantify key performance measures associated with abundance, survival-productivity, distribution, and diversity metrics.

BPA Project 2010-057-00 (B-Run Steelhead Supplementation Effectiveness Research) research is linked to RPA Action 41, which focuses on B-Run steelhead supplementation effectiveness research to better address the abundance, productivity, spatial structure, and diversity of B-Run steelhead in the Clearwater River Basin.

BPA Project 1992-026-04 (Grande Ronde Early Life History of Spring Chinook and Steelhead) focused on the Snake River ESU and DPS on the Grande Ronde River populations of Chinook salmon and summer steelhead. The objectives of this study are to estimate egg-to-migrant survival for spring Chinook salmon and migrant survival for steelhead, estimate the smolts-per-spawner for four populations of spring Chinook salmon, and assess stream conditions in selected study streams.

BPA Project 1998-007-02 (Grande Ronde Supplementation Operation and Maintenance, and Monitoring and Evaluation on Lostine River) was initiated to assess status and trends of natural- and hatchery-origin spring Chinook salmon using life history, survival, and productivity performance measures for the Lostine River and the SRCP.

BPA Projects 1998-007-03 (Grande Ronde Supplementation Operation and Maintenance on Catherine Creek/Upper Grande Ronde River) and 1998-007-04 (Grande Ronde Spring Chinook on Lostine/Catherine Creek/ Upper Grande Ronde Rivers) reported on fish culture activity (holding and spawning of adults, rearing juveniles, fish health monitoring, and redd surveys) for these programs, which are run in conjunction with the LSRCP. These projects are associated with this subaction because they also collect spawner (redd count) information.

BPA Project 1998-016-00 (Escapement and productivity of spring Chinook and steelhead) collected information on the status, trends, and distribution of spawning activity, juvenile salmonids, and aquatic habitat conditions within the John Day River Basin. This project also collected information on steelhead (mid-Columbia River steelhead DPS) and Chinook salmon (non-listed mid-Columbia Chinook ESU) in the John Day River. This project is important because there are no hatchery fish released into the basin and therefore this basin can be as a comparison reference condition.

BPA Project 2007-083-00 (Grande Ronde Supplementation Monitoring and Evaluation on Catherine Creek/Upper Grande Ronde River) monitored and evaluated supplementation of endemic spring Chinook salmon in Catherine Creek and the upper Grande Ronde River, which are part of the Snake River spring/summer Chinook ESU. This study continued to collect important information on abundance, productivity, and life history attributes of Snake River Chinook ESU and steelhead DPS.

BPA Project 2010-042-00 (Tucannon Expanded PIT Tagging) is focused on increasing the detection of PIT-tagged steelhead (Snake River steelhead DPS) and spring Chinook salmon (Snake River spring/summer Chinook ESU) that enter the river upon return as adults. Increased detection will assist managers in determining abundance and origin of primarily steelhead (Chinook redd count and carcass surveys are much more effective than steelhead surveys) entering the Tucannon River and detect fish that may stray into the river.

Snake River Sockeye Salmon ESU

BPA Project 2007-402-00 (Snake River Sockeye Salmon Captive Broodstock) is intended to utilize captive broodstock technology to conserve the population's unique genetics of the Snake River sockeye salmon ESU. The long-term goal is to reach interim abundance guidelines for delisting and provide for sport and tribal harvest.

Lower Columbia River Chum Salmon ESU

BPA Project 2008-710-00 (Development of an Integrated strategy for Chum Salmon Restoration in the tributaries below Bonneville Dam) goals include: (1) reintroduction of chum salmon (that are part of the lower Columbia River chum salmon ESU) into Duncan Creek by providing off-channel high-quality spawning and incubation areas; and (2) simultaneously evaluation of natural recolonization, direct adult supplementation, and hatchery fed-fry supplementation.

Basin-wide

Efforts to facilitate the formation of a regional workgroup (currently designated the Columbia River Hatchery Effects Evaluation Team (CRHEET)) to coordinate monitoring of regional hatchery effectiveness, as well as implementation of the recommendations made by the Ad Hoc Supplementation Workgroups are on hold while NOAA Fisheries completes the ESA consultations on FCRPS mitigation hatcheries (see AMIP Amendment 6 of this document).

2. *Determine the effect that implemented hatchery reform actions have on the recovery of targeted salmon and steelhead populations.*

For this subaction, the projects are being funded to support RME for populations associated with the implementation of RPA Action 40 (Ensure that Hatchery Programs Funded by the FCRPS Action Agencies as Mitigation for the FCRPS are not Impeding Recovery of ESUs or steelhead DPSs).

Information needed to support this RPA subaction includes two categories of RME: 1) population status and trend, and 2) hatchery-reform monitoring. Metrics such as abundance and productivity by origin (i.e., hatchery or natural), stray rates of hatchery-origin fish, survival between treatments, and life history characteristics enable managers to understand how well hatchery-reform program is affecting the VSP parameters that indicate viability, and ultimately, recovery. Progress is being made in understanding the effect that implemented hatchery reform actions are having in the recovery of targeted salmon and steelhead populations through the projects below.

Basin-wide

BPA Project 2002-031-00 (Growth Modulation in Salmon Supplementation) has focused on quantifying mini-jack rates prior to release in hatchery programs throughout the Columbia basin and, through laboratory and hatchery scale experimentation and developed hatchery reform protocols to control production of unnaturally high rates. Reduction in mini-jack production leads to direct increases in smolt production, reductions in domestication selection, higher adult return rates, hatchery cost savings, reduced negative ecological interactions (competition, predation) between hatchery fish and wild fish. One of the major findings of this RME project, to date, is the difference in mini-jack rates between segregated and integrated spring Chinook salmon hatchery programs. This work does not represent a controlled laboratory experiment (see future recommendation below), but the results suggest that there are differences between these two broadly defined hatchery management strategies in terms of their potential to produce mini-jacks. These data are currently being compiled in a peer-reviewed publication being submitted in FY 2015 with management recommendations expected specific to RPA 63.2 related to the impacts of altering ponding date on life history composition of hatchery fish.

Upper Columbia River Steelhead DPS

BPA Project 1993-056-00 (Advance Hatchery Reform Research) is currently focused on assessing whether steelhead raised at the Winthrop National Fish Hatchery (Upper Columbia steelhead DPS) over a two-year period perform better (survival and reproductive success) than steelhead raised in a typical one-year period. In addition, laboratory studies are determining the physiological and behavioral mechanisms that affect body size, smolt development, age-at-maturity, and rates of residualism, migration, and survival for the various groups of fish.

In the Methow basin, beginning in 2015 an evaluation of smolt-to-adult return rates, reproductive traits, and assessments of the relative fitness of S1 and S2 spawners and the survival of their progeny (2015-2018) will address whether PHOS levels recommended for conventional steelhead hatcheries need to be adjusted (up or down) for local broodstock programs. The effects of transitioned (local broodstock) hatchery programs on VSP parameters of natural populations require a full assessment of the smolt quality and adult fitness parameters. Once complete, our evaluation will provide information to help estimate VSP parameters, and will provide guidance that informs implementation of reform actions in other hatcheries transitioning to local steelhead broodstocks (1993-056-00). The results from this project are being prepared for peer-reviewed scientific publications and the data are regularly presented at regional workshops and conferences.

Snake River Spring Summer Chinook ESU and Steelhead DPS

BPA Project 2010-042-00 (Tucannon Expanded PIT Tagging) and 2010-050-00 (Evaluation of the Tucannon Endemic Program), addressed this RPA subaction regarding steelhead and Chinook populations in the Tucannon River (Snake River spring summer Chinook ESU and steelhead DPS). See additional information under RPA 63.1 above.

RPA Action 64 – Investigate Hatchery Critical Uncertainties

The Action Agencies will continue to fund selected research directed at resolving artificial propagation critical uncertainties:

1. *Continue to estimate the relative reproductive success of hatchery-origin salmon and steelhead compared to reproductive success of their natural-origin counterparts for ESA-listed spring/summer Chinook population in the Upper Grande Ronde, Lostine River, and Catherine Creek; listed spring Chinook in the Wenatchee River; and listed steelhead in the Hood River.*

Continue to fund the ongoing relative reproductive success feasibility study for Snake River fall Chinook to completion in 2009.

Since the early 2000s, several studies have been funded through BPA's Fish & Wildlife Program to estimate the relative reproductive success (RRS) of hatchery-origin salmon and steelhead compared to reproductive success of their natural-origin counterparts. RRS studies have been conducted for ESA-listed spring/summer Chinook population in the Upper Grande Ronde, Lostine River, and Catherine Creek; listed spring Chinook in the Wenatchee River; and listed steelhead in the Hood River and in the Methow Basin. These studies have attempted to address a key uncertainty for evaluating how hatchery supplementation programs. are contributing to the recovery of listed populations. In cases where hatchery origin spawners have reduced reproductive success, researchers are beginning to investigate the mechanisms that may be contributing factors. Traits such as body size, egg size, migration and spawning time, spawning location, and behavioral characteristics have been studied and some of these factors have been found to contribute lower RS in some studies. Through improved understanding of the mechanisms that can improve reproductive success of hatchery origin fish, then adaptive management and hatchery reform can guide conservation hatchery practices to improve RRS of fish that are meant to supplement the natural population in the wild.

Snake River Spring/Summer Chinook ESU and Steelhead DPS

BPA Project 1989-096-00 (Genetic Monitoring and Evaluation Program for Salmon and Steelhead) collected information on adult returns, age class, and genetic pedigree analysis that enabled the researchers to estimate reproductive success in hatchery- and natural-origin steelhead in Little Sheep Creek and spring/summer Chinook salmon in the Lostine River and Catherine Creek.

BPA Project 2007-083-00 (Grande Ronde Supplementation Monitoring and Evaluation on Catherine Creek/Upper Grande Ronde River) continued to monitor and evaluate supplementation of endemic spring Chinook salmon in Catherine Creek and the upper Grande Ronde River, which are part of the Snake River spring/summer Chinook ESU. This study continues to collect important information on abundance, productivity, and life history attributes of Snake River Chinook ESU and steelhead DPS.

Upper Columbia Spring Chinook ESU

BPA Project 2003-039-00 (Monitoring and Evaluation Reproductive Success and Survival in Wenatchee River) continued to quantitatively evaluate the Relative Reproductive Success (RRS) of naturally spawning hatchery- and natural-origin spring Chinook salmon in the Wenatchee River (upper Columbia River spring Chinook ESU). Research is currently focused on the mechanisms that may be causing the reduced RRS of hatchery-origin fish compared to natural-origin fish.

Lower Columbia River Steelhead DPS

BPA Project 2003-054-00 (Evaluate the Relative Reproductive Success of Hatchery-Origin and Wild-Origin Steelhead Spawning Naturally in the Hood River) evaluated the RRS of hatchery- versus natural-origin steelhead in the Hood River (lower Columbia River steelhead DPS). Information collected primarily consisted of genetic sampling of returning adults passing Powerdale Dam (now removed). In 2014, three peer-reviewed articles were published based on the results of this research.

2. *Determine if properly designed intervention programs using artificial production make a net positive contribution to recovery of listed populations.*

The intent of this subaction is similar to RPA Subaction 63.1. For this subaction, several projects continue to be funded to support RME for populations that are not associated with the implementation of RPA Actions 41 and 42 (Implement Conservation Programs to Build Genetic Resources, Reduce Short-term Extinction Risk and Assist in Promoting Recovery). Generally, the intervention programs using artificial production have increased adult abundance, at least in the short term while supplementation using local broodstock is occurring.

Information needed to support this RPA subaction includes two categories of RME: 1) population status and trend, and 2) hatchery effectiveness monitoring. Metrics such as abundance and productivity by origin (i.e., hatchery or natural), stray rates of hatchery-origin fish, and life history characteristics enable managers to understand how well the hatchery program is affecting the VSP parameters that indicate viability, and ultimately recovery.

Snake River Fall Chinook ESU

BPA Project 1983-350-03 (Nez Perce Tribal Hatchery Monitoring and Evaluation) includes the monitoring and evaluation of hatchery and natural fish. This project is involved in PIT tagging, weir operation and spawning ground surveys, and screw trap monitoring among other monitoring and evaluation activities.

BPA Project 1990-005-00 (Umatilla Hatchery Monitoring and Evaluation) concerns fall Chinook salmon (Snake River fall Chinook ESU; this project also tracks Mid-Columbia spring/summer Chinook salmon and Mid-Columbia steelhead). The primary goal of this project is to monitor and evaluate different rearing and release scenarios by documenting travel time and survival from release to Three Mile Dam (Umatilla River Basin) and Columbia River dams. In addition, straying of adult returns outside the Umatilla Basin is also documented.

Snake River Spring/Summer Chinook ESU and Steelhead DPS

BPA Project 2010-031-00 (Snake River Chinook and Steelhead Parental Based Tagging) continued to develop and evaluate a new genetic technology called Parental Based Tagging (PBT), that can serve as a versatile tool for mass marking of steelhead and Chinook salmon in the Snake River Basin (Snake River spring/summer Chinook ESU and steelhead DPS). It is anticipated that this tool will have the capability to address aspects of hatchery evaluation and reform, salmonid life history, harvest patterns, and trait heritability.

BPA Project 1997-030-00 (Chinook Salmon Adult Abundance Monitoring) continued to monitor escapement of natural-origin spring/summer Chinook salmon (Snake River spring/summer Chinook ESU) in the Secesh River and steelhead (Snake River DPS) in Joseph Creek. Escapement in the Secesh River is estimated using dual frequency identification sonar (DIDSON) technology. Validation monitoring of DIDSON target counts with underwater optical cameras occurs for the purpose of species identification. The project is also collecting escapement, origin, age structure, sex composition, and population life history information on Joseph Creek steelhead by capturing adult steelhead by use of a floating weir.

BPA Project 1997-015-01 (Imnaha River Smolt Monitoring) continued to monitor spring Chinook salmon and steelhead (Snake River spring/summer Chinook ESU and steelhead DPS) emigrating from the Imnaha River and report the real-time information to the FPC.

BPA Project 2010-032-00 (Imnaha River Steelhead Adult Monitoring Project) continued to provide status information on Snake River steelhead in the Imnaha River Subbasin by collecting information to inform the VSP parameters. In addition to population viability monitoring, a sub-goal is to ensure that the information can be used to inform the co-managers on potential fisheries.

Mid-Columbia Steelhead DPS

BPA Project 2000-039-00 (Walla Walla River Basin Monitoring and Evaluation) continued to provide information on the reintroduction of spring Chinook salmon (non-listed hatchery stock) through a hatchery program and natural-origin steelhead (Mid-Columbia DPS) by assessing population status.

BPA Project 2007-299-00 (Investigation of Relative Reproductive Success of Stray Hatchery & Wild Steelhead & Influence of Hatchery Strays on Natural Productivity in Deschutes) continued to assess the effects that naturally spawning hatchery steelhead have on the viability of their wild steelhead counterparts in the Deschutes River Basin (mid-Columbia steelhead DPS).

BPA Project 1990-005-00 (Umatilla Hatchery Monitoring and Evaluation concerns steelhead (mid-Columbia steelhead DPS) continued to monitor and assess juvenile migration timing and survival of hatchery smolts to Three Mile Falls Dam and Columbia River dams.

Lower Columbia River Chinook ESU and Steelhead DPS

BPA Project 1988-053-04 (Hood River Pelton Ladder Evaluation Studies) continued to collect information related to the Hood River Production Program. This project collects information to estimate juvenile production with screw traps; harvest (all species); natural production of steelhead; natural production of cutthroat; natural production of bull trout; migration timing and other life history traits for adult summer and winter steelhead (lower Columbia River steelhead DPS), jack and adult spring and fall Chinook salmon, and coho. For hatchery production, for broodstock information collection includes; number of juveniles released and post release survival.

BPA Project 1988-053-15 (Parkdale NOAA Fisheries Comparative Hatchery Study) continued to implement one of the Hood River Production Program’s objectives to “provide co-managers with the best available information for determining a long-term biologically sound and cost-effective spring Chinook salmon (lower Columbia River Chinook ESU) production strategy for the Hood River Basin that balances harvest needs with ecological considerations.” The objective of this evaluation is to conduct a multi-year (2008–2018) comparative study of Hood River spring Chinook reared at three different hatchery facilities prior to being moved to the West Fork Hood River for final acclimation and release.

BPA Project 2003-063-00 (Natural Reproductive Success and Demographic Effects of Hatchery-Origin Steelhead in Abernathy Creek, Washington) continued to assess natural reproductive success and mean relative fitness of hatchery-origin and natural-origin steelhead (lower Columbia River steelhead DPS) in Abernathy Creek, Washington, and to assess the overall demographic effects of hatchery fish.

Mid-Columbia Spring Chinook ESU (Non-listed)

BPA Project 1990-005-00 (Umatilla Hatchery Monitoring and Evaluation) concerns spring Chinook salmon (non-listed hatchery stock) continued to monitor and assess juvenile migration timing and survival of hatchery smolts to Three Mile Falls Dam and Columbia River dams.

BPA Project 1995-063-25 (Yakima River Monitoring and Evaluation-YKFP) focuses on Yakima River spring Chinook salmon (mid-Columbia spring Chinook salmon ESU) which are not listed under the ESA. The goal of the project is to monitor, evaluate, and conduct research related to the YKFP. The project includes research occurring over many facets of artificial supplementation. The project has targeted research regarding relative reproductive success, ecological interactions between non-target taxa of concern and hatchery-origin salmon, effects of domestication on predation and competitive dominance, reproductive ecology, and effects of predation on natural production.

BPA Project 2008-458-00 (Upper-Columbia River Steelhead Kelt Reconditioning Project) is a kelt reconditioning project within the UCR (Upper Columbia River steelhead DPS) to test whether the abundance of naturally-produced UCR steelhead on natural spawning grounds can be increased through the use of long-term kelt reconditioning methods. Kelts have been collected for the project through live-spawning of natural-origin steelhead broodstock, the application of temporary tributary traps, and collection at Rock Island Dam. Long-term reconditioning methods consisting of feeding and treatment regiments were applied for approximately 6 months. Kelts were returned to their rivers of origin (or near their respective capture sites) following reconditioning. Ongoing monitoring and evaluation efforts have focused on comparing movement and survival between reconditioned kelts and maiden spawners and evaluating reproductive success of reconditioned kelts.

Multiple DPS of Steelhead

BPA Project 2007-401-00 (Kelt reconditioning and reproductive success evaluation research) provides research, monitoring, and evaluation (RME) of kelt reconditioning and ultimately reproductive success. Fish used as part of this project originate from Yakima River Basin (mid-Columbia River steelhead DPS) and the Snake River Basin (Snake River steelhead DPS). The objectives are to evaluate methodologies to produce viable artificially reconditioned repeat steelhead spawners and to determine the productivity of repeat spawners.

Multiple ESUs of Chinook

BPA Project 2002-031-00 (Growth modulation in salmon supplementation) continued to compare the physiology and development of naturally rearing wild and hatchery-reared salmon in the mid-Columbia and Snake River basins. This project has focused on quantifying mini-jack rates prior to release in hatchery programs throughout the Columbia basin and, through laboratory and hatchery scale experimentation, developed hatchery reform protocols to control unnaturally high rates of mini-jack production.

3. *In collaboration with the other entities responsible for steelhead mitigation in the Methow River, BPA will fund a new relative reproductive success study for ESA-listed steelhead in the Methow River. BPA will also fund a new relative reproductive success study for listed fall Chinook in the Snake River. NOAA Fisheries will provide technical assistance to the Action Agencies in development of conceptual study designs suitable for use by the Action Agencies in obtaining a contractor to implement the new studies.*

For this subaction, projects are being funded to support RME for the specific populations described within the subaction. Even though RRS has not been estimated for Snake River fall Chinook salmon, as directed under this subaction, information has been collected that shows little genetic differentiation between natural- and hatchery-origin fall Chinook. In addition, BPA Project 2003-060-00 (Evaluate the Relative Reproductive Success of Wild and Hatchery Origin Snake River Fall Chinook Spawners Upstream of Lower Granite Dam) documented reproductive success of hatchery-origin fall Chinook in terms of juvenile production. Implementing the original intent of this subaction was not possible due to logistical issues (e.g., not capturing enough juveniles and not genotyping a large enough percentage of the adults passing Lower Granite Dam). Methods are currently being developed to estimate reach specific natural origin (wild) abundance. Together these results may enable generation of pHOS estimates and potentially monitoring of reach specific productivity.

For Methow River steelhead, the project (BPA Project 2010-033-00, Study Reproductive Success of Hatchery and Natural Origin Steelhead in the Methow) remains in its early phases. However, early indications are that the life history characteristics of the hatchery- and natural-origin populations are similar. This finding is not surprising considering that hatchery-origin fish have dominated the spawning grounds in the Methow River Basin for decades.

Information needed to support this RPA subaction includes uncertainty research, including metrics such as abundance, origin, genotype, and age structure.

In the following section, a summary of the projects that are covering this RPA subaction is discussed for each population.

Snake River Fall Chinook ESU

BPA Project 2003-060-00 (Evaluate the Relative Reproductive Success of Wild and Hatchery Origin Snake River Fall Chinook Spawners Upstream of Lower Granite Dam) continued to address components of this RPA subaction. After it was determined in 2011 that BPA Project 2003-060-00 (Evaluate the Relative Reproductive Success of Wild and Hatchery Origin Snake River Fall Chinook Spawners Upstream of Lower Granite Dam) would be infeasible to implement at this time, a letter dated February 2, 2012, was sent to BPA from NOAA Fisheries concerning monitoring needs associated with satisfying RPA Actions 64 and 65 as they relate to Snake River fall Chinook salmon. The monitoring actions associated with the letter are consistent with the two HGMPs that cover Snake River fall Chinook salmon, from the WDFW and the NPT. The letter from NOAA Fisheries identifies alternative actions that will satisfy the states that the intent of RPA Actions 64 and 65 with regards to Snake River fall

Chinook. Research questions addressed in this project include investigation of release site fidelity and fall back at Lower Granite Dam.

Upper Columbia Steelhead DPS

BPA Project 2010-033-00 (Study Reproductive Success of Hatchery and Natural Origin Steelhead in the Methow) continued to monitor and evaluate reproductive success of Methow River steelhead (upper Columbia River steelhead DPS) and a suite of demographic characteristics. Differences in the run-timing, spawn-timing, age-composition, length-at-age, sex-ratio, and spawning distribution are measured between hatchery- and natural-origin fish that may explain differences in relative reproductive success if it occurs. The RRS study in the Twisp River, tributary to the Methow River, began a few years ago. There are three objectives: (1) directly measure the relative reproductive success (RRS) of hatchery and wild steelhead in the natural environment using a DNA pedigree approach; (2) determine the degree to which any differences in RRS between hatchery and wild steelhead can be explained by measurable biological characteristics such as run timing, morphology, spawn timing, or spawning location; and (3) estimate the relative fitness of hatchery-lineage steelhead after they have experienced an entire generation in the natural environment. This project is ongoing and they are currently collecting data to address the objectives stated above.

RPA Action 65 – Investigate Hatchery Critical Uncertainties

The Action Agencies will fund research directed at resolving critical uncertainties:

1. *In the mainstem Snake River above the Lower Granite Dam, estimate the effectiveness/fitness in nature of hatchery-origin fall Chinook salmon from federally funded Snake River hatchery programs relative to natural origin Snake River fall Chinook.*

Information needed to support this RPA subaction includes hatchery effectiveness monitoring. Metrics such as abundance and productivity by origin (i.e., hatchery or natural), stray rates, and life history characteristics enable managers to understand how well the hatchery program is affecting natural-origin fish. Monitoring of this population's status and trends and response to multiple management actions and anthropogenic impacts is accomplished via much collaboration from the projects below as well as others.

Supplementation of fall Chinook salmon above Lower Granite Dam since 1996 has increased natural and hatchery escapement in the Snake River Basin from less than 1,000 adults/year for 20 years after Lower Granite's construction in 1975 to over 60,000 adults in 2013 and 2014. The 2015 composition of 58,363 estimated adults returning to LGR included 27.4 percent natural, 47.5 percent unclipped hatchery and 25.1 percent clipped hatchery. The composition of hatchery fall Chinook adults returning to and escaping above LGR in 2015 consisted of 42 percent AD clipped and 58 percent unclipped fish. Radio tagging, parental based tagging, redd surveys, and multistage life cycle modeling for the Snake River basin fall Chinook Salmon ESU are being conducted to address this RPA subaction.

Snake River Fall Chinook ESU

BPA Project 1983-350-03 (Nez Perce Tribal Hatchery Monitoring and Evaluation) includes the monitoring and evaluation of hatchery and natural fish. This project is involved in PIT tagging, weir operation and spawning ground surveys, and screw trap monitoring among other monitoring and evaluation activities.

BPA Project 1991-029-00 (RME of emerging issues and measures to recover the Snake River fall Chinook salmon ESU) continued to collect data that is intended to inform the management and recovery of fall Chinook salmon (Snake River fall Chinook ESU). Research includes monitoring of redd counts, spawning site use, parr growth and survival, post-release performance of hatchery-origin fish through the Snake and Columbia rivers, comparison of different hatchery release strategies, and growth and food habits of Snake River fall Chinook salmon.

BPA Project 2012-013-00 (Snake River Fall Chinook Monitoring and Evaluation) expands monitoring of Snake River fall Chinook (Snake River fall Chinook salmon ESU) adult distribution by tracking the fidelity of returning adult hatchery-origin fish to release sites. This information will inform estimates of pHOS (the percentage of fish on the spawning grounds that are of hatchery origin) for specific spawning aggregates within the entire Snake River Basin. In addition, information on the fallback rate of adults to areas downstream of Lower Granite Dam will help refine estimates of adult escapement upstream of Lower Granite Dam.

2. *Estimate fall Chinook hatchery program effects on the productivity of the fall Chinook salmon ESU.*

To address the siginifican extinction risk for the Snake River fall Chinook salmon ESU, three integrated mitigation/conservation hatchery programs were initiated (Lyons Ferry Hatchery, Nez Perce Tribal Hatchery, and Idaho Power Company). The Snake River fall Chinook ESU is comprised of a single extant population. It is identified as priority for fish in and fish out monitoring in the 2014-2018 Implementation Plan. Monitoring of this population's status and trends and response to multiple management actions and anthropogenic impacts is accomplished via much collaboration from the projects below as well as others.

Supplementation of fall Chinook salmon above Lower Granite Dam since 1996 has increased natural and hatchery escapement in the Snake River Basin from less than 1,000 adults/year for 20 years after Lower Granite's construction in 1975 to over 60,000 adults in 2013 and 2014. The 2015 composition of 58,363 estimated adults returning to LGR included 27.4 percent natural, 47.5 percent unclipped hatchery and 25.1 percent clipped hatchery. Radio tagging, parental based tagging, redd surveys, and multistage life cycle modeling for the Snake River basin fall Chinook Salmon ESU are being conducted to address this RPA subaction.

BPA Project 1991-029-00 (RME of emerging issues and measures to recover the Snake River fall Chinook salmon ESU) conducted RME associated with management and recovery of fall Chinook salmon (Snake River fall Chinook ESU). Research that addresses this RPA focuses on (1) numeric and habitat use responses by natural- and hatchery-origin spawners, (2) phenotypic and numeric responses by natural-origin juveniles, and (3) predator responses in the Snake River upper and lower reaches as abundance of adult and juvenile fall Chinook salmon increased in the last 10 years.

BPA Project 1983-350-03 (Nez Perce Tribal Hatchery Monitoring and Evaluation) includes the monitoring and evaluation of hatchery and natural fish. This project is involved in PIT tagging, weir operation and spawning ground surveys, and screw trap monitoring among other monitoring and evaluation activities.

BPA Project 1998-010-04 (Monitor and Evaluate Performance of Juvenile Snake River Fall Chinook Salmon from Fall Chinook Acclimation Project) evaluated the success of fall Chinook supplementation above Lower Granite Dam and informs management decisions for the future conservation and perpetuation of naturally spawning populations of fall Chinook salmon in the Snake and Clearwater Rivers above Lower Granite Dam.

BPA Project 2012-013-00 (Snake River Fall Chinook Monitoring and Evaluation) expands monitoring of Snake River fall Chinook (Snake River fall Chinook salmon ESU) adult distribution by tracking the fidelity of returning adult hatchery-origin fish to release sites. This information will inform estimates of pHOS for specific spawning aggregates within the entire Snake River Basin. In addition, information on the fallback rate of adults to areas downstream of Lower Granite Dam will help refine estimates of adult escapement upstream of Lower Granite Dam.

3. *NOAA Fisheries will provide technical assistance to the Action Agencies in development of conceptual study designs suitable for use by the Action Agencies in obtaining a contractor to implement new studies.*

NOAA Fisheries and other regional technical experts provided technical assistance to BPA in 2010 to support development of targeted solicitations for the new Snake River fall Chinook salmon relative reproductive success study and any additional study or studies needed to estimate the effects of the fall Chinook hatchery programs on productivity of the ESU. In addition, there has been associated monitoring and evaluation under development in order to meet and satisfy research needs identified in the HGMP. The Action Agencies and NOAA Fisheries have agreed that there are necessary prerequisite studies which need to be conducted prior to the implementation of a relative reproductive success study or other studies of hatchery effects in Snake River fall Chinook.

RPA Action 66 – Monitor and Evaluate the Caspian Tern Population in the Columbia River Estuary

The Action Agencies will monitor the tern population in the estuary and its impacts on outmigrating juvenile salmonids, as well as the effectiveness of the Caspian tern management plan.

One BPA project was continued to fully address this RPA subaction. BPA Project 1997-024-00 (Avian Predation on Juvenile Salmonids) provided for the monitoring of the Caspian tern colony on East Sand Island. Colony size, reproduction rates, diet composition, and predation rates were monitored to determine the effect of the colony on juvenile salmon.

Corps study AVS-P-08-02 continued to monitor the effectiveness of Caspian tern habitat creation / enhancement at six alternate sites in interior Oregon and Northern California in 2015.

RPA Action 67 – Monitor and Evaluate the Double-Crested Cormorant Population in the Columbia River Estuary

The Action Agencies will monitor the cormorant population in the estuary and its impacts on outmigrating juvenile salmonids and develop and implement a management plan to decrease predation rates, if warranted.

In 2015, the double-crested cormorant colony size on East Sand Island was monitored via aerial surveys of the island.

RPA Action 68 – Monitor and Evaluate Inland Avian Predators

The Action Agencies will monitor avian predator populations in the Mid-Columbia River and evaluate their impacts on outmigrating juvenile salmonids and develop and implement a management plan to decrease predations rates, if warranted.

The final Inland Avian Predation Management Plan developed by the Corps and Reclamation, was completed and released in January 2014 with initial Phase 1 actions initiated at the Caspian tern colony at Goose Island (Potholes Reservoir) in 2014 and Phase 2 actions additionally incorporating Crescent Island dissuasion and out of basin actions in 2015. Monitoring and evaluation of avian predation on the Columbia Plateau by the Corps and Reclamation focused on Caspian tern colonies in 2015 to evaluate effects associated with implementing the Inland Avian Predation Management Plan (IAPMP). Additionally, recently modified habitat in Don Edwards National Wildlife Refuge (San Francisco Bay) was evaluated for tern use in 2015 as part of implementing the IAPMP and estuary tern EIS. Reports discussing 2015 IAPMP implementation results were finalized in March 2015 (Collis et al. 2016, Hartman et al. 2016).

RPA Action 69 – Monitoring Related to Marine Mammal Predation

1. *Estimate overall sea lion abundance immediately below Bonneville Dam. (Initiate in FY 2007–2010 Projects).*

   From January 11 to May 31, 2015, the Corps continued to visually monitor the abundance of California and Steller sea lions in the Bonneville Dam tailrace observation area. In addition, BPA Project No. 2008-004-00 (Sea Lion Nonlethal Hazing and Monitoring) estimated general sea lion abundance while conducting in-river hazing on sea lions. See the discussion in Section 1 of this report for more detail.

2. *Monitor the spatial and temporal distribution of sea lion predation attempts and estimate predation rates. (Initiate in FY 2007-2010 Projects).*

   In 2015, the Corps continued land-based visual observations to monitor sea lion predation on adult salmonids, white sturgeon, and lamprey in the Bonneville Dam tailrace observation area. The Corps also monitored the date and location of individual sea lion predation events. BPA Project No. 2008-004-00 (Sea Lion Nonlethal Hazing and Monitoring) observed the total number of sea lion predation events and recorded their location and time. See the discussion in Section 1 of this report for more detail.

3. *Monitor the effectiveness of deterrent actions (e.g., exclusion gates, acoustics, harassment and other measures) and their timing of application on spring runs of anadromous fish passing Bonneville Dam. (Initiate in FY 2007-2010 Projects).*

   The effectiveness of deterrent actions and the timing of application on spring runs were determined in 2015 through BPA- and Corps-funded efforts.

RPA Action 70 – Monitoring Related to Piscivorous (Fish) Predation

The Action Agencies will:

1. *Continue to update and estimate the cumulative benefits of sustained removals of northern pikeminnow since 1990.*

   BPA Project 1990-077-00 (Development of System-wide Predator Control (PSMFC)) continued the Northern Pikeminnow Management Program which is a basin-wide program to harvest northern pikeminnow that was started in 1991 to reduce predation by northern pikeminnow on juvenile salmonids during their emigration to the ocean. The project conducts annual research to evaluate the exploitation rate of northern pikeminnow and the cumulative benefits of sustained removal. In 2015, system-wide exploitation of northern pikeminnow greater than or equal to 200 mm FL during the Sport Reward Fishery was 12.4 percent (95 percent confidence interval 8.9–15.9).

2. *Continue to evaluate if inter- and intra-compensation is occurring.*

   BPA Project 1990-077-00 (Development of System-wide Predator Control (PSMFC)) encompasses the Northern Pikeminnow Management Program which is a basin-wide program to harvest northern pikeminnow that was started in 1991 to reduce predation by northern pikeminnow on juvenile salmonids during their emigration to the ocean. Under the PSMFC program, annual monitoring is conducted to test for the possibility of a compensatory response by northern pikeminnow and other piscivorous fish due to the pikeminnow removal program.

3. *Evaluate the benefit of additional removals and resultant increase in exploitation rate's effect on reduction in predator mortality since the 2004 program incentive increase.*

   BPA Project 1990-077-00 (Development of System-wide Predator Control (PSMFC)) The Northern Pikeminnow Management Program conducts annual research to evaluate the exploitation rate of northern pikeminnow and the cumulative benefits of sustained removal, including the 2015 program incentive increase.

4. *Develop a study plan to review, evaluate, and develop strategies to reduce non-indigenous piscivorous predation.*

   BPA Project 2008-719-00 (Research Non-Indigenous Actions (USGS)) documented the food habits of non-native predators in the lower Columbia River during the late summer and fall to assess the role of juvenile American shad in their diets and any impacts on their health and condition, and assessed the potential efficacy of localized reductions of smallmouth bass for predation control. Results of the study have been published and researchers determined that for walleye and smallmouth bass, consumption of juvenile shad did not improve their condition or overwintering survival.

RPA Action 71 – Coordination

The Action Agencies will coordinate RME activities with other Federal, State and Tribal agencies on an ongoing annual basis, including:

1. *Organizing and supporting the Corps AFEP.*

   The Corps has, since 1952, sponsored biological studies in an integrated, applied research program. These RME studies are managed under the Anadromous Fish Evaluation Program (AFEP). In 2015, the Corps again implemented the AFEP program. The primary activity was the development and selection of experimental designs and methodologies of research projects to be carried out in 2016. This process was extensively coordinated with other federal agencies, states, and tribal interests through their involvement in the Studies Review Work Group, which met several times throughout the planning year. In December 2015, an annual review, open to all interested parties, was held to present the results of AFEP funded research conducted during the year.

   The AFEP program also includes the Fish Facility Design Review Workgroup (FFDRWG), which provides ongoing review of fish facility design activities. The Fish Passage Operations and Maintenance (FPOM) Workgroup is outside of AFEP and provides ongoing review of operational activities related to fish passage. All federal, state, and tribal fishery agencies are invited to participate in the quarterly FFDRWG meetings and monthly FPOM meetings.

2. *Supporting and participating in the Council's Columbia River Basin Fish and Wildlife Program project planning and review efforts.*

   BPA continued to work with the NPCC in coordinating BPA's Fish and Wildlife Program and the FCRPS BiOp to achieve an integrated program. Achievements beyond the annual review of projects and budgets included the review and update of the Fish and Wildlife Program, the collaborative Fish Tagging Forum, and the Geographic Review of habitat work (see http://www.nwcouncil.org/fw/reviews/ for more detailed information on review efforts).

3. *Supporting the standardization and coordination of tagging and monitoring efforts through participation and leadership in regional coordination forums such as PNAMP.*

   Under BPA Project 2004-002-00 (Pacific Northwest Aquatic Monitoring Program), and Reclamation Project 4930 and Reclamation Interagency Agreement with USGS (IA R13-PG-10-428), continued funding for PNAMP was provided for facilitation, technical support and a collaborative forum for the standardization and coordination of fish and habitat monitoring. PNAMP continued promoting monitoring resources and tools to support monitoring in 2015. Their 2015 report highlighted efforts to manage a monitoring protocol and method library (with 977 protocols and 1,688 methods in the system at the end of 2015).

4. *Working with regional monitoring agencies to develop, cooperatively fund, and implement standard metrics, business practices, and information collection and reporting tools needed to cooperatively track and report on the status of regional fish improvement and fish monitoring projects.*

   BPA Projects 1988-108-04 (StreamNet – Coordinated Information System/Northwest Environmental Database (NED) managed by PNAMP staff at the USGS continued to support the implementation of the Coordinated Assessments Projects through PNAMP, CBFWA, and StreamNet to develop standard data exchange templates across the Northwest for the indicators of adult spawner abundance and juvenile salmonid out-migrant production. In 2015, for the Coordinated Assessment effort made progress obtaining priority fish population indicators. Additional progress on advancing data exchange for hatchery indicators was made in 2015.

BPA Project 2004-002-00 (Pacific Northwest Aquatic Monitoring Program Coordination) and Reclamation Interagency Agreement with USGS (IA R13-PG-10-428) continued the PNAMP's Coordinated Assessments Project, in collaboration with CBFWA and StreamNet to develop integrated data-sharing for anadromous-fish-related data among the co-managers (state fish and wildlife agencies and tribes) and Action Agencies of the Columbia River Basin.

BPA Project 2007-083-00 (Grande Ronde Supplementation Monitoring and Evaluation on Catherine Creek/upper Grande Ronde River) supported CTUIR participation in the Coordinated Assessments workshops.

BPA Project 2003-017-00 (ISEMP) supported development of the data dictionaries in http://www.monitoringmethods.org related to habitat classifications. The ISEMP project also played a critical role in supporting the PNAMP ISTM project in development of the Master Sample which is now being managed under the http://www.monitoringresources.org Sample Designer tool.

BPA Project 2003-022-00 (Okanogan Basin Monitoring & Evaluation Program - OBMEP) continued BPA's participation in the PNAMP steering committee and supported development of the data dictionaries in monitoringmethods.org related to habitat classifications and attended the Coordinated Assessments workshops resulting in the development of their data management strategy to exchange fish abundance data.

BPA Project 2008-507-00 (CRITFC's Tribal Data Network Accord Project) was implemented to demonstrate implementation of coordination and standardization tools through evaluation and application of handheld technologies for data capture (e.g., the Digital Pen). In the first phase of the data inventory, CRITFC and all four member tribes have identified repositories for some of their monitoring data and submitted this information to Monitoringmethods.org.

BPA Project 2011-006-00 (Columbia Habitat and Monitoring Program - Pilot (CHaMP-P)) developed and implemented a standardized habitat monitoring program for habitat status and trend to support habitat and fish relationship development used in limiting factor assessments and for planning and evaluation of habitat actions. In 2015, CHaMP increased coordination with watershed groups to support restoration planning and prioritization.

5. *Coordinating the further development and implementation of Hydrosystem, Tributary Habitat, Estuary/Ocean, Harvest, Hatchery, and Predation RME through leadership and participation in ongoing collaboration and review processes and workgroups.*

BPA Project 2003-017-00 (Integrated Status and Effectiveness Monitoring Program (ISEMP) provided extensive coordination of the development and implementation of tributary habitat RME in the pilot watersheds.

BPA Project 2004-002-00 (The Pacific Northwest Aquatic Monitoring Program Coordination Project) supported regional coordination and standardization of fish population and habitat monitoring programs in 2015.

6. *Coordinating implementation with other appropriate regional collaboration processes. This includes coordination related to statutory provisions for the Federal government (BPA/Council), voluntary coordination among Federal agencies (Federal Caucus), and coordination with regional processes for Federal/non-Federal engagement (Technical Management Team (TMT), System Configuration Team (SCT), PNAMP, Northwest Environmental Data- Network (NED), and others.*

   The Action Agencies actively participated in regional forums and accomplished this subaction through subactions 71.1-71.5 above. Coordination related to statutory provisions for the federal government (BPA/NPCC), federal agencies (Federal Caucus), and coordination with regional processes for federal/non-federal engagement (TMT, SCT, PNAMP) continued to support the FCRPS BiOp.

   AMIP Category III required a coordinated monitoring strategy to be completed at the end of 2009. The Anadromous Salmonid Monitoring Strategy (ASMS) was completed in 2009 and outlined distinctions in monitoring requirements for the FCRPS BiOp and other regulatory needs to support ESA recovery monitoring needs. This work continued to support planning and implementation of monitoring in 2015.

RPA Action 72 – Data Management

The Action Agencies will ensure that the information obtained under the auspices of the FCRPS RME Program is archived in appropriate data management systems.

1. *Continue to work with regional Federal, State and Tribal agencies to establish a coordinated and standardized information system network to support the RME program and related performance assessments. The coordination of this development will occur primarily through leadership, participation, and joint funding support in regional coordination forums such as the NED workgroup, and PNAMP and the ongoing RME pilot studies in the Wenatchee River, John Day River, Upper Salmon River, and Columbia River Estuary. (Initiate in FY 2007- 2009 Projects).*

   BPA Project 1988-108-04 (StreamNet – Coordinated Information System/Northwest Environmental Database) managed by StreamNet Staff at the PSMFC. The USGS continued to support the implementation of the Coordinated Assessments Projects by PNAMP, CBFWA, and StreamNet to develop standard data exchange templates across the Northwest for the indicators of adult spawner abundance and juvenile salmonid out-migrant production. As reported in RPA 71, in 2015, an initial pilot effort was completed and Data Exchange Standards (DES) were developed for priority fish population indicators. Additional progress on advancing data exchange for Hatchery indicators was initiated in 2014.

   BPA Project 1990-080-00 (Columbia Basin PIT Tag Information) manages the PTAGIS data system which is operated and maintained at http://www.ptagis.org. PTAGIS continued to further develop exchange format to ensure PIT tag data is consumable other data systems and integrated into other tag management systems, like the data system/tools at http://www.Fishgen.net for genetics management. PIT tags are primarily used for hydro system and tributary survival assessments, as well as tributary assessments of population adult return abundance and diversity to help assess viable salmon population attributes of spawner abundance, adult productivity, spatial distribution, and diversity. In 2014, data loading processes, validation, and notifications were significantly enhanced, two new adult detection sites were installed at Little Goose and Lower Monumental dams, coordinated and planned a 2015 PIT Tag Workshop.

BPA Project 1996-019-00 (Data Access in Real Time (DART)) supported ISEMP and PTAGIS in development of software to rapidly assess PIT tag array detections for population adult escapement which could be supported across the basin.

BPA Project 2003-007-00 (Lower Columbia River Estuary Ecosystem Monitoring Program) supported development of data exchange templates and standard data entry forms to exchange estuary monitoring data with the Corps' Oncor database in 2015 being developed by the Corps. In addition, the Lower Columbia River Estuary Partnership (LCREP) further developed its website in 2014 to display the Columbia River estuary habitat classification and Catena GIS data at http://maps.lcrep.org.

BPA Project 2003-017-00 (Integrated Status and Effectiveness Monitoring Program) integrated data management efforts with project 2011-006-00 and 1988-108-04 to replace the STEM data system.

BPA Project 2003-022-00 (Okanogan Basin Monitoring & Evaluation Program) biologists coordinated directly with other entities performing M&E related activities throughout the region to ensure compatibility with other regional M&E and salmon recovery efforts. On-going coordination with other monitoring practitioners is critical to the success of OBMEP's ability to collect useful data that can be easily assimilated to larger spatial scales.

BPA Project 2004-002-00 (Pacific Northwest Aquatic Monitoring Program Coordination) continued the mission of NED in PNAMP through regional coordination of the Data Management Leadership team (DMLT). PNAMP further developed the Monitoring Resources tools to facilitate standards in protocol and location documentation at http://www.monitoringresources.org.

BPA Project 2008-507-00 (Tribal Data Network) explored use of digital pens to support improved data transfer and QA/QC to biologist to improve data exchange processes, in addition to providing parallel by project 1998-031-00. In the first phase of the data inventory, CRITFC and all four member tribes have identified repositories for some of their monitoring data and submitted this information to Monitoringmethods.org. In 2015, it published the SARs from the Comparative Survival Study (CSS) on the CRITFC web site and transferring many of them to the Coordinated Assessment Exchange System (CA XCT) for Wild Spring/Fall Chinook and Steelhead and Hatchery Spring/Fall Chinook and Steelhead assisted with the regional standardization of historical and current SARs

BPA Project 2011-006-00 (Columbia Habitat and Monitoring Program), In 2015, CHaMP staff worked in conjunction with ISEMP, and staff from BPA, BOR and NOAA, to identify and develop a suite of ISEMP-CHaMP data products that would be generated to help support Expert Panel assessments for 10 populations of listed Chinook and steelhead within the region. Analyses were focused on eight limiting factors or ecological concerns including Riparian Condition, Large Wood Recruitment, Side Channel and Wetland Condition, Floodplain Condition, Instream Complexity, Increased Sediment Quantity, and Stream Temperature. Maps, plots of CHaMP metrics, and model outputs summarized by Assessment Unit in each of the population groups comprise the Expert Panel product bundles.

AFEP Project EST-P-12-01 (Synthesis and Evaluation of Research, Monitoring, and Restoration Project Data in the Lower Columbia River and Estuary) in 2015 further developed RME project database ("Oncor") in coordination with regional managers, including the Estuary Partnership Science Work Group which is represented by state and federal agencies, tribal nations and non-governmental organizations managing habitat restoration in the lower Columbia River estuary. Product development included development of data sharing agreements and a technology transfer plan, and data exchange templates consistent with Pacific Northwest Aquatic Monitoring Program terms and definitions.

2. *Contribute funding for data system components that support the information management needs of individual Hydrosystem, Tributary Habitat, Estuary/Ocean, Harvest, Hatchery, and Predation RME. (Initiate in FY 2007-2009 Projects).*

AFEP Project EST-P-12-01 (Synthesis and Evaluation of Research, Monitoring, and Restoration Project Data in the Lower Columbia River and Estuary) developed a web-based, geospatial data management and analysis system (called "Oncor") for research, monitoring and evaluation (RME) data. Development included (1) coordination with agencies and regional stakeholders; (2) database construction; (); (3) formulation of data reduction procedures and data exchange templates; and (4) upload of data for 13 monitoring indicators: water surface elevation, water temperature, salinity, sediment accretion, photo points, herbaceous vegetation, forested vegetation, shrub/scrub vegetation, fish catch, fish density, fish size, fish diet and prey.

BPA Projects 1988-108-04 (StreamNet – Coordinated Information System/Northwest Environmental Database (NED) managed by StreamNet Staff at the PSMFC continued to support the implementation of the Coordinated Assessments process by PNAMP, CBFWA, and StreamNet to develop standard data exchange templates across the Northwest for the indicators of adult spawner abundance and juvenile salmonid out-migrant production.

BPA Project 1990-080-00 (Columbia Basin PIT Tag Information) managed the PTAGIS data system which is operated and maintained at http://www.ptagis.org. PTAGIS continued to further develop exchange format to ensure PIT tag data is consumable other data systems and integrated into other tag management systems, like the Fishgen.net data system for genetics management. PIT tags are primarily used for hydro system and tributary survival assessments, as well as tributary assessments of population adult return abundance and diversity to help assess viable salmon population attributes of spawner abundance, adult productivity, spatial distribution, and diversity).

BPA Project 1994-033-00 (Fish Passage Center) maintains an extensive website in which all FPC monitoring data, calculated data and analyses are easily available to the public. The website supports all components of Biological Opinion RPA implementation, and makes all of these data available to the public in real time as well as maintaining access to historical data, including environmental conditions, juvenile and adult fish passage metrics, PIT tag detection data, which applies to the hydro system historical and real time map based hatchery release data that applies to hatchery production. The FPC develops data, analyses, smolt to adult return and juvenile timing and passage duration by hatchery group. These summary reports are submitted to the region and hatchery managers. The site includes links to run forecasting which applies to harvest. The FPC analyses of CSS mark groups includes mark groups generated by tributary sampling which then connects the mainstem data with tributary habitat production data. The FPC website and data system provides a data management, distribution and access structure that supports all RPAs and H's of the Biological Opinion.

BPA Project 1996-019-00 (Data Access in Real Time (DART)) supported ISEMP and PTAGIS in development of software to rapidly assess PIT tag array detections for population adult escapement which could be supported across the basin. In-season real-time run predictions for juvenile and adult stocks with an annual review of run-timing predictions were completed for 2015.

BPA Project 1997-015-01 (Imnaha River Smolt Monitoring) provided the FPC's SMP with tributary specific emigration data from the Imnaha River. It continued a collection of a time series data set for Chinook salmon and steelhead smolt arrival and survival information to mainstem dams.

BPA Project 2003-017-00 (Integrated Status and Effectiveness Monitoring Program) mainly contributed to the data system components that support RME information management needs through a database that houses all fish data collected under ISEMP, and operation and maintenance of Instream PIT Tag Detection Systems (IPTDS) in the Upper Columbia, John Day and Salmon River subbasins for the Upper Columbia River Spring-Run Chinook ESU and Upper Columbia River steelhead DPS; Snake River Steelhead DPS, Snake River Spring/Summer-Run Chinook ESU, and Middle Columbia River Steelhead DPS. The data management systems previously developed for ISEMP are still in place. The Fish and In-Stream PIT Tag Detection Systems (IPTDS) database run by Quantitative Consultants, Inc. (Boise, ID) continue to house remote capture and tag data, PIT array detections and infrastructure information and electronically transfer required information to PTAGIS. The Status and Effectiveness Monitoring Databank (STEM Databank) serves as a repository for ISEMP field data collected between 2004 and 2010.

BPA Project 2004-002-00 (Pacific Northwest Aquatic Monitoring Program Coordination) continued the mission of NED in PNAMP through regional coordination of the Data Management Leadership team (DMLT). PNAMP further developed the Monitoring Resources tools to facilitate standards in protocol and location documentation at http://www.monitoringresources.org. Reclamation's Interagency Agreement with USGS (1A R13-PG-10-428) also provided funding for PNAMP to support Monitoring Resources Tool Development. The 2015 PNAMP report highlighted efforts to manage a monitoring protocol and method library (with 977 protocols and 1,688 methods in the system at the end of 2015).

BPA Project 2008-507-00 (Tribal Data Network) explored use of digital pens to support improved data transfer and QA/QC to biologist to improve data exchange processes, in addition to providing parallel support in BPA Project 1998-031-00. In the first phase of the data inventory, CRITFC and all four member tribes have identified repositories for some of their monitoring data and submitted this information to Monitoringmethods.org and the CA.

BPA Project 2011-006-00 (Columbia Habitat and Monitoring Program), through CHaMP, led the way in protocol documentation in the http://www.monitoringmethods.org tool to demonstrate the level of information required to support metadata development with creation of standard data entry forms for rapid exchange of data from the field to the data systems. In 2015, CHaMP (and ISEMP and AEM) crews continued to use the CHaMP Topographic Toolbar in ArcGIS to process topographic data collected using total stations during field visits to sites, and to automate the calculation and sharing of habitat status and trends metrics and indicators via the CHaMPMonitoring.org data management system (https://www.champmonitoring.org/).

Reclamation Project R15-AC-00005 (Building an Integrated Data Harvester and Analysis Software for the Methow Basin) with Washington State University completed a pilot data management tool for the Methow IMW demonstration in 2015.

3. *Participate in Northwest regional coordination and collaboration efforts such as the current PNAMP and NED efforts to develop and implement a regional management strategy for water, fish and habitat data. (Initiate in FY 2007-2009 Projects).*

BPA Projects 1988-108-04 (StreamNet – Coordinated Information System/Northwest Environmental Database (NED) managed by PNAMP staff at the USGS continued to support the implementation of the Coordinated Assessments Projects through PNAMP, CBFWA, and StreamNet to develop standard data exchange templates across the Northwest for the indicators of adult spawner abundance and juvenile salmonid out-migrant production. In 2015, an initial pilot effort was completed and Data Exchange Standards (DES) were tested with data exchanges from all state partners for priority fish population indicators, but many priority population did not exchange NOSA or juvenile out-migrant data. Additional progress on advancing data exchange for hatchery indicators was delayed in 2015 to ensure the right managers were attending. Work is ongoing through BPA contracts, PNAMP initiatives, and data management RPAs. Not all entities, contractors, and co-managers possess adequate infrastructure or staffing to enable web accessible data.

BPA Project 2003-007-00 (Lower Columbia River Estuary Ecosystem Monitoring Program) continued to coordinate with the BPA and the US Army Corps in the development of an online database (Oncor) to store habitat, fish, and water quality data collected at restoration, status, and trend sites. This work includes implementing data reduction protocols and quality assurance practices for pre- and post-restoration habitat monitoring. The result is an increase in the amount and quality of monitoring data.

BPA Project 2004-002-00 (Pacific Northwest Aquatic Monitoring Program Coordination) continued the mission of NED in PNAMP through regional coordination of the Data Management Leadership team (DMLT). In 2015, PNAMP lead a data management webinar series to support discussions on *Monitoringresources.org* tools and regional best management practices for environmental data. PNAMP further developed the Monitoring Resources tools to facilitate standards in protocol and location documentation at http://www.monitoringresources.org. Using crosswalks between CHaMP and PIBO data, the monitoring resources tools successfully displayed field data as indicators in a pilot tool for BPA to inform habitat management.

BPA Project 2008-507-00 (Tribal Data Network) explored use of digital pens to support improved data transfer and QA/QC to biologist to improve data exchange processes, in addition to providing support in BPA Project 1992-031-00. In the first phase of the data inventory, CRITFC and all four member tribes have identified repositories for some of their monitoring data and submitted this information to Monitoringmethods.org.

BPA Project 2011-006-00 (Columbia Habitat and Monitoring Program) CHaMP continued to participate in northwest regional coordination and collaboration efforts for data management by working closely with private state, tribal and federal agency programs within the Columbia River Basin to share data, applications, and lessons learned. CHaMP continued its efforts to provide tools to allow area and regional managers to report consistent metrics and results, and provide meta-data to ensure proper use of project results by collaborators within the region. Data management coordination efforts took multiple forms including meetings with the Pacific Northwest Aquatic Monitoring Partnership (PNAMP) and the regional AEM program, defining data flow time lines, managing contract information, distributing GIS data, maintaining website information, and facilitating data compilation and distribution.

As a follow-up to an exploration of CHaMP-PIBO metric comparison work that the BPA funded CHaMP to conduct in 2014, in 2015 the BPA requested that CHaMP pursue the development and population of a common database to facilitate data sharing between the two regional programs, and broaden the suite of analytical products available to support regional management decisions. Both CHaMP and PIBO practitioners proposed that a demonstration of the utility of data sharing should be conducted prior to committing additional limited resources to a conceptual project. To this end, CHaMP and PIBO staff drafted a proposal to assess the feasibility of integrating data from both monitoring programs through additional, new analyses that would be conducted in the John Day Basin.

A notable achievement in 2015 was the initiation of a partnership between the USGS and CHaMP to develop a prototype version of an online decision-support tool that uses CHaMP metrics and indicators.

RPA Action 73 – Implementation and Compliance Monitoring

The Action Agencies will use the project-level detail contained in the Action Agencies' Biological Opinion databases to track results and assess our progress in meeting programmatic level performance targets. This performance tracking will be reported through annual progress reports and the comprehensive reports scheduled for 2013 and 2016.

1. *Annually monitor the successful implementation of projects through standard procedures and requirements of contract oversight and management, and review of project deliverables and final reports.*

   The implementation of all BPA projects is tracked in the Pisces database. Pisces data includes project status, implementation metrics, focal species, location, and budget.

2. *Maintain project and action level details for planning and reporting purposes. This approach will provide the most up-to-date information about the status of actions and projects being implemented.*

   To further support coordination and planning within the Action Agencies and beyond, of monitoring projects that support the FCRPS BiOp, BPA contracted PNAMP through Project 2008-727-00 which was consolidated into contract 2004-002-00 to develop a http://www.monitoringresources.org "Monitoring Explorer" tool.

3. *Maintain a comprehensive habitat project tracking system where relevant project information is contained in an accessible comprehensive data system. The data system will contain project level information that is needed for both implementation and effectiveness monitoring. The system will include the set of minimum metrics and metadata for RME data design listed in Data Management Needs for Regional Project Tracking to Support Implementation and Effectiveness Monitoring (Katz et al. 2006). (Initiate in FY 2008).*

   The Action Agencies have recorded project implementation and associated metric information for tributary habitat actions since implementation of tributary habitat actions became part of the FCRPS BiOp RPA in 2000. Examples of these data are presented in Appendix A for RPA Action 35 and in Appendix B for RPA Action 37. These data for BPA and Reclamation currently are tracked in BPA's Pisces contracting database and reported at http://www.cbfish.org for BPA-funded restoration actions. Actions for which Reclamation provides technical assistance are tracked in a separate Reclamation database.

   BPA developed an automated report through the http://www.cbfish.org to annually provide habitat restoration action information to the NOAA Fisheries Pacific Coast Salmon Recovery Fund system. The automated exchange of that information was completed in 2012 and occurs annually to fully comply with this RPA. The list of BPA metrics and relationships to the NOAA Fisheries system is available at http://www.cbfish.org/WorkElement.mvc/Landing.

Adaptive Management Implementation Plan (AMIP) Actions

In September 2009, the FCRPS 2008 BiOp was enhanced through an Adaptive Management Implementation Plan, which includes accelerated actions, additional research related to fish status and climate change, and precautionary use of biological triggers and contingency plans in case there is an unexpected, significant fish decline. The original AMIP actions and six new implementation actions that were amended to the AMIP were incorporated into the NOAA Fisheries 2010 and 2014 Supplemental BiOps. The following table provides information on BiOp AMIP actions implemented by NOAA Fisheries and the Action Agencies as of 2015. Information on the status of continuing or ongoing actions follows the table.

Table 20. Status of AMIP actions for 2015.

AMIP Ref	Action Description	Status
AMIP Category: II Acceleration & Enhancement of RPA Mitigation Actions		
II. A	Estuary Habitat Improvement & Memorandum of Agreement on Columbia River Estuary Actions with State of Washington	See Section II. A following this table.
II. B	Reintroduction *The NWFSC is now initiating an evaluation of additional opportunities for reintroduction of listed fish in areas downstream of Chief Joseph Dam and the Hells Canyon Complex. The NWFSC will examine the potential benefits of additional reintroductions, considering locations where reintroduction will advance recovery and further lower the risk of extinction.* • *The NWFSC will evaluate the conditions under which reintroduction would be a robust strategy and describe the relative*	This action is completed. NOAA Fisheries developed a manuscript on principles of reintroduction for anadromous salmonids in collaboration with the Federal, State and Tribal members of the Recovery Science Implementation Team. That document is available at http://www.salmonrecovery.gov/Files/2011%20APR%20files/New%20Folder%203/McClure_et_al_2011_Reintro_gnrl_prncpls_v5_final_review_draft_100411.pdf

AMIP Ref	Action Description	Status
	costs and benefits in this and other situations. • *The NWFSC will evaluate the costs and benefits of the alternative reintroduction strategies and techniques.* *The NWFSC will complete a report outlining potential reintroduction projects in the Columbia Basin by December 2010. This report will guide both decisions regarding which Long-term Contingency Actions should be implemented if a trigger is tripped and actions taken to implement recovery plans. This report will be discussed with the federal agencies and the Regional Implementation Oversight Group (RIOG).*	
II. C	Predator & Invasive Species Controls *The Action Agencies and NOAA Fisheries will move forward in the three highest priority areas to establish baseline information for future predator control activities:* 1. *Shad: document the influence of juvenile shad on the growth and condition of introduced predators in the fall as they (the predators) prepare for overwintering* 2. *Catfish: document the distribution and predation rates of channel catfish* 3. *Smallmouth bass: document whether removals of smallmouth bass in areas of intense predation could reduce the mortality of juvenile salmonids* *For these three priority approaches and in order to accelerate implementation of the RPA, by November 2009 BPA will develop a research study design proposal, and will promptly request an expedited review of the proposal by the Independent Scientific Review Panel (ISRP) to accelerate field implementation. The Action Agencies will implement the research study during the next field season(s), anticipated by December 2010. Once this research supports a specific management strategy, the Action Agencies could implement site-specific removals of smallmouth bass and could exclude adult American shad from upper mainstem dams as early as the following migration season.*	The action was completed on schedule in 2010.
II. D	Spill	See Section II. D following this table.
AMIP Category: III Enhanced Research Monitoring & Evaluation		
	Collaborate with state and tribal co-managers to develop a shared Columbia Basin Monitoring Strategy. The goal of the collaboration is to develop an efficient salmon and steelhead monitoring framework and implementation strategy that will support viable salmonid populations and habitat and hatchery effectiveness monitoring needs, including those of the 2008 BiOp and RPA, recovery plans, regional fisheries management objectives, and other programs. This collaborative process will be completed in December, 2009.	A monitoring strategy was completed on schedule in 2009. The ISRP's review of the Anadromous Salmonid Monitoring Strategy (ASMS) was subsequently completed in February 2011 and is found at http://www.salmonrecovery.gov/Files/2011%20APR%20files/New%20Folder%203/ISRP_ISAB_2011-1.pdf.
III. A	Enhanced Life-Cycle Monitoring for Evaluation of Contingencies	See Section III. A following this table.

III. B	Adult Status & Trend Monitoring *By December 2011, NOAA Fisheries will improve existing adult status and trend monitoring to obtain adult natural spawner abundance and full life-cycle productivity estimates, with known statistical certainty and power, for additional ESA-listed populations. These improvements will better inform decisions regarding which Rapid Response Actions and Long-term Contingency Actions will be taken if a trigger is tripped, as well as ongoing viability assessments. Additionally, by December 2010, NOAA Fisheries will develop mechanisms for the timely and efficient reporting and dissemination of these data, in order to ensure they can provide for the early detection of regional or population specific changes in status.*	Mechanisms for data reporting and dissemination were completed on schedule in 2010. NOAA Fisheries' NWFSC created the Salmon Population Summary database, which is available online at https://www.webapps.nwfsc.noaa.gov/sps to disseminate data to enable early detection of regional population specific changes in status.
III. C	Juvenile Status & Trend Monitoring	The strategy was completed on schedule in 2010. Consistent with ISRP comments, in 2011 BPA proceeded with partial implementation and evaluation for CHaMP and associated paired fish population monitoring.
III. D	Habitat Condition Status & Trend Monitoring	In 2011, BPA proceeded with partial implementation and evaluation of CHaMP consistent with ISRP comments
III. E	Intensively Monitored Watersheds *The Action Agencies are implementing IMWs under RPA Actions 56 and 57 for fish status monitoring and habitat effectiveness monitoring in the John Day, Wenatchee, Entiat, Methow, Lemhi, and South Fork Salmon basins. NOAA Fisheries funds five additional or complementary IMWs in interior subbasins in Idaho (Upper Potlatch River, Lemhi River); Oregon (Upper Middle Fork John Day River); and Washington (Yakima River, Asotin Creek).* *The Action Agencies' IMWs have been through independent science evaluation and review by the NPCC. Under the RPA provisions, enhancements to these efforts are already planned or underway. As part of an enhanced commitment to IMWs, by September, 2010, NOAA Fisheries and the Action Agencies will complete an analysis of existing IMWs to ensure:* *1. Timely funding and implementation of intensive habitat actions to ensure, where practical, an adequate treatment effect* *2. Sufficiently diverse representation of IMWs (geographically and with respect to limiting factors) and appropriate monitoring (e.g., temperature, flow) to detect climate change impacts* *3. Results are applicable to future habitat planning and for the implementation of Rapid Response Actions* *This review will inform the prioritization of BPA placeholder funds budgeted for IMWs, as well as the allocation of new or re-focused NOAA Fisheries funds (e.g., distributed through the Pacific Coastal Salmon Recovery Fund). IMW updates will go through an independent science review process and review by the NPCC. Results will be*	The action was completed on schedule in 2010 as documented in the Action Agencies/NOAA Fisheries/NPCC RME Workgroup "Recommendations for Implementing Research, Monitoring and Evaluation for the 2008 NOAA Fisheries FCRPS BiOp" (May 2010) consistent with the regional Anadromous Salmonid Monitoring Strategy.

	coordinated with the RIOG and reported annually to the region.	
III. F	Climate Change Monitoring & Evaluation	See Section III. F following this table.
AMIP Category: IV Contingency Plans in Case of Early Warning or Significant Fish Declines		
IV. A.1.	Early Warning Indicator for Chinook Salmon & Steelhead *The Action Agencies and NOAA Fisheries will develop, in coordination with the RIOG, at least one additional Early Warning Indicator by December, 2010, which may be revised pending additional analyses and discussion. Specifically, the additional Early Warning Indicator(s) would evaluate whether a species is likely to have substantially reduced abundance (and productivity) in the future based on two years of adult return information, preliminary biological information, and environmental indicators or known environmental disasters.* *These indicators may include, but are not limited to, low jack counts or numbers of juvenile outmigrants (biological), indicators of ocean conditions predicting very low abundance of adult returns for recent outmigrants (environmental indicators), or wide-spread forest fires, increased distribution and virulence of pathogens, new invasive species, prolonged severe droughts, etc. environmental disasters). Unlike the interim Early Warning Indicators, which evaluates information at the species level, the additional Early Warning Indicators may use information more representative of effects on major population groups (MPGs), important management units (e.g., A-run vs. B-Run Snake River steelhead, or key populations).* *Responses to impacts affecting a specific MPG or subset of populations would be tailored to the appropriate scale.*	The action was completed in 2011. The NWFSC developed a forecasting tool that satisfies this requirement.
IV. A.2.	Significant Decline Trigger for Chinook Salmon & Steelhead *The Action Agencies and NOAA Fisheries, in coordination with the RIOG, will further improve the Significant Decline Trigger no later than December 2010 by incorporating a metric indicative of trend.*	The action was completed in 2010. The approach developed by NWFSC, NOAA and AA staff was adopted and memorialized in a letter from L. Bodi, BPA, to Barry Thom, NOAA on 12/23/10.
IV. A.3.	Contingency Plan Implementation for Snake River Sockeye Salmon	See Section IV. A. 3 following this table.
IV. B	Rapid Response Actions – Hydro, Predator Control, Harvest, Safety Net Hatchery Programs *Within 90 days of NOAA Fisheries determining that a significant decline trigger has been tripped, the Action Agencies, in coordination with NOAA Fisheries and the RIOG, will assess alternative Rapid Response Actions and determine which action(s) will be implemented. The Rapid Response Actions will be implemented as soon as practicable after a decision is made, and not later than 12 months after a Significant Decline Trigger is tripped. Most, if not all, Rapid Response Actions will be temporary in nature.*	The Rapid Response Plan addressed all actions at left and was finalized on schedule in 2011. The Plan was subsequently modified to incorporate comments and was delivered to NOAA Fisheries on February 7, 2012. The plan is available at https://www.salmonrecovery.gov/Files/2011%20APR%20files/2011_RRandLTC_Plan.pdf

	By December 2011, the Action Agencies and NOAA Fisheries will develop a Rapid Response Plan, which will include a detailed description of these potential Rapid Response Actions together with implementation milestones.	
IV. C	Long-Term Contingency Action – Hydro, Reintroduction, Predator Control, Harvest, Conservation Hatcheries, Hatchery Reform, John Day Reservoir Operation at MOP, Breaching Lower Snake River Dams: Within four to six months of a Significant Decline trigger being tripped, the Action Agencies (in coordination with NOAA Fisheries, the RIOG and other regional parties) will conduct an All-H Diagnosis and life-cycle model analysis to determine if the Rapid Response Action(s) are likely to be sufficient or if Long-term Contingency Actions will need to be implemented, and if so, what Long-term Contingency Actions are appropriate for implementation. If necessary, the Long-term Contingency Actions will then be implemented as soon as practicable thereafter. Unlike the Rapid Response Actions, all of which have been determined to be implementable within 1 to 12 months of a triggering event, each Long-Term Contingency Action has a unique timeline for implementation depending on its complexity. *By December 2011, the Action Agencies and NOAA Fisheries will develop a Long-term Contingency Plan, which will include a detailed description of potential Long-term Contingency Actions, a selection process and implementation milestones for the following potential Long-term contingency actions as further described in the AMIP:* *1. Phase II Hydro Actions* *2. Reintroduction* *3. Predator Control* *4. Harvest* *5. Conservation Hatcheries* *6. Hatchery Reform* *7. John Day Reservoir at Minimum Operating Pool from April – June.* *8. Breaching Lower Snake River Dams: By March, 2010, the Corps in coordination with NOAA Fisheries and the other Action Agencies will complete a “Study Plan” for breaching of lower Snake River dams.*	The Long-Term Contingency Plan that addresses actions 1 through 6 (left) (Phase II Hydro Actions, Reintroduction, Predator Control, Harvest, Conservation Hatcheries, Hatchery Reform) of this action was completed on schedule in 2011. The plan is available at https://www.salmonrecovery.gov/Files/2011 APR files/2011_RRandLTC_Plan.pdf . The Corps submitted the final plan of study for the John Day Minimum Operating Pool (action 7 left) to NOAA Fisheries on July 26, 2012. The plan is available at https://www.salmonrecovery.gov/Files/BiologicalOpinions/2012/JDA%20MOP%20Final%20Plan%20of%20Study%20with%20letter%20comments%20and%20responses%20(071112).pdf The Corps completed the study plan for the breaching of lower Snake River dams in 2010 (action 8 left). The plan is available at http://www.nww.usace.army.mil/Library/DamBreachingPlanofStudy.aspx.
AMIP Category: Amendments		
Amend-ment 1	Identify the use and location of adult salmon thermal refugia in Lower Columbia and Lower Snake Rivers *Under RPA Action 55 the Action Agencies will undertake selected hydrosystem research to resolve critical uncertainties. As part of this action, by June 2012, the Corps will complete a report to identify the use and location of adult salmon thermal refugia in the lower Columbia and lower Snake Rivers using existing information on adult migration, temperature monitoring data, and modeling efforts. Additional investigation or action may be warranted based on the results.*	The Corps completed the Location and Use of Adult Salmon Thermal Refugia in the Lower Columbia and Lower Snake Rivers FCRPS Pools report in 2012. The report is available at https://www.salmonrecovery.gov/Files/BiologicalOpinions/2010/Thermal%20refugia%20report%20Feb%2014%202013.pdf
Amend-ment 2	Assess feasibility of adding adult PIT Tag detection systems at The Dalles Dam and John Day Dam.	See Amendment 2 following the table.

Amend-ment 3	Action Agencies to provide temperature data for NOAA's regional temperature database.	See Amendment 3 following the table.
Amend-ment 4	Action Agencies to provide tributary habitat effectiveness study data for NOAA's regional climate change database.	See Amendment 4 following the table.
Amend-ment 5	Action Agencies will provide available invasive species and site-specific toxicology information for consideration by the expert panels.	See Amendment 5 following the table.
Amend-ment 6	Action Agencies will assist NOAA to develop or modify existing studies that address the Ad Hoc Supplementation Workgroup Recommendations Report.	See Amendment 6 following the table.

AMIP Category II – Acceleration and Enhancement of RPA Mitigation Actions (Actions A-D) Ongoing Actions

II. A. Estuary Habitat Improvement & Memorandum of Agreement on Columbia River Estuary Actions with State of Washington

Under RPA Actions 36 and 37, the Action Agencies are implementing a major program of estuary habitat restoration and research. The Washington Estuary Memorandum of Agreement will enhance this effort significantly by identifying and describing estuary projects and augmenting the suite of RPA actions in the 2008 RPA. In selecting the projects for inclusion in the Washington Estuary Memorandum of Agreement, an initial suite of potential projects was evaluated by Washington Department of Fish and Wildlife (WDFW) scientists for biological benefits and certainty of success using the scientific methodology described in the RPA (Actions 36 and 37). As a result of this evaluation, an additional 21 projects were selected for implementation.

Acceleration & Enhancement of RPA Mitigation Actions (Actions A-D) II. A. Estuary Habitat Improvement & Memorandum of Agreement on Columbia River Estuary Actions with State of Washington: Under RPA Actions 36 and 37, the Action Agencies are implementing a major program of estuary habitat restoration and research. The Washington Estuary Memorandum of Agreement will enhance this effort significantly by identifying and describing estuary projects and augmenting the suite of RPA actions in the 2008 RPA. In selecting the projects for inclusion in the Washington Estuary Memorandum of Agreement, an initial suite of potential projects was evaluated by Washington Department of Fish and Wildlife (WDFW) scientists for biological benefits and certainty of success using the scientific methodology described in the RPA (Actions 36 and 37). As a result of this evaluation, an additional 21 projects were selected for implementation.

The MOA was executed by parties on September 16, 2009. The estuary program was accelerated in 2013; see the discussion in RPA 37 for information on habitat actions.

II. D. Spill

Spring Spill: *Assess data from previous years and discuss with the RIOG parties each year to inform transport/spill operation decisions for the subsequent year. There is no longer a presumptive spill/transport operation for the spring RPA action 29.*

This process was carried out in 2015 as specified in the AMIP.

Summer Spill: *To further enhance the summer spill program, the Action Agencies will develop an appropriate safeguard, based on adult returns, that continues summer spill at the Snake River* *projects through August 31, during the subsequent juvenile outmigration. Using this trigger, low abundance of naturally-produced Snake River fall Chinook in one year would trigger spill through August 31 at the Snake River projects the following year, regardless of the number of juveniles collected. The Agencies will coordinate with the RIOG in developing the trigger, to be in place for the 2010 juvenile fish migration.*

Completed on schedule in 2010. Consistent with this AMIP requirement, a June 11, 2010 letter from Witt Anderson to Barry Thom indicated that spill would continue through August 31 only in years following a year in which 400 or fewer natural-origin adult Snake River fall Chinook salmon are counted at Lower Granite Dam. However, pursuant to the opinion and order from the United States District Court for the District of Oregon, dated August 2, 2011, the Action Agencies continued summer spill at the Snake River projects through August 31 in prior years, consistent with the Court's previous spill orders. In 2015, while no longer under court order, the Action Agencies elected to continue spill operations consistent with previous years' operation. As part of the agreement to continue operations, the Action Agencies would not have implemented the August spill curtailment trigger in 2015 even if trigger conditions had been met. Spill at the four Snake River dams continued through August 31.

AMIP Category III – Enhanced Research Monitoring & Evaluation (Actions A-F) Ongoing Actions

Collaborate with state and tribal co-managers to develop a shared Columbia Basin Monitoring Strategy. The goal of the collaboration is to develop an efficient salmon and steelhead monitoring framework and implementation strategy that will support viable salmonid populations and habitat and hatchery effectiveness monitoring needs, including those of the 2008 BiOp and RPA, recovery plans, regional fisheries management objectives, and other programs. This collaborative process will be completed in December, 2009.

III. A. Enhanced Lifecycle Monitoring for Evaluation of Contingencies

Starting in 2010, NOAA Fisheries and the Action Agencies will jointly fund and implement updates to the existing life cycle models. The updates to the life-cycle models will be implemented by December, 2012. These enhancements will be developed using the same approach as for the COMPASS model, a transparent process and independent science peer review. Results will be discussed with the RIOG and reported annually to the region.

The life cycle modeling project began in 2010 and has continued through 2015. The model development group consists of scientists from state (IDFG, WDFW, ODFW), tribal (CRITFC, Nez Perce), and federal (NOAA, USGS, BOR, USFWS) agencies. The group completed a document in December 2012 that described model developments and presented model results. This document was publicly reviewed and then presented to the ISAB for review in June 2013. The model development group met quarterly and continues to meet and make progress. The modeling has made progress in the following areas:

1. Incorporating habitat relationships into life cycle models: There are ongoing efforts to gather data and estimate relationships between tributary habitat conditions and capacity or survival for spring Chinook in the Grande Ronde and Upper Columbia, and Chinook and steelhead in the Salmon River.

2. Continued development of hydro scenarios for rapid response and long-term

contingency planning: An avian predation survival relationship was added to the COMPASS model.

3. Steelhead and subyearling Chinook salmon life-history characterizations: In 2014, a team from the USFWS, Nez Perce tribe, and USGS assembled multiple years of data for a stock-recruitment model for fall-run Chinook in the Snake River Basin. They were able to incorporate subyearling and yearling (reservoir type) outmigration patterns, estimate density effects at the life stages upstream and downstream of Lower Granite Dam, and estimate survival metrics for hatchery and wild origin fish.

4. Estuary and ocean survival NOAA has estimated predation rates by pinnipeds on spring-run Chinook in the estuary for several years, and this may soon be available for incorporation in COMPASS and other models.

5. Climate change scenario characterizations: Relationships between flow, temperature, and survival rates were estimated for tributaries of the Salmon River.

6. Modeling of hatchery-wild interactions based on ongoing analyses: In 2014, scientists in the AMIP modeling group reported a major analysis of stock recruitment rates for Chinook and steelhead populations in the interior Columbia River Basin (2014 Suppl. BiOp, Appendix C). They concluded that density-dependence processes influence abundance patterns and population trends in most of the wild ESUs.

III. F. Climate Change Monitoring & Evaluation

This AMIP Action enhances or clarifies other RPA actions as follows:

1. *RPA Action 2 requires the inclusion of new climate change research findings in the Action Agencies' annual progress reports NOAA Fisheries will annually provide the Action Agencies with a literature review relevant to the implementation of the RPA.*

   On November 16, 2016, NOAA Fisheries provided the Action Agencies with a Northwest Fisheries Science Center review of new literature on climate science and oceanographic conditions relevant to Columbia River Basin salmonids (see Appendix A).

2. *Consistent with RPA Actions 56-61, data on habitat conditions and action effectiveness will be collected during ongoing and enhanced tributary habitat and ocean research. By December 2011, the Action Agencies and NOAA Fisheries will ensure that this information is appropriately managed in a database allowing changes to be tracked over time.*

   The action is ongoing. BPA funded the creation of the CHaMP data system for tributary habitat status and trend monitoring associated with RPAs 56 and 57 at http://www.champmonitoring.org. BPA and NOAA Fisheries' NWFSC funded tributary habitat action effectiveness monitoring for RPA 56 and 57, the ISEMP Project 2003-017-00, found at http://www.nwfsc.noaa.gov/research/divisions/cbd/mathbio/isemp/index.cfm, which tracks and manages data in the Status and Trend Effectiveness Monitoring Databank at https://www.webapps.nwfsc.noaa.gov.

   For estuarine habitat data, the Corps funded the AFEP "Synthesis and Evaluation" project with Battelle's Pacific Northwest Labs for the development of the data system to track and maintain BPA habitat status and trends and action effectiveness. In the estuary, BPA also co-funds a site of the Science and Technology University Research Network within the Center for Coastal Margin Observation & Prediction. Data related to food web and water quality (flow, temperature, dissolved oxygen, pH, plankton (nontoxic or pharmaceutical)) is stored at http://www.stccmop.org/saturn.

For ocean habitat conditions, data from BPA and NOAA Fisheries' NWFSC Project 1998-014-00 (Ocean Survival of Salmonids) may be found at the NOAA Fisheries' Ocean Indicators Tool (https://www.nwfsc.noaa.gov/research/divisions/fe/estuarine/oeip/index.cfm). Additional data on ocean conditions for the BPA-funded "Canada-USA Shelf Salmon Survival Study," conducted with the Canadian Department of Fisheries and Oceans (DFO), are reported in the Pacific Region Oceanography Database at http://www.pac.dfo-mpo.gc.ca/science/oceans/data-donnees/index-eng.htm.

3. *Under RPA Actions 35-57, the Action Agencies will use the new climate change information to guide tributary and estuary habitat project selection and prioritization and other aspects of adaptive management.*

The action is ongoing. The 2011 and 2012 reviews of new climate change literature provided by NOAA Fisheries under AMIP Action III.F (AMIP pg. 25) were shared with the tributary habitat Expert Panels in advance of the workshops held in 2012 on the Expert Panel Website.

The Action Agencies are also tracking juvenile fish status and trends at monitoring sites throughout the estuary to support the early detection of substantial changes in abundance, productivity, or survival over time. These trends may be correlated with trends of habitat indicators (e.g., temperature); and by tracking habitat status and trends (including water quality and temperature) at monitoring sites throughout the estuary to detect changes in baseline conditions over time. These may be correlated with status and trends of juvenile fish densities.

4. *Under RPA Action 7, the Action Agencies investigate the impacts of possible climate change scenarios on listed salmon and steelhead. As part of this effort, the Action Agencies will use new climate change information to improve regional hydrological models. In addition, the Action Agencies will review existing forecasting tools. As new procedures and techniques are identified with significant potential to reduce forecast error and improve forecast reliability, the Action Agencies will review these with the RIOG and other interested parties.*

This action is ongoing. The results of the work from the three agencies are available in three major reports and a summary report as part of the Climate and Hydrology Datasets for use in the RMJOC Agencies' Longer-Term Planning Studies at http://www.bpa.gov/power/pgf/HydrPNW.shtml. Reclamation, BPA, and the Corps engaged in a collaborative effort to focus on how water supply changes due to climate change could impact the Columbia River Basin and the operation of federal dams in the future. The RMJOC's four-part climate change reports were completed in 2011. The report titles and dates completed are:

Part I – Future Climate and Hydrology Datasets, dated December 2010;

Part II – Reservoir Operations Assessment for Reclamation Tributary Basins, January 2011;

Part III – Reservoir Operations Assessment: Columbia Basin Flood Control and

Hydropower, May 2011; and

Part IV – Summary, Climate and Hydrology Datasets for Use in the River Management Joint Operating Committee (RMJOC) Agencies' Longer-Term Planning Studies, September 2011.

The reports can be found at http://www.bpa.gov/power/pgf/HydrPNW.shtml. BPA also solicited comments from stakeholders and the public on the Summary report in August 2011, and these are posted at: http://www.bpa.gov/applications/publiccomments/CommentList.aspx?ID=134.

5. *Enhanced monitoring of adult status and trends, juvenile status and trends, habitat condition status and trend and IMWs (flows and temperature) will contribute to climate change assessments. Climate change information will be discussed with the RIOG and reported to the region annually.*

The action is ongoing. Enhanced monitoring under AMIP III B, C, D, and E (adult, juvenile, habitat status, and IMWs) all support and contribute to climate change assessments. See these sections above for more information.

AMIP Category IV – Contingency Plans in Case of Early Warning or Significant Fish Declines

IV. A. Expanded Contingency Process

IV. A. 3. – Contingency Plan Implementation for Snake River Sockeye Salmon: *The Action Agencies will continue the safety net hatchery program; further expand the sockeye program (up to 1 million fish released as smolts); investigate the feasibility of transporting adults from Lower Granite Dam to Sawtooth Valley lakes or artificial production facilities; and investigate the highly variable juvenile mortality rates between Sawtooth Valley and Lower Granite Dam.*

The safety net hatchery program is ongoing. The investigation of adult transport feasibility is complete.

Contingency actions include the safety net hatchery program; construction, operation, and maintenance of the Springfield Sockeye Hatchery to expand smolt production up to one million smolts; and a multi-year investigation of the highly variable juvenile mortality rates between Sawtooth Valley and Lower Granite Dam.

AMIP Category: Amendments with Ongoing Actions

Amendment 2

Under RPA Action 52, the Action Agencies will enhance fish population monitoring. As part of this action, in February 2011 the Corps will initiate a study at The Dalles and John Day Dams to determine a cost-effective adult PIT Tag detection system design and whether installation of PIT Tag detectors will improve inter-dam adult survival estimates. The study will be completed by December 2012. Following the results of the study, by April 2013, the Action Agencies will determine in coordination with NOAA Fisheries if one or both of these PIT Tag detectors substantially improve inter-dam adult *loss estimates. If warranted, the Action Agencies will proceed to construction. Funding will be scheduled consistent with the RPA requirement and priorities for performance standard testing and achievement of these performance standards at the projects.*

Adult PIT tag monitoring systems were installed at The Dalles Dam in 2013. These were originally intended to be temporary. However, since they proved to have very high detection efficiencies and appear to be durable and reliable, they will be maintained by the Corps as the long-term systems.

Amendment 3

Under RPA Action 15, the Action Agencies are providing water quality information and implement water quality measures to enhance fish survival and protect habitat. As part of this action, the Action Agencies will contribute to regional climate change impact evaluations by providing NOAA Fisheries past and future water temperature data from their existing monitoring stations, to be used as part of a regional temperature database. The Action Agencies will begin to provide data to NOAA Fisheries within 6 months following the establishment of a regional database and annually thereafter. NOAA Fisheries anticipates having a regional database established no later than 2012.

NOAA Fisheries and the Action Agencies are satisfying this requirement by submitting data developed for FCRPS BiOp RME to the USFS's Rocky Mountain Research stream and air temperature database. This project will provide a mapping tool to help those in the western U.S. organize temperature monitoring efforts.

Amendment 4

Under RPA Action 35, the Action Agencies are identifying tributary habitat projects for implementation and consider potential effects of climate change on limiting factors. As part of this action, the Action Agencies will continue to coordinate with NOAA Fisheries in its efforts to use existing tributary habitat effectiveness studies, IMWs, and the NOAA Fisheries enhanced lifecycle modeling to track climate change impacts. Starting in September 2011, the Action Agencies will annually provide NOAA Fisheries with study data to be used as part of a regional climate change database. After 2011, new climate change findings will be provided to the tributary habitat expert panels to apply and use to help identify and prioritize habitat improvement actions.

The Action Agencies regard the climate science research as limited in the ability to improve understanding of the impact of habitat actions in ameliorating for effects of climate impacts. Given this, the Action Agencies focus is on the ability of habitat action to improve habitat condition and/or species and habitat resilience, believing that increased diversity and resilience can contribute to population persistence in the face of a changing climate. To that end, the Action Agencies continued to coordinate with NOAA in 2014 by sharing habitat effectiveness study results, IMW results, and life cycle model updates. As reported in the 2013 CE, climate change information was shared during the 2012 expert panel process and updates to these data will be shared during the 2016 expert panel process.

The Action Agencies continue to fund the development of climate data and to participate in regional discussions to update thinking on climate change. In 2014, regional meetings were convened by Federal Caucus member agencies and attended by their staff, including Action

Agency staff. When data and information become available the Action Agencies encourage[17] the expert panels to consider climate impacts when evaluating habitat improvement actions and the effect on limiting factors. By looking at the types of actions funded by the tributary habitat program (e.g., riparian restoration, flow acquisition, water conservation, floodplain reconnection; dike, levee, and mine tailing removal; barrier removal; culvert replacement; road improvement and obliteration; establishment of conservation easements; land acquisition the Action Agencies can evaluate whether and to what degree the actions increase diversity or improve resilience as a function of ameliorating for effects from changes in flow quantity, timing, and duration; changes in precipitation patterns; changes in water and air temperature; and changes in vegetation composition.

Amendment 5

Under RPA Action 35, the Action Agencies are identifying tributary habitat projects for implementation based on the population specific overall habitat quality improvement identified in the RPA Action. As part of this action, after 2011, the Action Agencies will include as a consideration in the expert panel project evaluation process (1) the presence of invasive species and (2) site-specific toxicology issues, based on information made available by the appropriate state and Federal agencies.

The action was completed on schedule. When available, the information was considered in preparation for the 2016 panels. Specific citations are included on the Reclamation web site that was made available prior to each workshop in 2015 and 2016. The Action Agencies relied on individual panel members to discuss any of this information during the panel workshops. As necessary, the panel contacted non-panel members in the resource agencies to answer specific questions that could be informed by this information. The Action Agencies documented the circumstances when this occurred, pursuant to recommendations in the 2014 BiOp supplement for documentation of panel deliberations.

Amendment 6

Under RPA Action 64 and under the AMIP Hatchery Effects p. 22, the Action Agencies are supporting efforts to resolve hatchery critical uncertainties. As part of this effort, beginning in December 2010, the Action Agencies will assist NOAA Fisheries to further develop or modify existing studies that address the Ad Hoc Supplementation Workgroup Recommendations Report and that additionally address potential density-dependent impacts of FCRPS hatchery releases on listed species. These studies would provide support for future hatchery management actions to reduce potential adverse hatchery effects. By December 2010, the Action Agencies will work with NOAA Fisheries to convene a technical workgroup with fishery managers to discuss potential studies and potential management tools. The goal for the workgroup will be to complete its work by December 2011.

The CRHEET was proposed, in part, to respond to the AMIP requirement to convene a technical workgroup with fishery managers. NOAA Fisheries has postponed implementation of the CRHEET to allow for the undertaking of an extensive ESA consultation process on FCRPS mitigation hatchery programs (RPA 39). These consultations require significant

[17] *Beyond research to predict changes in timing of flow events; peak and base flows; shifts in air and water temperature; and changes in precipitation patterns the existing body of climate science work is limited insofar as its utility for examining the effect of habitat improvement actions in ameliorating for effects of climate change.*

involvement from many of the people proposed to participate in CRHEET. Recognizing this overlap, BPA agreed with NOAA Fisheries that CRHEET would best be informed by the outcomes of the consultations and so further development of CRHEET has been deferred.

References, Citations, and Sources of Data

ACOE 2013	U.S. Army Corps of Engineers. 2013. Turbine Survival Program Phase II. U.S. Army Corps of Engineers. U.S. Army Corps of Engineers, Turbine Survival Program.
ACOE 2014	U.S. Army Corps of Engineers. 2014. TDG Monitoring Plan for 2015-2018. U.S. Army Corps of Engineers, Northwestern Division, Portland Oregon.
ACOE 2015a	U.S. Army Corps of Engineers. 2015. 2015 Fish Passage Plan. U.S. Army Corps of Engineers, Northwestern Division, Portland Oregon.
ACOE 2015b	U.S. Army Corps of Engineers. 2015. 2015 Total Dissolved Gas Report, Columbia River Basin. U.S. Army Corps of Engineers, Northwestern Division, Portland, Oregon.
ACOE 2016	U.S. Army Corps of Engineers. 2016. 2015 Annual Fish Passage Report, Columbia and Snake Rivers, for Salmon, Steelhead, Shad and Lamprey. U.S. Army Corps of Engineers, Northwestern Division, Portland, Oregon.
Anderson et al. 2012	Anderson J.J., K.D. Ham, and J.L. Gosselin. 2012. Snake River Basin Differential Delayed Mortality Synthesis, Final Report. PNWD-4283, prepared for the US Army Corps of Engineers, Walla Walla District, Walla Walla, Washington, by Battelle–Pacific Northwest Division, Richland, Washington.
Beechie et al. 2008	Beechie, T. J., G. R. Pess, P. Roni, and G. Giannico. 2008. Setting river restoration priorities: a review of approaches and a general protocol for identifying and prioritizing actions. North American Journal of Fisheries Management, 28(3):891-905. http://dx.doi.org/10.1577/M06-174.1
Beechie et al. 2010	Beechie, T. J., D. A. Sear, J. D. Olden, G. R. Pess, J. M. Buffington, H. Moir, P. Roni, and M. M. Pollock. 2010. Process-based Principles for Restoring River Ecosystems. BioScience 60 (3):209-222.
Bellmore and Baxter 2013	Bellmore, J.R. and C.V. Baxter. 2013. Effects of geomorphic process domains on river ecosystems: A comparison of floodplain and confined valley segments. River Research and Applications (2013). John Wiley & Sons Online Library.
Bellmore et al. 2013	Bellmore, J.R., C.V. Baxter, K. Martens, and P.J. Connolly. 2013. The floodplain food web mosaic: a study of its importance to salmon and steelhead with implications for their recovery. Ecological Applications 23(1) 189-207.
Bellmore et al. 2014	Bellmore, J.R., A.K. Fremier, F. Mejia, and M. Newsom. 2014. The response of stream periphyton to Pacific salmon: using a model to understand the role of environmental context. Freshwater Biology (2014) 59, 1437-1452.
Bellmore et al. 2015	Bellmore, J. R., C.V. Baxter, and P.J. Connolly. 2015. Spatial complexity reduces interaction strenghts in the meta-food web of a river floodplain mosaic. Ecology 96(1): 274-283.

Benjamin and Bellmore 2016	Benjamin, J.R., and Bellmore, J.R., 2016, Aquatic trophic productivity model: A decision support model for river restoration planning in the Methow River, Washington: U.S. Geological Survey Open-File Report 2016–1075, 85p., http://dx.doi.org/10.3133/ofr20161075.
Benjamin et al. 2013	Benjamin, J.R., L.A. Wetzel, K.D. Martens, K. Larsen, and P.J. Connolly. 2013. Spatio-temporal variability in movement, age, and growth of mountain whitefish (Prosopium williamsoni) in a river network based on PIT tagging and otolith chemistry. Can. J. Fish Aquat. Sci. 71: 131-140 (2013).
Benjamin et al. 2016	Benjamin, Joseph R., J. Ryan Bellmore, and Grace A. Watson. 2016. Response of ecosystem metabolism to low densities of spawning Chinook salmon. Freshwater Science. 2016. 35(3).
BPA 2013	Bonneville Power Administration (BPA). 2013. Science and the Evaluation of Habitat Improvement Projects in Columbia River Tributaries. Bonneville Power Administration, Portland, Oregon. Available at http://www.usbr.gov/pn/fcrps/habitat/panels/reference/index.html.
BPA and ACOE 2015	Bonneville Power Administration and U.S. Army Corps of Engineers. 2015. Columbia Estuary Ecosystem Restoration Program: 2015 Restoration and Monitoring Plan. Final Report, prepared by the Bonneville Power Administration and U.S. Army Corps of Engineers, Portland, Oregon.
BPA and ACOE 2016	Bonneville Power Administration and U.S. Army Corps of Engineers. 2016. Columbia Estuary Ecosystem Restoration Program: 2016 Restoration and Monitoring Plan. Final Report, prepared by the Bonneville Power Administration and U.S. Army Corps of Engineers, Portland, Oregon.
BPA et al. 2013	Bonneville Power Administration, Corps of Engineers, Bureau of Reclamation, and National Oceanic and Atmospheric Administration. 2013. The Status & Needs of the Columbia Basin PIT Tag Information System as Related to FCRPS BiOp RME Requirements.
BPA et al. 2014a	Bonneville Power Administration, U.S. Army Corps of Engineers, and Bureau of Reclamation. 2014. 2015 Water Management Plan.
BPA et al. 2014b	Bonneville Power Administration, U.S. Army Corps of Engineers, Bureau of Reclamation. 2014. Endangered Species Act Federal Columbia River Power System 2014-2018 Implementation Plan.
BPA et al. 2014c	Bonneville Power Administration, U.S. Army Corps of Engineers, Bureau of Reclamation. 2014. Endangered Species Act Federal Columbia River Power System 2013 Comprehensive Evaluation.
Bracis and Anderson 2013	Bracis, C., and J.J. Anderson. 2013. Inferring the relative oceanic distribution of salmon from patterns in age-specific arrival timing. Transactions of the American Fisheries Society, 142(2), 556-567.

Brown et al. 2013	Brown, R.S., Z.D. Deng, K.V. Cook, B.D. Pflugrath, X. Li, T. Fu, J.J. Martinez, H. Li, and F.O. McMichael. 2013. Performance Evaluation of Externally JSATS-Tagged Subyearling Chinook Salmon. PNNL-22131, Pacific Northwest National Laboratory, Richland, Washington.
Burke et al. 2013a	Burke, B.J., M.C. Liermann, D.J. Teel, and J.J. Anderson. 2013. Environmental and geospatial factors drive juvenile Chinook salmon distribution during early ocean migration. Canadian Journal of Fisheries and Aquatic Sciences 70(8):1167-1177.
Burke et al. 2013b	Burke, B.J., J.J. Anderson, and A.M. Baptista. 2013. Evidence for Navigational Sensory Capabilities of Yearling Chinook Salmon. Pp. 33-37 in 3rd International Workshop on Migration and Survival Mechanisms of Juvenile Salmon and Steelhead in Ocean Ecosystems, edited by N.D. Davis and C. Chan. Honolulu Hawaii: North Pacific Anadromous Fish Commission.
Burke et al. 2016	Burke, B. J., J.J. Anderson, J.A. Miller, L. Tomaro, D.J. Teel, N.S. Banas, and A.M. Baptista. 2016. Estimating behavior in a black box: how coastal oceanographic dynamics influence yearling Chinook salmon marine growth and migration behaviors. Environmental Biology of Fishes, 99(8-9), 671-686.
Carlson et al. 2010	Carlson, T.J., R.S. Brown, J.R. Stephenson, A.J. Gingerich, B.D. Pflugrath, A.H. Colotelo, A.E. Welch, P.L. Benjamin, J.R. Skalski, A.G. Seaburg, and R.L. Townsend. 2010. Assessment of Barotrauma in Untagged and Tagged Juvenile Chinook Salmon Exposed to Simulated Hydro Turbine Passage, PNNL-19625, Pacific Northwest National Laboratory, Richland, Washington.
Coleman et al. 2015	Coleman, A.M., H.L. Diefenderfer, D.L. Ward, and A.B. Borde. 2015. A Spatially Based Area–Time Inundation Index Model Developed to Assess Habitat Opportunity in Tidal–fluvial Wetlands and Restoration Sites. Ecological Engineering 82:624-642.
Collis et al. 2015	Collis, K., D.D. Roby, C. Baird, T. Lawes, A. Wilson, C. Congdon, and A.F. Evans. Monitoring and Predator Control at the Corps-Constructed Caspian Tern Islands in Southeastern Oregon and Northeastern California, 2015. Report submitted to the U.S. Army Corps of Engineers, Portland District, Portland, Oregon.
Collis et al. 2016	Collis, K., D.D. Roby, P.J. Loschl, Y. Suzuki, A. Munes, J. Mulligan, E. Schniedermeyer, A.F. Evans, B. Cramer, A. Turecek, and Q. Payton. 2016. Implementation of the Inland Avian Predation Management Plan, 2015. Report submitted to the U.S. Army Corps of Engineers, Walla Walla District, Walla Walla Washington.
Daly et al. 2015	Daly, E.A., K.E. Dale, and R.D. Brodeur. 2015. Interannual variability in the diets and survival of subyearling Chinook salmon with consideration of oceanographic conditions. Presentation at the Salmon Ocean Ecology Meeting, March 24-26, 2015, Victoria, British Columbia.

Deng et al. 2014	Deng, Z.D., X. Li, T. Fu, R.S. Brown, J.J. Martinez, P.S. Titzler, J.S. Hughes, G.A. McMichael, M.A. Weiland, A.H. Colotelo, J.R. Skalski, and R.L. Townsend. 2014. Depth distribution of yearling and subyearling Chinook salmon and juvenile steelhead. Report of the Pacific Northwest National Laboratory to the US Army Corps of Engineers, Walla Walla District, Walla Walla, Washington.
Deng et al. 2015	Deng, Z., J.P. Duncan, T. Fu, J.L. Arnold. 2015. Post-Construction Evaluation of Ice Harbor Dam Spillbay 2 Ogee and Deflector Modification Using Sensor Fish, 2015. Report of the Pacific Northwest National Laboratory, Richland WA, to the U.S. Department of Energy. PNNL-24886.
Ecovista, 2003	Ecovista. 2003. Draft Clearwater Subbasin Management Plan. Prepared for the Nez Perce Tribe Watershed Division. Available from http://www.nwcouncil.org/fw/subbasinplanning/clearwater/plan
ERTG 2016	ERTG (Expert Regional Technical Group). 2016. Large Wood in Estuaries: Structure, Hydrologic and Ecological Functions, and Influence on Fish Survival. ERTG 2016-01, prepared for the Bonneville Power Administration, U.S. Army Corps of Engineers, and NOAA Fisheries. Portland, Oregon. Available from https://www.cbfish.org/EstuaryAction.mvc/Index.
Faulkner et al. 2016	Faulkner, J.R., D.L. Widener, S.G. Smith, T.M. Marsh, R.W.Zabel. 2016. Survival Estimates for the Passage of Spring-Migrating Juvenile Salmonids through Snake and Columbia River Dams and Reservoirs, 2015. Report of research by Northwest Fisheries Science Center, National Oceanic and Atmospheric Administration, for Bonneville Power Administration, Portland, Oregon.
Favrot and Jonasson 2015	Favrot, S.D., and B.C. Jonasson. 2015. Spring Emigration Reach-Specific Survival and Travel Time of Catherine Creek Juvenile Spring Chinook Salmon Through the Grande Ronde Valley. Prepared for the Bonneville Power Administration, Portland, Oregon, and the Bureau of Reclamation, Boise, Idaho.
FCRPS 2010a	Federal Columbia River Power System. 2010. FCRPS 2010-2013 Implementation Plan.
FCRPS 2010b	Federal Columbia River Power System. 2010 Endangered Species Act Federal Columbia River Power System 2009 Annual Progress Report.
Fish Field Unit	Fish Field Unit. 2016. 2015 Field Report: Evaluation of Pinniped Predation on Adult Salmonids and Other Fish in the Bonneville Dam Tailrace, 2014. Fish Field Unit, U.S. Army Corps of Engineers, Portland District, Cascade Locks, Oregon.
Frick et al. 2015	Frick, K.E., B.J. Burke, J. Garnett, M.A. Jepson, M.L. Keefer, and C.C. Caudill. 2015. Passage evaluation of radio-tagged Chinook and sockeye salmon after modifications at The Dalles and John Day Dams, 2014. Technical Report of NOAA Fisheries and the University of Idaho to U.S. Army Corps of Engineers, Portland District.

Ham et al. 2013	Ham, K.D., P.S. Titzler, and D.M. Trott. 2013. Evaluation of the effect of McNary Dam operating gate position on fish guidance efficiency. Report of the Pacific Northwest National Laboratory to the US Army Corps of Engineers, Walla Walla District, Walla Walla, Washington.
Ham et al. 2015	Ham, K.D., R.P. Mueller, and P.S. Titzler. 2015. Evaluation of adult steelhead passage with TSW spill during the winter of 2014-2015 at McNary Dam. PNNL-24856. Pacific Northwest National Laboratory, Richland, Washington.
Hankin and Richards 2000	Hankin, D.G., and J. Richards. 2000. The Northern Pikeminnow Management Program, An Independent Review of Program Justification, Performance, and Cost-Effectiveness. Humboldt State University, Arcata, CA., and Portland State University, Portland, Oregon
Hanson et al. 2015	Hanson, A., A. Borde, J. Cordell, and M. Ramirez. 2015. Estuary Partnership -- Reed Canarygrass Research – Preliminary Findings. Presentation at a meeting of the Expert Regional Technical Group, September 22, 2015, Portland, OR.
Hartman et al. 2016	Hartman, C.A., Ackerman, J.T., Herzog, M.P., Strong, C., Trachtenbarg, D., Sawyer, K.A., and Shore, C.A., 2016, Evaluation of Caspian tern (*Hydroprogne caspia*) and snowy plover (*Charadrius alexandrinus nivosus*) nesting on modified islands at the Don Edwards San Francisco Bay National Wildlife Refuge, California—2015 Annual Report: U.S. Geological Survey Open-File Report 2016-1049, 36 p., http//dx.doi.org/10.3133/ofr20161049
Howe and Simenstad 2015	Howe, E., and CA Simenstad. 2015. Using isotopic measures of connectivity and ecosystem capacity to compare restoring and natural marshes in the Skokomish River estuary, WA, USA." *Estuaries and Coasts* 38:639–658.
Hughes et al. 2013	Hughes, J.S., M.A. Weiland, C.M. Woodley, G.R. Ploskey, S.M. Carpenter, M.J. Hennen, E.F. Fischer, G.W. Batten III, T.J. Carlson, A.W. Cushing, Z. Deng, D.J. Etherington, T. Fu, M.J. Greiner, M. Ingraham, J. Kim, X. Li, J. Martinez, T.D. Mitchell, B. Rayamajhi, A. Seaburg, J.R. Skalski, R.L. Townsend, K.A. Wagner, and S.A. Zimmerman. 2013. Survival and Passage of Yearling and Subyearling Chinook Salmon and Steelhead at McNary Dam, 2012. PNNL-22788. Report submitted by the Pacific Northwest National Laboratory to the U.S. Army Corps of Engineers, Walla Walla, Washington
ISAB 2014	Independent Scientific Advisory Board. 2014. Review of the Expert Regional Technical Group (ERTG) Process for Columbia River Estuary Habitat Restoration. Report ISAB 2014-1. Northwest Power and Conservation Council, Portland, Oregon.

Jepson et al. 2011	Jepson, M.A., M. L. Keefer, C. C. Caudill, and B. J. Burke. 2011. Behavior of Radio-Tagged Adult Spring-Summer Chinook Salmon at The Dalles Dam in Relation to Spill Volume and the Presence of the Bay 8/9 Spill Wall and at John Day Dam in Relation to North Shore Ladder Modifications, 2010. Idaho Cooperative Fish and Wildlife Research Unit Technical Report 2011-2 for the U. S. Army Corps of Engineers, Portland District, Portland, Oregon.
Johnson et al. 2011	Johnson G.E., J.R. Skalski, T.J. Carlson, G.R. Ploskey, M.A. Weiland, Z. Deng, E.S. Fischer, J.S. Hughes, F. Khan, J.A. Kim, and R.L. Townsend. 2011. Survival and Passage of Yearling and Subyearling Chinook Salmon and Steelhead at The Dalles Dam, 2010. PNNL-20626, Pacific Northwest National Laboratory, Richland, WA.
Li et al. 2015	Li, X., Z.D. Deng, R.S. Brown, T. Fu, J.J. Martinez, G.A. McMichael, J.R. Skalski, R.L. Townsend, B.A. Trumbo, M.L. Ahmann and J.F. Renholds. 2015. Migration depth and residence time of juvenile salmonids in the forebays of hydropower dams prior to passage through turbines or juvenile bypass systems: implications for turbine-passage survival. Conservation Physiology 3: Pages 1-17. doi:10.1093/conphys/cou064.
Lyon and Galloway 2013	Lyon, E.W., Jr., and E. Galloway. 2013. Yankee Fork Fluvial Habitat Rehabilitation Plan, Yankee Fork of the Salmon River, Custer County, Idaho. 2013 working version. Prepared by Bureau of Reclamation and the Shoshone-Bannock Tribes for the Yankee Fork Interdisciplinary Team.
Martens and Connolly 2010	Martens, K.D. and P.J. Connolly. 2010. Effectiveness of a redesigned water diversion using rock vortex weirs to enhance longitudinal connectivity for small salmonids. North American Journal of Fisheries Management 30:1544-1552.
Martens and Connolly 2014	Martens, K.D. and P.J. Connolly. 2014. Juvenile anadromous salmonid production in Upper Columbia River side channels with different levels of hydrologic connection. Transactions of the American Fisheries Society 143: 757-767.
McNatt et al. 2015	McNatt, R, S. Hinton, D. Teel, and D. Bottom. 2015. Use of the Columbia River estuary by interior salmon and steelhead stocks. Presentation at the Conference of the Coastal and Estuarine Research Federation, November 8-12, 2015, Portland, OR. http://www.erf.org/cerf2015.
Mejia et al. 2016	Mejia, F.H., C.V. Baxter, E.K. Berntsen, A.K. Fremier. 2016. Linking groundwater-surface water exchange to food production and salmonid growth. Canadian Journal of Fisheries and Aquatic Sciences.
Monzyk et al. 2009	Monzyk, F.R., B.C. Jonasson, T.L. Hoffnagle, P.J. Keniry, R.W. Carmichael, and P.J. Cleary. 2009. Migration characteristics of hatchery and natural spring Chinook salmon smolts from the Grande Ronde River Basin, Oregon, to Lower Granite Dam on the Snake River. Transactions of the American Fisheries Society 138:1093–1108.

Normandeau 2015	Direct injury and survival of yearling Chinook salmon passing the removable spillway weir following ogee and deflector modifications to spillbay 2 at Ice Harbor Dam, Snake River, 2015. 2015. Prepared by Normandeau Associates for the U.S. Army Corps of Engineers, Walla Walla District, Walla Walla, Washington.
Polivka et al. 2015	Polivka, K.M., E. Ashley Steele, and J.L. Novak. 2015. Juvenile salmon and steelhead occupancy of stream pools treated and not treated with restoration structures, Entiat River, Washington. Can. J. Fish. Aq. Sci. 72:1-9
Rieman and Beamesderfer 1990	Rieman, B.E., and R.C. Beamesderfer. 1990. Dynamics of a northern squawfish population and the potential to reduce predation on juvenile salmonids in a Columbia River Reservoir. North American Journal of Fisheries Management 10:228-241.
Roby et al. 2016a	Roby, D.D., K. Collis, D.E. Lyons, Y. Suzuki, P.J. Loschl, T.J. Lawes, K.S. Bixler, A. Piggott, A. Evans, B. Cramer, A. Turecek, Q. Payton, M. Hawbecker, and D. Kuligowski. 2016. Avian Predation on Juvenile Salmonids: Evaluation of the Caspian Tern Management Plan in the Columbia River Estuary. 2015 Final Annual Report. Prepared for the Bonneville Power Administration, Portland, Oregon.
Roby et al. 2016b	Roby, D.D., K. Collis, D. Lyons, T. Lawes, Y. Suzuki, P. Loschl, K. Bixler, E. Hanwacker, J. Mulligan, A. Munes, E. Schniedermeyer, A. Evans, B. Cramer, A. Turecek, Q. Payton, and M. Hawbecker. Evaluation of Foraging Behavior, Dispersal, and Predation on ESA-listed Salmonids by Caspian Terns Displaced from Managed Colonies in the Columbia Plateau Region. 2015 Final Annual Report. Prepared for the Grant County PUD / Priest Rapids Coordinating Committee.
Roegner et al. 2015	Roegner, C., D. Bottom, A Baptista, L. Campbell, P. Goertler, S. Hinton, R. McNatt, C. Simenstad, D. Teel, and K. Fresh. 2015. Salmon Habitat Use of Tidal-fluvial Habitats of the Columbia River Estuary, 2010-2013. Final Report. Report of research by NOAA Fisheries, Northwest Fisheries Science Center to U.S. Army Corps of Engineers, Portland District, Portland, Oregon.
Romine et al. 2013	Romine, J.G., J.R. Benjamin, R.W. Perry, L. Casal, P.J. Connolly, and S.S. Sauter. 2013. Theoretical life history responses of juvenile *Oncorhynchus mykiss* to changes in food availability using a dynamic state-dependent approach. United States Department of the Interior, Geological Survey Open-File Report 2013-1154.
Roni et al. 2002	Roni, P., T. J. Beechie, R. E. Bilby, F. E. Leonetti, M. M. Pollock, and G. R. Pess. 2002. A Review of Stream Restoration Techniques and a Hierarchical Strategy for Prioritizing Restoration in Pacific Northwest Watersheds. North American Journal of Fisheries Management 22:1–20.
Roni et al. 2008	Roni P., K. Hanson, and T. Beechie. 2008. Global Review of the Physical and Biological Effectiveness of Stream Habitat Rehabilitation Techniques. North American Journal of Fisheries Management 28:856–890.

Skalski et al. 2012a	Skalski, J.R., R.L. Townsend, A. Seaburg, G.R. Ploskey, and T.J. Carlson. 2012. Compliance Monitoring of Yearling Chinook Salmon and Juvenile Steelhead Survival and Passage at Bonneville Dam, Spring 2011. PNNL-21175, Final Report, Pacific Northwest National Laboratory, Richland, Washington.
Skalski et al. 2012b	Skalski, J.R., R.L. Townsend, A.G. Seaburg, G.E. Johnson, and T.J. Carlson. 2012. Compliance Monitoring of Juvenile Yearling Chinook Salmon and Steelhead Survival and Passage at The Dalles Dam, Spring 2011. PNNL-21124, compliance report submitted to the U.S. Army Corps of Engineers, Portland District, Portland, Oregon, by Pacific Northwest National Laboratory, Richland, Washington and the University of Washington, Seattle, Washington.
Skalski et al. 2012c	Skalski, J.R., R.L. Townsend, A. Seaburg, M.A. Weiland, C.M. Woodley, J.S. Hughes, and T.J. Carlson. 2012. Compliance Monitoring of Yearling Chinook Salmon and Juvenile Steelhead Survival and Passage at John Day Dam, Spring 2011. PNNL-21176, Final Report, Pacific Northwest National Laboratory, Richland, Washington.
Skalski et al. 2013a	Skalski, J.R., R.L. Townsend, A. Seaburg, G.R. Ploskey, M.A. Weiland, J.S. Hughes, C.M. Woodley, Z. Deng, and T.J. Carlson. 2013. Compliance Monitoring of Subyearling Chinook Salmon Survival and Passage at Bonneville Dam, Summer 2012. PNNL-22188, Pacific Northwest National Laboratory, Richland, Washington.
Skalski et al. 2013b	Skalski, J.R., R.L. Townsend, A. Seaburg, G.R. Ploskey, M.A. Weiland, J.S. Hughes, C.M. Woodley, Z. Deng, T.J. Carlson, and G.E. Johnson. 2013. Compliance Monitoring of Subyearling Chinook Salmon Survival and Passage at The Dalles Dam, Summer 2012. PNNL-22195, Pacific Northwest National Laboratory, Richland, Washington.
Skalski et al. 2013c	Skalski, J.R., R.L. Townsend, A. Seaburg, M.A. Weiland, C.M. Woodley, J.S. Hughes, G.R. Ploskey, Z. Deng, and T.J. Carlson. 2013. Compliance Monitoring of Yearling and Subyearling Chinook Salmon and Juvenile Steelhead Survival and Passage at John Day Dam, 2012 . PNNL-22152, Pacific Northwest National Laboratory, Richland, Washington.
Skalski et al. 2013d	Skalski, J.R., R.L. Townsend, A.G. Seaburg, G.A. McMichael, R.A. Harnish, E.W. Oldenburg, K.D. Ham, A.H. Colotelo, K.A. Deters, and Z.D. Deng. 2013. BiOp Performance Testing: Passage and Survival of Yearling and Subyearling Chinook Salmon and Juvenile Steelhead at Lower Monumental Dam, 2012. PNNL-22100, Pacific Northwest National Laboratory, Richland, Washington.
Skalski et al. 2013e	Skalski, J.R., R.L. Townsend, A.G. Seaburg, G.A. McMichael, E.W. Oldenburg, R.A. Harnish, K.D. Ham, A.H. Colotelo, K.A. Deters, and Z.D. Deng. 2013. BiOp Performance Testing: Passage and Survival of Yearling and Subyearling Chinook Salmon and Juvenile Steelhead at Little Goose Dam, 2012. PNNL-22140, Pacific Northwest National Laboratory, Richland, Washington.

Skalski et al. 2014	Skalski J.R., R.L. Townsend, A.G. Seaburg, G.A. McMichael, R.A. Harnish, E.W. Oldenburg, K.D. Ham, A.H. Colotelo, K.A. Deters, Z.D. Deng, P.S. Titzler, E.V. Arntzen, and C.R. Vernon. 2014. FINAL BiOp Performance Testing: Passage and Survival of Subyearling Chinook Salmon at Little Goose and Lower Monumental Dams, 2013. PNNL-22706, Pacific Northwest National Laboratory, Richland, Washington.
Skalski et al. 2015a	Skalski, J.R., R.L. Townsend, M.A. Weiland, C.M. Woodley, and J. Kim. 2014. Compliance Monitoring of Subyearling Chinook Salmon Survival and Passage at John Day Dam, 2014. PNNL-23951, Pacific Northwest National Laboratory, Richland, Washington.
Skalski et al. 2015b	Skalski, J.R., R.L. Townsend, M.A. Weiland, C.M. Woodley, and J. Kim. 2014. Compliance Monitoring of Yearling and Subyearling Chinook Salmon and Juvenile Steelhead Survival and Passage at McNary Dam, 2014. PNNL-23979, Pacific Northwest National Laboratory, Richland, Washington.
Tackley and Clugston 2011	Tackley, S. and D. Clugston. 2011. Estimated benefits of operating the Ice and Trash Sluiceway (ITS) at The Dalles Dam from December 1-15 and March 1-April 10 for overwintering steelhead and out-migrating steelhead kelts. Portland, OR. US Army Corps of Engineers, Portland District. Memorandum for the Record.
TMT 2015a	Technical Management Team. 2015. Columbia River Regional Forum Technical Management Team Year End Review, December 2, 2015, Facilitators' Summary. Available from U.S. Army Corps of Engineers, Northwestern Division, Portland, Oregon.
TMT 2015b	Technical Management Team. 2015. Columbia River Regional Forum Technical Management Team Annual Review of Lessons Learned – 2015. Downloaded March 23, 2016, from http://www.nwd-wc.usace.army.mil/tmt/agendas/2015/1202_Agenda.html.
Trumbo et al. 2013	Trumbo, B., M. Shutters, M. Ahmann, J. Renholds, S. Nelson and K. Crum. 2013. Statistical and Biological Study Design Options to Evaluate New Turbine Runners Designed for Safer Fish Passage at Ice Harbor Dam on the Lower Snake River, Washington. U.S. Army Corps of Engineers, Walla Walla District, Walla Walla, Washington.
Trumbo et al. 2014	Trumbo, B.A., M.L. Ahmann, J.F. Renholds, R.S. Brown, A.H. Colotelo and Z.D. Deng. 2014. Improving hydroturbine pressures to enhance salmon passage survival and recovery. Reviews in Fish Biology and Fisheries 24:955-965 DOI: 10.1007/s11160-013-9340-8.
USGS 2014a	USGS. 2014. Methow River Studies, Washington-Abundance estimates from Beaver Creek and the Chewuch River Screw Trap, Methodology testing in the Whitefish Island side channel, and survival and detection estimates from hatchery releases, 2013. USGS Open-File Report 2014-1154.
USGS 2014b	USGS. 2014. Methow and Columbia River Studies, Washington-Summary of data collection, comparison of database structure and habitat protocols, and impact of additional PIT tag interrogation systems to survival estimates, 2008-2012. USGS Open-File Report 2014-1016.

Weigel et al. 2013a	Weigel, D.E., P.J. Connolly, K.D. Martens, and M.S. Powell. 2013. Colonization of steelhead in a native stream after barrier removal. Transactions of the American Fisheries Society 142:4, 920-930.
Weigel et al. 2013b	Weigel, D.E., P.J. Connolly, and M.S. Powell. 2013. Fluvial rainbow trout contribute to the colonization of steelhead (*Oncorhynchus mykiss*) in a small stream. Environ. Biol. Fish. Springer Online. doi:10.1007/s10641-013-0204-9
Weiland et al. 2015	Weiland, M.A, C.M. Woodley, T.J. Carlson, B. Rayamajhi, and J. Kim. 2015. Systematic Review of JSATS Passage and Survival Data at Bonneville and The Dalles Dams during Alternate Turbine and Spillbay Operations from 2008–2012. PNNL-24260. Pacific Northwest National Laboratory, Richland, Washington.
Weitkamp et al. 2015	Weitkamp, L, DJ Teel, M Liermann, SA Hinton, DM Van Doornik, and PJ Bentley. 2015. Stock-specific size and timing at ocean entry of Columbia River juvenile Chinook salmon and steelhead: implications for early ocean growth. *Marine and Coastal Fisheries: Dynamics, Management, and Ecosystem Science* 7:370–392.

Acronyms

The “Action Agencies” refers to Bonneville Power Administration, the U.S. Army Corps of Engineers Northwestern Division, and the U.S. Bureau of Reclamation Pacific Northwest Region. Any references in this report to “we” or “us,” or to “our” activities, etc., refer collectively to these agencies.

AEM	Action Effectiveness Monitoring
AFEP	Anadromous Fish Evaluation Program
AMIP	Adaptive Management Implementation Plan
ASMS	Anadromous Salmonid Monitoring Strategy
ATIIM	Area-Time Inundation Index Model
BA	Biological Assessment
BiOp	Biological Opinion
BPA	Bonneville Power Administration
CBFWA	Columbia Basin Fish and Wildlife Authority
cfs	cubic feet per second
CEERP	Columbia Estuary Ecosystem Restoration Plan
CEQUAL-W2	Two dimensional (longitudinal/vertical), hydrodynamic and water quality model
CHaMP	Columbia Habitat Monitoring Program
c.i.	confidence interval (or, for Bayesian statistics, credible interval)
COMPASS	COMprehensive Fish PASSage Model
COP	Configuration and Operational Plan
Corps	U.S. Army Corps of Engineers
CREST	Columbia River Estuary Study Taskforce
CRFG	Columbia River Forecast Group, formed by the Action Agencies and Fish Accord partners
CRHEET	Columbia River Hatchery Effects Evaluation Team
CRITFC	Columbia River Inter-tribal Fish Commission
CRTOC	Columbia River Treaty Operating Committee
CSS	Comparative Survival Study
CTUIR	Confederated Tribes of the Umatilla Indian Reservation
CWT	coded wire tag
DART	Data Access in Real Time
DEIS	Draft Environmental Impact Statement
DIDSON	dual frequency identification sonar
DMLT	Data Management Leadership Team
DPS	distinct population segment
EIS	Environmental Impact Statement
ERTG	Expert Regional Technical Group
ESA	Endangered Species Act
ESP	Ensemble Streamflow Prediction
ESU	evolutionarily significant unit
FCRPS	Federal Columbia River Power System
FEIS	Final Environmental Impact Statement
FFDRWG	Fish Facility Design Review Workgroup
FGE	fish guidance efficiency
FONSI	Finding of No Significant Impact
FOP	Fish Operations Plan
FPC	Fish Passage Center

FPOM	Fish Passage Operations and Maintenance Workgroup
FPP	Fish Passage Plan
FRM	flood risk management
GBT	gas bubble trauma
GSI	genetic stock identification
HGMP	Hatchery and Genetic Management Plan
HQI	Habitat Quality Improvement
HRPP	Hood River Production Plan
IAPMP	Inland Avian Predation Management Plan
IDFG	Idaho Department of Fish and Game
IMW	intensively monitored watershed
ISAB	Independent Scientific Advisory Board
ISEMP	Integrated Status and Effectiveness Monitoring Program
ISRP	Independent Scientific Review Panel
ISTM	PNAMP's Integrated Status and Trends Monitoring program
JSATS	Juvenile Salmon Acoustic Telemetry System
kaf	thousand acre feet
kcfs	thousand cubic feet per second
km	kilometers
KMP	Kelt Management Plan
LCRE	Lower Columbia River and Estuary
LCEP	Lower Columbia Estuary Partnership, formerly the Lower Columbia River Estuary Partnership or LCREP
LRISRP	Lake Roosevelt Incremental Storage Release Program
Maf	million acre-feet
MCE	minimum control elevation
MOP	minimum operating pool
MPG	major population group
NED	Northwest Environmental Database
NEPA	National Environmental Policy Act
NFH	National Fish Hatchery
NMFS	NOAA's National Marine Fisheries Service
NOAA Fisheries	Alternative designation for National Oceanic and Atmospheric Administration's National Marine Fisheries Service
NPCC	Northwest Power and Conservation Council
NPMP	Northern Pikeminnow Management Program
NPT	Nez Perce Tribe
NTS	non-treaty storage
NTSA	Non-Treaty Storage Agreement
NWFSC	Northwest Fisheries Science Center
NWRFC	Northwest River Forecast Center
ODFW	Oregon Department of Fish and Wildlife
PH2	Second Powerhouse (Bonneville Dam)
pHOS	percentage of hatchery-origin fish on the spawning grounds
PIT	Passive Integrated Transponder
PNAMP	Pacific Northwest Aquatic Monitoring Partnership
PNNL	Pacific Northwest National Laboratory
PSMFC	Pacific States Marine Fisheries Commission
PTAGIS	PIT Tag Information System
Reclamation	U.S. Bureau of Reclamation
RIOG	Regional Implementation Oversight Group
rkm	river kilometer
RME or RM&E	research, monitoring, and evaluation

RMJOC	River Management Joint Operating Committee
RPA	Reasonable and Prudent Alternative
RPM	Reasonable and Prudent Measure
SAR	smolt-to-adult return ratio
SBU	Survival Benefit Unit
SLED	sea lion exclusion device
SMP	Smolt Monitoring Program
SYSTDG	System Total Dissolved Gas
TDG	total dissolved gas
TMT	Technical Management Team
USDA	U.S. Department of Agriculture
USFWS	U.S. Fish and Wildlife Service
USGS	U.S. Geological Survey
VARQ	variable outflow flood risk management procedure
VDL	variable draft limit
WDFW	Washington Department of Fish and Wildlife
WMP	Water Management Plan
WSF	water supply forecast
YKFP	Yakima/Klickitat Fisheries Project
YN	Yakama Nation

Appendix A – Action Agency 2007-2016 Tributary Habitat Projects

Table A-1. 2015 tributary habitat completed metrics. All Chinook projects on this list also benefit steelhead, and therefore show up again in the steelhead projects portion of this table. As a result, the "Total Steelhead (All DPSs)" numbers on the last row of this table provide valid metrics for the tributary habitat restoration program as a whole, e.g., the total length of all streams with improved access.

			Water Quantity		Entrain-ment	Passage		Channel Complexity	Water Quality Riparian Protection and Enhancement			
ESU/DPS	MPG	Population* (18 Priority Populations in Bold)	Acre-feet Protected	CFS protected	# of screens addressed	# of barriers addressed	Stream miles with improved access	Instream miles improved	Stream miles protected	Stream miles improved	Riparian acres protected	Riparian acres improved
Snake River Spring/ Summer-run Chinook Salmon ESU	Dry Clearwater	Lapwai/Big Canyon	0	0	0	0	0	0	0	0.26	0	1.28
		Potlatch River	0	0	0	1	35.00	0	0	1.75	12.00	55.55
		Laywer Creek	0	0	0	0	0	0	0	0	0	0
		Upper South Fork Clearwater	0	0	0	6	17.20	0	0	0.60	0	12.45
	Grande Ronde /Imnaha	**Catherine Creek**	815.10	5.05	0	2	8.07	2.00	3.00	8.75	28.00	27.52
		Big Sheep Creek	0	0	0	0	0	0	0	0	0	0
		Grande Ronde River upper mainstem	168.00	1.69	0	1	0	5.30	35.60	15.29	373.00	212.72
		Imnaha River mainstem	0	0	0	0	0	0	0	0	0	0
		Lostine River	1,980.00	25.00	0	0	0	0	0	0	0	0.28
	Lower Snake	Asotin Creek	0	0	0	0	0	0	0	0	0	0
		Tucannon River	0	0	0	1	0	4.75	0	1.28	0	63.86
	Middle Fork Salmon River	Big Creek	0	0	0	0	0	0	0	0	0	0
		Camas Creek	0	0	0	0	0	0	0	0	0	0
		Marsh Creek	0	0	0	0	0	0	0	0	0	0
		Chamberlain Creek	0	0	0	0	0	0	0	0	0	0
	South Fork Salmon River	East Fork South Fork Salmon River	0	0	0	0	0	0	0	0	0	0
		Little Salmon River	0	0	0	2	2.60	0	0	0	0	0
		Secesh River	0	0	0	0	0	0	0	0	0	2.00
		South Fork Salmon River mainstem	0	0	0	0	0	0	0	0	0	0

			Water Quantity		Entrain-ment	Passage		Channel Complexity	Water Quality Riparian Protection and Enhancement			
ESU/DPS	MPG	Population* (18 Priority Populations in Bold)	Acre-feet Protected	CFS protected	# of screens addressed	# of barriers addressed	Stream miles with improved access	Instream miles improved	Stream miles protected	Stream miles improved	Riparian acres protected	Riparian acres improved
Snake River Spring/ Summer-run Chinook Salmon ESU (cont)	Upper Salmon River	East Fork Salmon River	0	0	0	0	0	0	0	0	0	0
		Lemhi River	1502.10	20.55	2	1	3.20	0	0.42	0.97	10.06	22.20
		Pahsimeroi River	0	0	3	4	12.30	0	0.71	2.00	40.00	6.00
		Panther Creek	0	0	0	0	0	0	0	0	0	0
		Salmon River lower mainstem below Redfish Lake Creek	659.00	4.13	2	2	8.70	0	0	0	0	0
		Salmon River upper mainstem above Redfish Lake Creek	834.00	5.90	2	2	20.00	0	3.40	0	2.40	0
		Valley Creek	0	0	0	0	0	0	0	0	0	0
		Yankee Fork	0	0	0	1	0	8.71	0	0	0	1.54
	Wet Clearwater	Lochsa River	0	0	0	0	0	0	0	25.00	0	0
		Meadow Creek	0	0	0	0	0	0	0	0	0	0
		Lolo Creek	0	0	0	0	0	0	0	2.00	0	1.00
Snake River Spring/Summer-run Chinook Salmon ESU		ESU Total:	**5958.20**	**62.32**	**9.00**	**23.00**	**107.07**	**20.76**	**43.13**	**57.90**	**465.46**	**406.40**
Upper Columbia River Spring-run Chinook Salmon ESU	Upper Columbia/East Slope Cascades	**Entiat River**	86.40	0.29	0	2	0	0.12	0	1.10	0	1.58
		Methow River	3251.40	11.26	1	2	10.00	2.85	0	0.26	0	3.34
		Wenatchee River	0	0	0	0	0	0.96	0	0	0	0
Upper Columbia River Spring-run Chinook Salmon ESU		ESU Total:	**3,337.80**	**11.55**	**1.00**	**4.00**	**10.00**	**3.93**	**0**	**1.36**	**0**	**4.92**
TOTAL Chinook Salmon (All ESUs)			9,296.00	73.87	10.00	27.00	117.07	24.69	43.13	59.26	465.46	411.32

			Water Quantity		Entrain-ment	Passage		Channel Complexity	Water Quality Riparian Protection and Enhancement			
ESU/DPS	MPG	Population* (18 Priority Populations in Bold)	Acre-feet Protected	CFS protected	# of screens addressed	# of barriers addressed	Stream miles with improved access	Instream miles improved	Stream miles protected	Stream miles improved	Riparian acres protected	Riparian acres improved
Middle Columbia River Steelhead DPS	Cascades Eastern Slope Tributaries	Deschutes River - eastside	0	0	0	2	0	0.07	0	2.21	0	0.52
		Deschutes River - westside	742.00	1.75	0	0	0	0	0	0	0	0
		Fifteenmile Creek (winter run)	1,147.80	4.58	0	0	0	0	0	0	0	0
		Klickitat River	0	0	0	0	0	0.50	0	2.93	0	10.90
		Rock Creek	0	0	0	0	0	0	0	0	0	1.00
		White Salmon River	136.00	0.88	0	0	0	0	0	0	0	0
		Crooked River	0	0	0	0	0	0	0	0	0	0
	John Day River	John Day River lower mainstem tributaries	0.40	0.01	7	12	46.24	11.92	27.75	14.50	499.45	23.00
		John Day River upper mainstem	4337.10	19.03	6	8	38.33	0	13.60	2.00	75.00	25.00
		Middle Fork John Day River	0	0	0	2	18.31	2.7	7.60	1.00	140.00	105.00
		North Fork John Day River	0	0	2	3	19.50	0.14	17.20	0.21	190.00	0.25
		South Fork John Day River	0	0	0	0	0	0	2.00	0	25.00	0
	Umatilla and Walla Walla River	Touchet River	239.00	2.08	0	0	0	0.75	6.00	0.75	300.00	7.00
		Umatilla River	467.00	2.79	0	0	0	0	0	8.16	425.00	28.94
		Walla Walla River	4,022.90	23.81	0	5	193.20	1.50	0	0.75	0	30.00
		Willow Creek	0	0	0	0	0	0	0	0	0	0
	Yakima River Group	Naches River	0	0	2	0	0	2.00	0	0	0	0
		Satus Creek	0	0	0	0	0	0	4.00	0	100.00	200.00
		Toppenish	0	0	0	0	0	0	0	2.00	0	6.00
		Yakima River upper mainstem	842.60	8.29	2	3	16.50	0.30	15.00	0	0	0
Middle Columbia River Steelhead DPS		DPS Total:	**11,934.80**	**63.22**	**19.00**	**35**	**332.08**	**19.88**	**93.15**	**34.51**	**1,754.45**	**437.61**

			Water Quantity		Entrain-ment	Passage		Channel Complexity	Water Quality Riparian Protection and Enhancement			
ESU/DPS	MPG	Population* (18 Priority Populations in Bold)	Acre-feet Protected	CFS protected	# of screens addressed	# of barriers addressed	Stream miles with improved access	Instream miles improved	Stream miles protected	Stream miles improved	Riparian acres protected	Riparian acres improved
Snake River Basin Steelhead DPS	Clearwater River	Clearwater River lower mainstem	0	0	0	1	35.00	0	0	2.01	12.00	56.83
		Lochsa River	0	0	0	0	0	0	0	25.00	0	0
		Lolo Creek	0	0	0	0	0	0	0	2.00	0	1.00
		Selway River	0	0	0	0	0	0	0	0	0	0
		South Fork Clearwater River	0	0	0	6	17.20	0	0	0.60	0	12.45
	Grande Ronde River	Grande Ronde River lower mainstem tributaries	0	0	0	0	0	0	1.00	0	5.00	0
		Grande Ronde River upper mainstem	983.10	6.74	0	3	8.07	7.30	38.60	24.04	401.00	240.24
		Joseph Creek	0	0	0	0	0	0	0	0	0	0
		Wallowa River	1,980.00	25.00	0	0	0	0	0	0	0	0.28
	Imnaha River	Imnaha River	0	0	0	0	0	0	0	0	0	0
	Lower Snake	Asotin Creek	0	0	0	0	0	0	0.20	0	1.00	2.00
		Tucannon River	0	0	0	1	0	4.75	0	1.28	0	63.86

			Water Quantity		Entrain-ment	Passage		Channel Complexity	Water Quality Riparian Protection and Enhancement			
ESU/DPS	MPG	Population* (18 Priority Populations in Bold)	Acre-feet Protected	CFS protected	# of screens addressed	# of barriers addressed	Stream miles with improved access	Instream miles improved	Stream miles protected	Stream miles improved	Riparian acres protected	Riparian acres improved
Snake River Basin Steelhead DPS (cont)	Salmon River	**Big, Camas, and Loon Creek**	0	0	0	0	0	0	0	0	0	0
		East Fork Salmon River	659.00	4.13	2	2	8.70	0	0	0	0	0
		Chamberlain Creek	0	0	0	0	0	0	0	0	0	0
		Lemhi River	1,502.10	20.55	2	1	3.20	0	0.42	0.97	10.06	22.20
		Middle Fork Salmon River upper mainstem	0	0	0	0	0	0	0	0	0	0
		Little Salmon and Rapid River	0	0	0	2	2.60	0	0	0	0	0
		Pahsimeroi River	0	0	3	4	12.30	0	0.71	2.00	40.00	6.00
		Panther Creek	0	0	0	0	0	0	0	0	0	0
		Salmon River upper mainstem	834.00	5.90	2	3	20.00	8.71	3.40	0	2.40	1.54
		Secesh River	0	0	0	0	0	0	0	0	0	2.00
		South Fork Salmon River	0	0	0	0	0	0	0	0	0	0
Snake River Basin Steelhead DPS		DPS Total:	**5,958.20**	**62.32**	**9.00**	**23.00**	**107.07**	**20.76**	**44.33**	**57.90**	**471.46**	**408.40**
Upper Columbia River Steelhead DPS	Upper Columbia / East Slope Cascades	**Entiat River**	86.40	0.29	0	2	0	0.12	0	1.10	1.58	0
		Methow River	3,251.40	11.26	1	2	10.00	2.85	0	0.26	3.34	0
		Okanogan River	0	0	11	1	12.00	0.35	0	0	5.00	0
		Wenatchee River	0	0	0	0	0	0.96	0	0	0	0
		Crab Creek	0	0	0	0	0	0	0	0	40.00	0
Upper Columbia River Steelhead DPS		DPS Total:	**3,337.80**	**11.55**	**12.00**	**5.00**	**22.00**	**4.28**	**0**	**1.36**	**0.00**	**0.00**
TOTAL Steelhead (All DPSs)			21,230.80	137.09	40.00	63	461.15	44.92	137.48	93.77	1756.85	846.01

Table A-2. HQI Table.

ESU/DPS	Major Population Group (MPG)	Population	HQI BiOp Commitment	HQI Through 2015	HQI Through 2018	Rollup Without Multiplier	HQI Multiplier Based on ICTRT Population Size [1]	HQI BiOp Commitment Adjusted	HQI Through 2015 Adjusted	HQI Through 2018 Adjusted	MPG Percentage HQI Through 2018 Adjusted [2]
Snake River Spring/ Summer Chinook	**Lower Snake**	Tucannon River	17	28.2	33.3		1.5	25.5	42.3	50.0	
		MPG TOTAL	**17**	**28.2**	**33.3**	**196%**		**25.5**	**42.3**	**50.0**	**196%**
	Grand Ronde/ Imnaha	Catherine Creek	23	10.8	16.3		1.5	34.5	16.2	24.5	
		Lostine/Wallowa River	2	6.2	11.5		2	4.0	12.4	23.0	
		Grand Ronde River upper mainstem	23	6.6	9.4		1.5	34.5	9.9	14.1	
		Imnaha River mainstem	1	1.0	1.0		1.5	1.5	1.5	1.5	
		MPG TOTAL	**49**	**24.6**	**38.2**	**78%**		**74.5**	**40.0**	**63.1**	**85%**
	S.F. Salmon	Secesh River	1	6.0	9.0		1.5	1.5	9.0	13.5	
		South Fork Salmon River Mainstem	<1[3]	3.9	7.4		2	2.0	7.8	14.8	
		MPG TOTAL	**2**	**9.9**	**16.4**	**820%**		**3.5**	**16.8**	**28.3**	**809%**

[1] The ICTRT population size categories for spring-summer Chinook are basic (500 individuals.); intermediate (750 individuals.); large (1,000 individuals); and very large (2,000 individuals.). The ICTRT population size categories for summer steelhead are basic (500 individuals.); intermediate (1,000 individuals.) and large (1,500 individuals). Based on this we used multipliers of 1, 1.5, 2.0, and 4 for spring-summer Chinook and 1, 2, and 3 for steelhead per the discussion in Appendix D of the 2014-2018 Implementation Plan.

[2] Represents the percent of the Action Agencies commitment delivered through 2018. Calculated based on the sum of the HQI Through 2018 Adjusted divided by the sum of the HQI BiOp Commitment Adjusted.

[3] Where the 2008 BiOp Table 5 HQI is "<1," the value of 1 was used to calculate HQI values. In this way, the calculation takes a conservative approach.

ESU / DPS	Major Population Group (MPG)	Population	HQI BiOp Commitment	HQI Through 2015	HQI Through 2018	Rollup Without Multiplier	HQI Multiplier Based on ICTRT Population Size [1]	HQI BiOp Commitment Adjusted	HQI Through 2015 Adjusted	HQI Through 2018 Adjusted	MPG Percentage HQI Through 2018 Adjusted [2]
Snake River Spring / Summer Chinook (cont.)	**M.F. Salmon**	Big Creek	1	0.6	1.2		2	2.0	1.2	2.4	
		MPG TOTAL	**1**	**0.6**	**1.2**	**120%**		**2.0**	**1.2**	**2.4**	**120%**
	Upper Salmon	East Fork Salmon River	1	2.0	2.0		2	2.0	4.0	4.0	
		Lemhi River	7	44.9	64.1		4	28.0	179.6	256.4	
		Pahsimeroi River	41	79.3	94.0		2	82.0	158.6	188.0	
		Salmon River Lower Main Below Redfish	1	3.5	3.9		4	4.0	14.0	15.6	
		Salmon River Upper Main Above Redfish Lake Creek	14	16.9	27.3		2	28.0	33.8	54.6	
		Valley Creek	1	12.6	14.5		1	1.0	12.6	14.5	
		Yankee Fork	30	30.6	35.8		1	30.0	30.6	35.8	
		MPG TOTAL	**95**	**189.8**	**241.6**	**254%**		**175.0**	**433.2**	**568.9**	**325%**
ESU TOTAL			**164**	**253.1**	**330.7**	**202%**		**280.5**	**533.5**	**712.7**	**254%**

Upper Columbia Spring Chinook	**Upper Columbia Below Chief Joseph**	Entiat River	22	9.0	20.3		1	22.0	9.0	20.3	
		Methow River	6	5.7	8.3		4	24.0	22.8	33.2	
		Wenatchee River	3	2.8	3.7		4	12.0	11.2	14.8	
		MPG TOTAL	**30**	**17.5**	**32.3**	**104%**		**58.0**	**43.0**	**68.3**	**118%**
ESU TOTAL			**31**	**17.5**	**32.3**	**104%**		**58.0**	**43.0**	**68.3**	**118%**

ESU/DPS	Major Population Group (MPG)	Population	HQI BiOp Commitment	HQI Through 2015	HQI Through 2018	Rollup Without Multiplier	HQI Multiplier Based on ICTRT Population Size [1]	HQI BiOp Commitment Adjusted	HQI Through 2015 Adjusted	HQI Through 2018 Adjusted	MPG Percentage HQI Through 2018 Adjusted [2]
Snake River Steelhead	**Clearwater River**	Lochsa River	16	6.3	6.9		2	32.0	12.6	13.8	
		Lolo Creek	12	7.1	8.8		1	12.0	7.1	8.8	
		Selway River	<1	0.5	1.2		2	2.0	1.0	2.4	
		Clearwater Lower Main	N/A	1.9	2.6		3	0	5.7	7.8	
		S. F. Clearwater River	14	7.0	8.9		2	28.0	14.0	17.8	
		MPG TOTAL	**43**	**22.8**	**28.4**	**66%**		**74.0**	**40.4**	**50.6**	**68%**
	Grand Ronde River	Grand Ronde River Lower Main Tribs	<1	0.1	0.2		1	1.0	0.1	0.2	
		Grand Ronde River Upper Main	4	3.8	4.9		3	12.0	11.4	14.7	
		Joseph Creek (OR)	<1	0.4	0.5		1	1.0	0.4	0.5	
		Joseph Creek (WA)	4	4.0	4.0		1	4.0	4.0	4.0	
		Wallowa River	<1	5.4	6.0		2	2.0	10.8	12.0	
		MPG TOTAL	**11**	**13.7**	**15.6**	**142%**		**20.0**	**26.7**	**31.4**	**157%**
	Hells Canyon	Hells Canyon	N/A	N/A	N/A		N/A	N/A	N/A	N/A	
		MPG TOTAL	N/A	N/A	N/A	N/A		N/A	N/A	N/A	N/A
	Imnaha River	Imnaha River	<1	1.2	1.3		2	2.0	2.4	2.6	
		MPG TOTAL	**1**	**1.2**	**1.3**	**130%**		**2.0**	**2.4**	**2.6**	**130%**

ESU / DPS	Major Population Group (MPG)	Population	HQI BiOp Commitment	HQI Through 2015	HQI Through 2018	Rollup Without Multiplier	HQI Multiplier Based on ICTRT Population Size [1]	HQI BiOp Commitment Adjusted	HQI Through 2015 Adjusted	HQI Through 2018 Adjusted	MPG Percentage HQI Through 2018 Adjusted [2]
Snake River Steelhead (cont.)	**Lower Snake**	Asotin River	4	7.0	8.3		1	4.0	7.0	8.3	
		Tucannon River	5	6.4	7.7		2	10.0	12.8	15.4	
		MPG TOTAL	**9**	**13.4**	**16.0**	**178%**		**14.0**	**19.8**	**23.7**	**169%**
	Salmon River	Lower Middle Fork Main (Big, Camas, Loon)	2	0.5	1.2		3	6.0	1.5	3.6	
		E.F. Salmon R.	2	3.8	4.2		2	4.0	7.6	8.4	
		Lemhi River	3	37.9	55.0		2	6.0	75.8	110.0	
		Pahsimeroi River	9	42.2	50.6		2	18.0	84.4	101.2	
		Salmon River Upper Main	6	16.4	22.9		2	12.0	32.8	45.8	
		Secesh River	6	5.7	7.1		1	6.0	5.7	7.1	
		S.F. Salmon R.	1	2.8	3.7		2	2.0	5.6	7.4	
		MPG TOTAL	**29**	**109.3**	**144.7**	**500%**		**54.0**	**209.6**	**279.3**	**525%**
DPS TOTAL			**92**	**159.9**	**205.3**	**223%**		**163.0**	**302.2**	**391.1**	**240%**

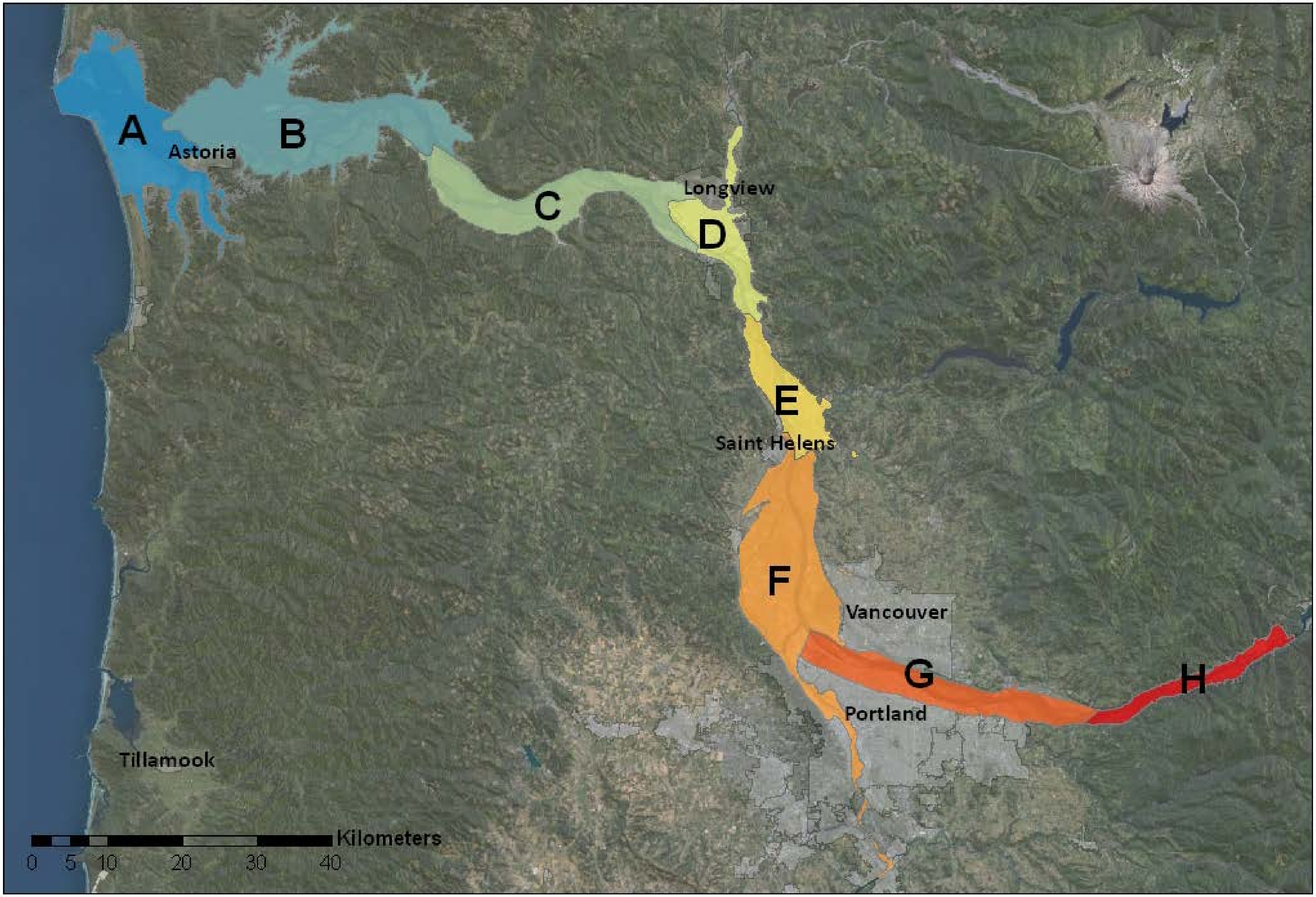
Upper Columbia Steelhead	**Upper Columbia Below Chief Joseph**	Entiat River	8	6.7	14.5		1	8.0	6.7	14.5	
		Methow River	4	5.2	7.2		2	8.0	10.4	14.4	
		Okanogan River	14	15.8	22.4		1	14.0	15.8	22.4	
		Wenatchee River	4	3.3	3.9		2	8.0	6.6	7.8	
		MPG TOTAL	**30**	**31.0**	**48.0**	**160%**		**38.0**	**39.5**	**59.1**	**156%**
DPS TOTAL			**30**	**31.0**	**48.0**	**160%**		**38.0**	**39.5**	**59.1**	**156%**

ESU / DPS	Major Population Group (MPG)	Population	HQI BiOp Commitment	HQI Through 2015	HQI Through 2018	Rollup Without Multiplier	HQI Multiplier Based on ICTRT Population Size [1]	HQI BiOp Commitment Adjusted	HQI Through 2015 Adjusted	HQI Through 2018 Adjusted	MPG Percentage HQI Through 2018 Adjusted [2]
Mid-Columbia Steelhead	**Yakima River group**	Yakima River upper mainstem	4	4	4						
		Naches River	4	4	4						
		Toppinish	4	4	4						
		Satus Creek	4	4	4						
		MPG TOTAL									
	Cascade Eastern Slope Tributaries	Deschutes River westside	<1	<1	<1						
		Deschutes River eastside	1	1	1						
		Klickitat River	4	4	4						
		Fifteen Mile Creek	1	1	1						
		MPG TOTAL									
	Umatilla and Walla Wall Rivers	Umatilla River	4	4	4						
		Walla Walla River	4	4	4						
		Touchet	4	4	4						
		MPG TOTAL									

ESU / DPS	Major Population Group (MPG)	Population	HQI BiOp Commitment	HQI Through 2015	HQI Through 2018	Rollup Without Multiplier	HQI Multiplier Based on ICTRT Population Size [1]	HQI BiOp Commitment Adjusted	HQI Through 2015 Adjusted	HQI Through 2018 Adjusted	MPG Percentage HQI Through 2018 Adjusted [2]
Mid-Columbia Steelhead (cont.)	**John Day River**	John Day River lower mainstem tributaries	<1	<1	<1						
		North Fork John Day River	<1	<1	<1						
		John Day River upper mainstem	<1	<1	<1						
		Middle Fork John Day River	<1	<1	<1						
		South Fork John Day River	1	1	1						
		MPG TOTAL									
DPS TOTAL											

Appendix B – Action Agency 2007-2016 Estuary Habitat Projects

Reaches of the Lower Columbia River and Estuary



Appendix B – Table B-1. Action Agency 2007–2016 Estuary Habitat Projects

Regarding "Estuary Module Action" types in Table B-1:

***CRE 1.3**: Actively purchase riparian areas in urban and rural settings that (1) cannot be effectively protected through regulation, (2) are intact, or (3) are degraded but have good restoration potential*

***CRE 1.4**: Restore and maintain ecological benefits in riparian areas; this includes managing vegetation on dikes and levees to enhance ecological function and adding shoreline/instream complexity for juvenile salmonid refugia*

***CRE 6.2**: Identify and implement dredged material beneficial use demonstration projects, including the notching and scrape-down of previously disposed materials and placement of new materials for habitat enhancement and/or creation*

***CRE 9.3**: Actively purchase off-channel habitats in urban and rural settings that (1) cannot be effectively protected through regulation, (2) are degraded but have good restoration potential, or (3) are highly degraded but could benefit from long-term restoration solutions (5 properties: #1 (55 acres) purchased in 2012; #2 (22 Acres) purchased in 2014; #3 (27 Acres) purchased in 2015; working on remaining*

***CRE 9.4**: Restore degraded off-channel habitats with high intrinsic potential for increasing habitat quality*

***CRE 10.1**: Breach or lower the elevation of dikes and levees; create and/or restore tidal marshes, shallow-water habitats, and tide channels*

***CRE 10.2**: Remove tide gates to improve the hydrology between wetlands and the channel and to provide juveniles with physical access to off-channel habitat; use a habitat connectivity index to prioritize projects*

***CRE 10.3**: Upgrade tide gates where (1) no other options exist, (2) upgraded structures can provide appropriate access for juveniles, and (3) ecosystem function would be improved over current conditions*

***CRE 15.3**: Implement projects to address infestations on public and private lands*

Regarding "SBU Type" in Table B-1:

***Action Agency (AA) Preliminary SBU Score**: One member of BPA's ecosystem restoration partners (Columbia Land Trust, Cowlitz Indian Tribe, Columbia River Estuary Study Taskforce, Lower Columbia Estuary Partnership, and Washington Department of Fish and Wildlife) used the Expert Regional Technical Group's (ERTG) scoring criteria, scoring spreadsheet, and the SBU calculator to provide preliminary SBU scores of project concepts. Partners recused themselves from scoring their own projects. The concepts consisted of a project goal map showing the 2-year flood inundation and all CRE restoration activities. Additionally, a representative of the BPA and Corps do a blind QA/QC analysis.*

***BA Final SBU Score**: Final scores that were included in the Biological Assessment were scores completed prior to the formation of the ERTG and were scored by the BPA contractor that developed the original SBU scoring mechanism. All BA final SBU scores were incorporated by NOAA as part of the Biological Opinion (BiOp).*

***ERTG Preliminary SBU Scores**: If a project includes a type of restoration that has not been previously reviewed by the ERTG or if a project requires significant funding early in process the AAs ask the ERTG for a preliminary score. These scores are not considered final but rather provide the AA with some level of assurance that the project is still worth pursuing. Once the project gets far enough along in the design phase then the projects are taken to the ERTG for a final SBU score.*

***ERTG Final SBU Scores**: Most if not all projects have either an AA or ERTG preliminary score to insure that the project meets selection criteria (see AA preliminary SBU scores above). Once a project reaches approximately 60% design, an ERTG template is completed and then sent to the ERTG for their review. In almost all cases the ERTG is then taken on a site visit to better evaluate the potential of each project. After The ERTG scoring is documented by the ERTG facilitator and then an ERTG Project SBU Report is developed. All scores are considered final unless the project constructed deviates in any significant way from the project presented to the ERTG. To date no project has been constructed in a manner deemed different enough to require re-scoring.*

***AA Final Scores:** AA final scores are only used to calculate the benefit of passive restoration associated with land acquisitions. The AAs use a similar approach to the ERTG, incorporating CRE subaction information from the Estuary Module of the Lower Columbia River Recovery Plan. The AAs provide scores for certainty of success, habitat capacity and quality, and access using the same criteria as the ERTG.*

Appendix B – Table 1. Action Agency 2007–2016 Estuary Habitat Projects

Location (Reach A-H)	Project Name	Project Number	Lead Agency / Sponsor	Estuary Module Action	Linear Miles of Riparian Stream or Channel Improved	Acres Restored	Ocean SBUs	Stream SBUs	SBU Type	Status	IP in which the project was identified
Completed in 2007											
A	Fort Clatsop	2003-011-00	BPA / CREST	CRE 10.2		45	0.250	0.100	BA Final	Completed in 2007	None
F	Scappoose Bottomlands Restoration	2003-011-00	BPA / Estuary Partnership	CRE 1.4	2		0.10	0.100	BA Final	Completed in 2007	None
				CRE 15.3		30					
F	Ramsey Lake Restoration	N/A	COE	CRE 10.3		5	0.120	0.050	BA Final	Completed in 2007	None
TOTAL completed in 2007					2	80	0.47	0.25			
Completed in 2008											
A	Walluski River North	2003-011-00	BPA / Columbia Land Trust	CRE 1.4	0.7		0.065	0.027	ERTG Final	Completed in 2008	None
				CRE 10.1		15					
				CRE 15.3		5.5					
				CRE 9.4		3.9					
B	Big Creek[1]	2003-011-00	BPA / CREST	CRE 1.4	0.3		0.008	0.003	ERTG Final	Completed in 2008	None
				CRE 10.3		13.3					
				CRE 15.3		2.8					
B	Wolf Bay – Phase 1	2003-011-00	BPA / Columbia Land Trust	CRE 9.3		70.2	0.031	0.012	AA Final	Completed in 2008	None
C	Willow Grove – Phase 1	2003-011-00	BPA / Columbia Land Trust	CRE 9.3		304	0.300	0.080	BA Final	Completed in 2008	None
F	Scappoose Bay	2003-011-00	BPA / Estuary Partnership	CRE 1.4	2		0.003	0.003	ERTG Final	Completed in 2008	None
				CRE 15.3		41.3					
G	Sandy River Delta Riparian Forest Restoration	2003-011-00 1999-025-00	Corps / BPA / USFS (Ash Creek Forestry)	CRE 1.4	0.6		0.004	0.004	ERTG Final	Completed in 2008	2010-2013 IP
				CRE 15.3		255					

[1] *The Ocean & Stream SBUs for this project decreased due to a calculator error – only 2 actions were affected (Big Creek and Perkins Creek)*

Location (Reach A-H)	Project Name	Project Number	Lead Agency / Sponsor	Estuary Module Action	Linear Miles of Riparian Stream or Channel Improved	Acres Restored	Ocean SBUs	Stream SBUs	SBU Type	Status	IP in which the project was identified
H	Mirror Lake – Phase 1[2]	2003-011-00	BPA /Estuary Partnership	CRE 1.4	0.7		0.160	0.069	ERTG Final	Completed in 2008	None
				CRE 9.4		3					
				CRE 10.3		165					
TOTAL completed in 2008					4.3	879.0	0.57	0.20			
Completed in 2009											
A	Perkins Creek[3]	2003-011-00	BPA / CREST	CRE 1.4	0.3		0.001	0.007	ERTG Final	Completed in 2009	None
				CRE 10.3		1.1					
				CRE 15.3		1.1					
B	Crazy Johnson – Phase 1	2003-011-00	BPA / Columbia Land Trust	CRE 1.3		150.9	0.012	0.012	AA Final	Completed in 2009	None
B	Elochoman Slough – Phase 1	2003-011-00	BPA / WDFW / Columbia Land Trust	CRE 9.3		196.4	0.100	0.037	AA Final	Completed in 2009	2014-2018 IP
B	Gray's River -Gorley Springs	2003-011-00	BPA / CREST	CRE 1.3		40	0.24	0.23	BA Final	Completed in 2009	None
				CRE 1.4	1.9						
G	Columbia Slough	2003-011-00	BPA / City of Portland	CRE 1.4	0.8		0.011	0.008	ERTG Final	Completed in 2009	None
				CRE 9.4		3.4					
G	Vancouver Water Resources Wetland	P2#142455	Corps / City of Vancouver	CRE 10.1		10	0.06	0.06	BA Final	Completed in 2009	2010-2013 IP
TOTAL completed in 2009					3	402.9	0.42	0.35			

[2] *Mirror Lake Phase #1 & #2 adjusted to accurately reflect the correct SBU/Acreage distribution rather than splitting equally (total SBUs did not change)*

[3] *The Ocean & Stream SBUs for this project decreased due to a calculator error – only 2 actions were affected (Big Creek and Perkins Creek)*

Location (Reach A-H)	Project Name	Project Number	Lead Agency / Sponsor	Estuary Module Action	Linear Miles of Riparian Stream or Channel Improved	Acres Restored	Ocean SBUs	Stream SBUs	SBU Type	Status	IP in which the project was identified
Completed in 2010											
A	Haven Island	2003-011-00	BPA / Columbia Land Trust	CRE 1.4	1.5		0.134	0.046	ERTG Final	Completed in 2010	None
				CRE 10.1		27.8					
				CRE 15.3		67.6					
				CRE 9.4		1.6					
B	Julia Butler Hansen NWR	P2#1173986	Corp	CRE 9.4		110	0.060	0.020	BA Final	Completed in 2010	2010-2013 IP
				CRE 15.3		210					
H	Mirror Lake – Phase 2[4]	2003-011-00	BPA / Estuary Partnership	CRE 1.4	1.4		0.021	0.016	ERTG Final	Completed in 2010	2010-2013 IP
				CRE 9.4y		3.3					
G	Sandy River Delta Riparian Forest Restoration	2003-011-00 1999-025-00	Corp / BPA / USFS (Ash Creek Forestry)	CRE 1.4	2.8		0.006	0.006	ERTG Final	Completed in 2010	2010-2013 IP
				CRE 15.3		192					
TOTAL completed in 2010					5.7	612.3	0.22	0.09			
Completed in 2011											
A	Fort Columbia[5]	2010-004-00	BPA / CREST	CRE 9.4		5.1	0.325	0.138	ERTG Final	Completed in 2011	2010-2013 IP
				CRE 10.2		80.0					
B	Mill Road (Grays River)	2003-011-00	BPA / Columbia Land Trust	CRE 1.4	0.5		0.397	0.128	ERTG Final	Completed in 2011	2010-2013 IP
				CRE 9.4		1.5					
				CRE 10.1		46.2					
				CRE 15.3		46.2					
C	Germany Creek-Floodplain	2003-011-00	BPA / Columbia Land Trust	CRE 1.4	0.4		0.090	0.090	BA Final	Completed in 2011	None
				CRE 9.4		2					
				CRE 15.3		6.6					

[4] *Mirror Lake Phase #1 & #2 adjusted to accurately reflect the correct SBU/Acreage distribution rather than splitting equally (total SBUs did not change)*

[5] *ERTG rescored action as CRE 10.2 rather than CRE 10.3*

Location (Reach A-H)	Project Name	Project Number	Lead Agency / Sponsor	Estuary Module Action	Linear Miles of Riparian Stream or Channel Improved	Acres Restored	Ocean SBUs	Stream SBUs	SBU Type	Status	IP in which the project was identified
G	Sandy River Delta Riparian Forest Restoration	2003-011-00 1999-025-00	BPA / USFS (Ash Creek Forestry)	CRE 1.4	0.6		0.003	0.003	ERTG Final	Restoration completed in phases from 2008 through 2011.	2010-2013 IP
				CRE 15.3		194					
TOTAL completed in 2011					1.5	381.6	0.82	0.36			
Completed in 2012											
A	Otter Point	2010-004-00 2003-011-00	BPA / CREST	CRE 9.4		3.9	0.234	0.080	ERTG Final	Completed in 2012	2010-2013 IP
				CRE 15.3		19.3					
				CRE 10.1		30					
A	Colewort Creek (Nutel Landing)	2010-004-00	BPA / CREST	CRE 1.4	0.4		0.117	0.043	ERTG Final	Completed in 2012	None
				CRE 10.1		14					
				CRE 9.4		3.9					
				CRE 15.3		17.5					
A	Wallacut River – Phase 1	2010-073-00 2003-011-00	BPA / Columbia Land Trust	CRE 9.3		81.6	0.051	0.019	AA Final	Completed in 2012	2014-2018 IP
B	Gnat Creek -Phase 1	2010-004-00	BPA / CREST	CRE 1.4	0.5		0.070	0.020	ERTG Final	Completed in 2012	None
				CRE 10.1		19					
B	South Tongue Point (Liberty Lane)	2003-011-00	BPA / CREST	CRE 1.4	0.3		0.006	0.003	ERTG Final	Completed in 2012	None
				CRE 9.4		0.5					
				CRE 10.2		6.8					
				CRE 15.3		7.7					
B	Brix Bay- Deep River Confluence – Phase 1	2010-073-00	BPA / Columbia Land Trust	CRE 9.3 (3 properties: #1 (55 acres) purchased in 2012; #2 & #3 (49.7 total acres) anticipated in 2013)		55	0.048	0.018	AA Final	Completed in 2012	2014-2018 IP
B	Elochoman Slough – Phase 2	2010-073-00	BPA / WDFW / Columbia Land Trust	CRE 1.3		89.6	.007	0.007	AA Final	Completed in 2012	2014-2018 IP
B	Knappton Cove – Phase 1	2010-073-00 2003-011-00	BPA / Columbia Land Trust	CRE 9.3		436	0.300	0.300	BA Final	Completed in 2012	None

Location (Reach A-H)	Project Name	Project Number	Lead Agency / Sponsor	Estuary Module Action	Linear Miles of Riparian Stream or Channel Improved	Acres Restored	Ocean SBUs	Stream SBUs	SBU Type	Status	IP in which the project was identified
C	Abernathy Creek	2009-016-00	BPA / WDFW	CRE 1.4	0.9		0.013	0.009	ERTG Final	Completed in 2012	2010-2013 IP
				CRE 9.4		1.8					
				CRE 10.3		2.7					
E	Columbia Stock Ranch – Phase 1	2010-073-00	BPA / COE / Columbia Land Trust	CRE 9.3		646.2	0.711	0.267	AA Final	Completed in 2012	2014-2018 IP
				TOTAL completed in 2012	2.1	1435.5	1.56	0.77			
Completed in 2013											
A	Chinook River – Phase 1	2010-070-00	BPA / WDFW	CRE 9.3		202	0.149	0.056	AA Final	Completed in 2013	2014-2018 IP
A	Wallooskee-Youngs – Phase 1	2012-015-00	BPA / Cowlitz Tribe	CRE 9.3		163.4	0.113	0.042	AA Final	Completed in 2013	2014-2018 IP
B	Grays River Confluence – Phase 1	2010-073-00	BPA / Columbia Land Trust	CRE 9.3		123	0.103	0.039	AA Final	Completed in 2013	2014-2018 IP
B	Gnat Creek – Phase 2	2010-004-00	BPA / CREST	CRE 10.1		67.8	0.432	0.133	ERTG Final	Completed in 2013	None
B	Kandoll Farm – Phase 2	2010-073-00	BPA / Columbia Land Trust	CRE 1.4	6.2		1.247	0.423	ERTG Final	Completed in 2013	None
				CRE 10.1		163					
				CRE 15.3		84					
				CRE 9.4		8.6					
B	Skamokowa Creek-Dead Slough	2003-011-00	BPA / Estuary Partnership / Wahkiakum Conservation District	CRE 1.4	4		0.077	0.052	ERTG Final	Completed in 2013	None
				CRE 10.3		8.6					
				CRE 15.3		30					
				CRE 9.4		31.9					
C	Kerry Island – Phase 1	2010-073-00	BPA / Columbia Land Trust	CRE 9.3		110	0.077	0.029	AA Final	Completed in 2013	2014-2018 IP
C	Dibblee Point	2010-007-00	BPA / CREST	CRE 1.4	0.4		0.021	0.010	ERTG Final	Completed in 2013	None
				CRE 10.2		12.1					
				CRE 15.3		2.1					
				CRE 9.4		1.1					

Location (Reach A-H)	Project Name	Project Number	Lead Agency / Sponsor	Estuary Module Action	Linear Miles of Riparian Stream or Channel Improved	Acres Restored	Ocean SBUs	Stream SBUs	SBU Type	Status	IP in which the project was identified
C	Louisiana Swamp	2003-011-00	BPA / Estuary Partnership / LCRWC	CRE 1.4	0.7		0.143	0.047	ERTG Final	Completed in 2013	None
				CRE 10.1		31.7					
				CRE 15.3		31.7					
				CRE 9.4		1.9					
F	Honeyman Creek	2003-011-00	BPA / Estuary Partnership / SBWC	CRE 10.2		58	0.103	0.041	ERTG Final	Completed in 2013	None
F	Sauvie Island, North Unit – Phase 1	2010-004-00	BPA / CREST	CRE 1.4	0.5		0.924	0.287	ERTG Final	Completed in 2013	None
				CRE 10.1		122.8					
				CRE 15.3		16.4					
				CRE 9.4		0.6					
G	Sandy River Dam Removal	P2#142456	COE / Forest Service	CRE 1.4	1		0.441	0.158	ERTG Final	Completed in 2013	2010-2013 IP
				CRE 10.1		50.7					
				CRE 15.3		1					
				CRE 6.2		0.7					
				CRE 9.4		5.8					
H	Horsetail Creek	2003-011-00	BPA / Estuary Partnership	CRE 1.4	1.3		0.062	0.034	ERTG Final	Completed in 2013	None
				CRE 10.3		96					
				CRE 15.3		30					
				CRE 9.4		12					
TOTAL completed in 2013					14.1	1466.9	3.89	1.35			

Completed in 2014											
A	Sharnelle Fee	2010-004-00	BPA / CREST	CRE 10.1		50	0.250	0.100	BA Final	Completed in 2014	None
A	Chinook River – Phase 2	2010-070-00	BPA / WDFW	CRE 10.3		310	0.694	0.358	ERTG Final	Completed in 2014	2014-2018 IP
				CRE 15.3		3					
				CRE 9.4		41					

Location (Reach A-H)	Project Name	Project Number	Lead Agency / Sponsor	Estuary Module Action	Linear Miles of Riparian Stream or Channel Improved	Acres Restored	Ocean SBUs	Stream SBUs	SBU Type	Status	IP in which the project was identified
B	Brix Bay- Deep River Confluence – Phase 2	2010-073-00	BPA / Columbia Land Trust	CRE 9.3		22	0.019	0.007	AA Final	Completed in 2014	2014-2018 IP
B	Julia Butler Hansen NWR – Steamboat Slough	n/a	COE / USFWS	CRE 1.4	1.6		0.384	0.135	ERTG Final	Completed in 2014	None
				CRE 10.1		67.6					
				CRE 15.3		67.6					
				CRE 9.4		7.7					
B	Karlson Island	2010-004-00	BPA / CREST	CRE 10.1		313.5	0.511	0.157	ERTG Final	Completed in 2014	2014-2018 IP
				CRE 15.3		6					
F	Sauvie Island, North Unit – Phase 2	2010-004-00	BPA / CREST	CRE 1.4	1.7		1.062	0.338	ERTG Final	Completed in 2014	2014-2018 IP
				CRE 10.1		137.9					
				CRE 15.3		20.1					
				CRE 9.4		3.3					
G	Thousand Acres (Sandy River Delta)	2003-011-00	BPA / Estuary Partnership	CRE 1.4	3.9		0.137	0.053	ERTG Final	Completed in 2014	2014-2018 IP
				CRE 10.1		28					
				CRE 15.3		75					
				CRE 9.4		3.5					
H	Multnomah & Wahkeena Creeks (Benson Lake Park)	2003-011-00	BPA / Estuary Partnership	CRE 10.3		23	0.038	0.019	AA Final	Completed in 2014	None
				CRE 9.4		3.5					
TOTAL completed in 2014					7.2	1182.7	3.10	1.17			

Location (Reach A-H)	Project Name	Project Number	Lead Agency / Sponsor	Estuary Module Action	Linear Miles of Riparian Stream or Channel Improved	Acres Restored	Ocean SBUs	Stream SBUs	SBU Type	Status	IP in which the project was identified
Completed in 2015											
B	Brix Bay- Deep River Confluence – Phase 3	2010-073-00	BPA / Columbia Land Trust	CRE 9.3		27.5	0.024	0.009	AA Final	Completed in 2015	2014-2018 IP
B	Crooked Creek – Phase 1	2010-073-00	BPA / Columbia Land Trust	CRE 9.3		18.3	0.015	0.006	AA Final	Completed in 2015	2014-2018 IP
B	Elochoman Slough – Phase 3	2010-070-00	BPA / WDFW	CRE 1.4	0.2		0.716	0.305	ERTG Final	Completed in 2015	2014-2018 IP
				CRE 10.2		255.4					
				CRE 15.3		296.5					
				CRE 9.4		10.7					
C	Batwater Station	2003-011-00	BPA / Estuary Partnership	CRE 1.4	0.2		0.258	0.083	ERTG Final	Completed in 2015	None
				CRE 10.1		25.6					
				CRE 15.3		25.6					
				CRE 9.4		1					
E	LaCenter Wetlands, Lewis River East Fork	2003-011-00	BPA / Estuary Partnership	CRE 1.4	1.6		1.491	0.468	ERTG Final	Completed in 2015	2014-2018 IP
				CRE 10.1		453					
				CRE 15.3		14					
				CRE 9.4		6.5					
F	Sauvie Island, North Unit – Phase 3	2010-004-00	BPA / CREST	CRE 1.4	0.4		0.345	0.108	ERTG Final	Completed in 2015	None
				CRE 10.1		90.6					
				CRE 15.3		6.4					
				CRE 9.4		2.2					
F	Buckmire Slough – Phase 1[6]	2010-004-00	BPA / CREST	CRE 10.1		64.8	0.548	0.221	ERTG Preliminary	Completed in 2015	2014-2018 IP
				CRE 9.4		22.2					
				TOTAL completed in 2015	2.4	1320.3	3.40	1.20			

[6] *The Buckmire Slough project was re-scored by ERTG in late 2016. The revised input scores were applied to assigned subactions.*

Location (Reach A-H)	Project Name	Project Number	Lead Agency / Sponsor	Estuary Module Action	Linear Miles of Riparian Stream or Channel Improved	Acres Restored	Ocean SBUs	Stream SBUs	SBU Type	Status	IP in which the project was identified
Completed in 2016											
A	Trestle Bay	n/a	COE / CREST	CRE 10.1		628	1.603	0.493	ERTG Final	Completed in 2016	2014-2018 IP
A	Wallacut River – Phase 2	2010-073-00	BPA / Columbia Land Trust	CRE 1.4	3.4		0.290	0.100	ERTG Final	Planned for completion in 2016	2014-2018 IP
				CRE 10.1		45.6					
				CRE 15.3		80					
				CRE 9.4		3.0					
C	Kerry Island – Phase 2	2010-073-00	BPA / Columbia Land Trust	CRE 1.4	2.0		1.109	0.374	ERTG Final	Planned for completion in 2016	2014-2018 IP
				CRE 10.1		95.5					
				CRE 15.3		110					
				CRE 9.4		5.6					
C	Westport Slough #1	2010-004-00	BPA / CREST	CRE 10.1		49.4	0.478	0.152	ERTG Final	Planned for completion in 2016	2014-2018 IP
				CRE 9.4		1.3					
F	Willow Bar	2010-004-00	BPA / CREST	CRE 1.4	0.9		0.019	0.013	ERTG Final	Planned for completion in 2016	None
				CRE 9.4		6.2					
				CRE 15.3		8.7					
F	Crane Slough-Domeyer Wetland	2010-004-00	BPA / CREST	CRE 10.1		34.9	0.225	0.072	ERTG Final	Planned for completion in 2016	None
				CRE 15.3		4.6					
				CRE 9.4		1.3					
TOTAL completed in 2016					6.3	1074.1	3.73	1.20			
TOTAL completed 2007-2016					48.6	8835.0	18.1	6.9			

Location (Reach A-H)	Project Name	Project Number	Lead Agency / Sponsor	Estuary Module Action	Linear Miles of Riparian Stream or Channel Improved	Acres Restored	Ocean SBUs	Stream SBUs	SBU Type	Status	IP in which the project was identified
Projects initiated by 2016, completion anticipated in 2017 & beyond (metrics are included within Estuary Module Action)											
A	Lewis & Clark River Upper #1	2010-004-00	BPA / CREST	CRE 10.1			0.19	0.06	AA Preliminary	Initiated feasibility in 2016	2014-2018 IP
				CRE 9.4 (1 Acre)							
A	Wallooskee-Youngs	2012-015-00	BPA / Cowlitz Tribe	CRE 1.4 (0.8 Miles)			2.13	0.76	ERTG Final	Construction initiated in 2016	2014-2018 IP
				CRE 10.1 (168.6 Acres)							
				CRE 15.3 (193.1 Acres)							
				CRE 9.4 (23.5 Acres)							
A	Youngs Bay/River Tidal Floodplain Reconnection	TBD	COE / BPA / Cowlitz Tribe	CRE 9.3 (251 Acres)			3.32	1.22	ERTG Preliminary	Continued feasibility in 2016	2014-2018 IP
				CRE 1.4 (0.5 Miles)							
				CRE 10.1 (375 Acres)							
				CRE 15.3 (66 Acres)							
				CRE 9.4 (67 Acres)							
B	Elochoman Slough – Phase 4	2010-073-00	BPA / Columbia Land Trust	CRE 1.4 (0.7 Miles)			0.010	0.007	ERTG Final	Final design completed in 2016	2014-2018 IP
				CRE 9.4 (1.8 Acres)							
B	Brix Bay-Deep River Confluence – Phase 3	2010-073-00	BPA / Columbia Land Trust	CRE 9.3 (5 properties: #1 (55 acres) purchased in 2012; #2 (22 Acres) purchased in 2014; #3 (27 Acres) purchased in 2015; working on remaining			0.85	0.37	AA Preliminary	Acquisition #1 complete in 2012; #2 completed in 2014; #3 completed in 2015; continued to negotiate additional parcels in 2016	2014-2018 IP
				CRE 9.4 (12 Acres)							
				CRE 10.2 (159 Acres)							

Location (Reach A-H)	Project Name	Project Number	Lead Agency / Sponsor	Estuary Module Action	Linear Miles of Riparian Stream or Channel Improved	Acres Restored	Ocean SBUs	Stream SBUs	SBU Type	Status	IP in which the project was identified
B	Crooked Creek Upstream – Phase 2	2010-073-00	BPA / Columbia Land Trust	CRE 9.3 (3 properties: #1 (18 acres) purchased in 2015; working on remaining)			1.05	0.34	AA Preliminary	Acquisition #1 completed in 2015 continued to negotiate additional parcels in 2016	2014-2018 IP
				CRE 10.1 (114 Acres)							
				CRE 9.4 (3.5 Acres)							
B	Grays River Confluence – Phase 2	2010-073-00	BPA / Columbia Land Trust	CRE 9.3 (7 properties: #1 (123 acres) purchased in 2013; working on remaining)			3.65	1.21	AA Preliminary	Acquisition #1 completed in 2013; continued to negotiate additional parcels in 2016	2014-2018 IP
				CRE 10.1 (282 Acres)							
				CRE 9.4 (16 Acres)							
B	Svensen Island	TBD	TBD	CRE 9.3 (306 Acres)			2.75	0.94	ERTG Preliminary	continued to negotiate additional parcels in 2016	2014-2018 IP
				CRE 10.1 (275 Acres)							
				CRE 9.4 (36 Acres)							
C	Crims Island – Phase 2	2010-004-00	BPA / CREST	CRE 10.1 (129 Acres)			0.51	0.16	AA Preliminary	Initiated feasibility in 2016	None
				CRE 9.4 (4 Acres)							
C	Westport Slough Hydrologic Enhancement (#2)[7]	2003-011-00	BPA / Estuary Partnership	CRE 10.2 (129 Acres)			0.73	0.42	ERTG Preliminary	Initiated feasibility in 2016	None
				CRE 9.4 (353 Acres)							
D	Carr Slough	2003-011-00	BPA / Estuary Partnership	CRE 1.4 (0.1 Miles)			0.26	0.12	AA Preliminary	Continued feasibility in 2016	None
				CRE 10.2 (99 Acres)							
				CRE 15.3 (99 Acres)							
				CRE 9.4 (11 Acres)							

[7] *Included in SBUs is a bump of 0.06/Ocean and 0.02/Stream to the Louisiana Swamp project (completed in 2013)*

Location (Reach A-H)	Project Name	Project Number	Lead Agency / Sponsor	Estuary Module Action	Linear Miles of Riparian Stream or Channel Improved	Acres Restored	Ocean SBUs	Stream SBUs	SBU Type	Status	IP in which the project was identified
E	Columbia Stock Ranch – Phase 2	2010-073-00	BPA / COE / Columbia Land Trust	CRE 1.4 (10 miles) CRE 10.1 (344 Acres) CRE 15.3 (414 Acres) CRE 9.4 (33.4 Acres)			4.98	1.74	ERTG Final	Final design initiated in 2016	2014-2018 IP
E	Large Dike Breach-Reach E	TBD	BPA	CRE 1.4 (38 miles) CRE 10.1 (2063 Acres) CRE 9.3 (3272 Acres) CRE 9.4 (272.8 Acres)			35.2	12.6	ERTG Preliminary	Continued feasibility in 2016	2014-2018 IP
F	Ridgefield NWR: Ridgeport Dairy Unit-Post Office Lake	2010-004-00	BPA / CREST	CRE 10.1 (168 Acres) CRE 10.2 (35 Acres) CRE 9.4 (1.6 Acres)			0.93	0.29	AA Preliminary	Continued feasibility in 2016	2014-2018 IP
F	Ridgefield NWR – Ridgeport Dairy Campbell Lake & Slough	2010-004-00	BPA / CREST	CRE 10.1 (312 Acres) CRE 10.2 (314 Acres) CRE 9.4 (28 Acres)			2.65	0.88	AA Preliminary	Continued feasibility in 2016	2014-2018 IP
F	Dairy Creek-Sturgeon Lake	TBD	COE / USFWS	CRE 10.2 (4100 Acres) CRE 9.4 (7.7 Acres)			0.34	0.14	ERTG Preliminary	Initiated design in 2016	2010-2013 IP
F	Flights End	2010-004-00	BPA / CREST	CRE 10.1 (42 Acres) CRE 9.4 (1 Acre)			0.29	0.09	AA Preliminary	Initiated feasibility in 2016	None
F	John R. Palensky	2010-004-00	BPA / CREST	CRE 10.1 (72 Acres)			0.48	0.15	AA Preliminary	Initiated feasibility in 2016	2010-2013 IP

Location (Reach A-H)	Project Name	Project Number	Lead Agency / Sponsor	Estuary Module Action	Linear Miles of Riparian Stream or Channel Improved	Acres Restored	Ocean SBUs	Stream SBUs	SBU Type	Status	IP in which the project was identified
F	Buckmire Slough – Phase 2	2010-070-00 2010-004-00	BPA / CREST / WDFW	CRE 10.1 (384.8 Acres)			2.89	1.06	ERTG Preliminary	Phase 1 completed in 2015; continued design of future phases in 2016	2014-2018 IP
				CRE 9.4 (70 Acres)							
				CRE 15.3 (11.2 Acres)							
G	Steigerwald NWR	TBD	BPA / COE	CRE 10.1 (570 Acres)			5.07	1.63	ERTG Preliminary	Initiated design in 2016	2014-2018 IP
				CRE 15.3 (780 Acres)							
				CRE 9.4 (27 Acres)							
TOTAL planned for 2017 & beyond							68.3	24.2			
TOTAL completed & planned							86.4	31.1			

Projects not implemented[8]											
A	Port of Astoria (Skipanon)	2010-004-00	BPA / CREST	No metrics to report						Project not implemented	2014-2018 IP
A	Port of Astoria – Phase 2	2010-004-00	BPA / CREST	No metrics to report						Project not implemented	2014-2018 IP
A	Skipanon Slough, 8th Street Dam	2010-004-00	BPA / CREST	No metrics to report						Project not implemented	2014-2018 IP
A	Walluski Bottomlands	2010-004-00	BPA / CREST	No metrics to report						Project not implemented	2014-2018 IP
C	Clatskanie River/Beaver Slough Confluence	2003-011-00	BPA / Estuary Partnership	No metrics to report						Project not implemented	2014-2018 IP
C	Erickson Dike Slough	2010-004-00	BPA / CREST	No metrics to report						Project not implemented	None
E	RM-81 Island	2010-073-00	BPA / CREST	No metrics to report						Project not implemented	2014-2018 IP
F	Duck Lake	2003-011-00	BPA / CREST	No metrics to report						Project not implemented	None
F	Scappoose Landing	2003-011-00	BPA / Estuary Partnership	No metrics to report						Project not implemented	2014-2018 IP

[8] *Projects fit new strategy, but could not be implemented due to circumstances beyond AA's control*

Appendix C

Impacts of Climate Change on Columbia River Salmon: A Review of the Scientific Literature Published in 2015

This page intentionally left blank.

Impacts of Climate Change on Salmon of the Pacific Northwest

A review of the scientific literature published in 2015

Lisa Crozier

Fish Ecology Division
Northwest Fisheries Science Center
National Marine Fisheries Service, NOAA
2725 Montlake Boulevard East
Seattle, Washington 98102

October 2016

Highlights

Physical Processes of Climate Change

Globally, nationally, and regionally, 2015 was a record-breaking climate year (Blunden and Arndt 2016). Enhanced by a strong El Niño, global annual surface temperature was the warmest ever recorded for the second year in a row, exceeding the pre-industrial average by over 1°C for the first time. New records were also set for global ocean heat content, sea level, and minimum sea ice extent.

Retrospective climate trends and future projections

The North Pacific marine heatwave from 2013-2015 displayed sea surface temperature anomalies over 3 SD above normal (Bond et al. 2015). Di Lorenzo and Mantua (2016) demonstrate that teleconnections between the North Pacific and El Niño maintained the anomalous conditions through multiple years. Climate model simulations indicate that extreme conditions such as this are likely to increase with greenhouse gas forcing.

Historical time series data show dramatic trends in rising temperatures apparent across the conterminous U.S. (Mutiibwa et al. 2015). As new records are set, attribution of these events specifically to rising greenhouse gases becomes easier statistically. Mera et al. (2015) linked climate change to extreme heat waves in the Central Valley, California. Analyses of the 2012-2014 California drought supported previous reports. Some aspects of the 2014 drought broke historical records (Williams et al. 2015), but extreme droughts of this or greater magnitude have been observed in the recent and ancient past, and are driven primarily by natural variability in precipitation (Diaz and Wahl 2015; Mann and Gleick 2015; Mao et al. 2015; Williams et al. 2015). Nonetheless, Mao et al. (2015) reported that anthropogenic warming has caused declines in snowpack and total spring runoff, which contributed to the drought and accounted for 8-27% of the drought anomaly. In brief, anthropogenic warming makes the combination of dry and warm years more likely, increasing the negative impacts of drought (Diffenbaugh et al. 2015).

In contrast to California, the Pacific Northwest (PNW) has experienced a decrease in drought due to increased precipitation (since 1979, Ficklin et al. 2015; since 1916, Mo and Lettenmaier 2015). However, not all PNW locations have exhibited these regional trends; this spatial heterogeneity is described by Duncan et al. (2015). Heavy snowfall has decreased in both the PNW and California (1930-2007, Kluver and Leathers 2015). Reduced snowfall has manifested in widespread glacier retreat documented in the Olympic (Riedel et al. 2015) and North Cascade range (Marcinkowski and Peterson 2015).

Looking toward the future, numerous studies focused on the increasing intensity and frequency of precipitation events. Atmospheric rivers are bands of warm, wet air that cross the central Pacific Ocean and cause heavy precipitation events along the west coast of North America. Global circulation model results show that rising greenhouse gases will cause atmospheric rivers to become more intense and frequent, with maximum change affecting northern California (Gao et al. 2015; Payne and Magnusdottir 2015; Radic et al. 2015; Warner et al. 2015).

Heavier and warmer precipitation will increase rain-on-snow events, particularly at mid-elevations (Safeeq et al. 2015). A systematic exploration of how seasonal change in temperature and precipitation will alter runoff across the PNW revealed that the Salmon River Basin, Idaho is one of the most sensitive areas (Vano et al. 2015b). Zeroing in on the Salmon River Basin, Tennant et al. (2015) focus specifically on the snowline. An increase of 3°C would shift the snowline from 1,980 to 2,440 m. Such a shift would entail a 42% loss of area in the basin now classified as snow-dominated.

Loss of snowpack will change the timing and quantity of runoff in the largest rivers of the PNW, which could affect hydropower production. Kao et al. (2015a) assessed power production for 132 federal dams and found a median expected loss of -2 TWh (ensemble uncertainty of +/- 9 TWh), which is 7% in annual production. In the Bonneville Power Administration study areas, annual production is projected to increase slightly, despite declines in annual runoff. This projection has an uncertainty range that includes declines in production, but does not exceed historical variability. While U.S. regions differ in the season during which they will be most affected, projected declines in runoff at Bonneville Power Administration installations were ~8-10% annually in the next decade, but might rebound after that. Kao et al. (2015a) projected 40-50% declines in summer runoff by 2040.

The terrestrial landscape profoundly affects water quality and quantity in streams. Hotter, drier summers in the PNW will promote a shift to more warm-adapted vegetation, but the rate at which this occurs is modulated by fire dynamics. Existing vegetation, climate, and fire suppression efforts interact in complex ways across the region (Holmes et al. 2015; Sheehan et al. 2015; Turner et al. 2015; Vano et al. 2015b).

Upwelling intensity and ocean acidification

In the marine domain, Rykaczewski et al. (2015) and Wang et al. (2015) explored how the intensification of along-shore winds projected by global climate models (GCMs) will intensify coastal upwelling. Both studies found a latitudinal gradient in impacts, with stronger effects at higher latitudes. However, the California Current system (CCS) is more uncertain than other eastern boundary systems, partly because processes other than along-shore winds also influence upwelling (Di Lorenzo 2015; Jacox et al. 2015a). Furthermore, biological impacts depend on source water in addition to wind strength (Jacox et al. 2015b). Therefore, these results should still be considered exploratory.

Bakun et al. (2015) discussed the potential for ocean changes to cause community shifts and predator/prey mismatches in timing, which could negatively affect salmon.

Ocean acidification is progressing quickly, as noted in previous reviews. Aragonite undersaturation in the Bering Sea is projected to exceed historical variability by 2044, and become chronic by 2062 (Mathis et al. 2015). Takeshita et al. (2015) explored how habitats within the CCS differ in buffering capacity and hence in vulnerability to ocean acidification.

Climate Impacts to Salmon

Sockeye run failure caused by high temperatures in 2015

In early summer 2015, unprecedented high temperatures hit the lower mainstem Columbia River and tributaries (DART 2016; NOAA Fisheries 2016). Of all Redfish Lake sockeye salmon detected passing Bonneville Dam, only 4% survived to Lower Granite Dam, and none survived after temperatures exceeded 20°C at Bonneville (NOAA Fisheries 2016).

Poor winter-run Chinook and Oregon coho survival

For Sacramento winter-run Chinook salmon, egg-to-fry survival in 2014 and 2015 was the lowest ever observed and is informally being attributed to the California drought (Martin et al. In press; Pacific Fishery Management Council 2016; Poytress 2016).

Oregon coho returns were far below forecast in a manner consistent with low returns from previous major El Niño events and negative impacts from "the blob" (Pacific Fishery Management Council 2016). However, future analysis is necessary to formally link coho ocean survival to the recent anomalous ocean conditions.

Acidification directly affects early life stages in salmon

Ou et al. (2015) significantly advanced our knowledge of direct physiological impacts of lower pH on developmental stages of pink salmon. They focused on acidification in freshwater, which has received less attention than ocean acidification. Their findings were consistent with negative impacts on growth observed in Atlantic salmon (Fivelstad et al. 2015). Lacking this direct evidence of negative effects of pH on early life stages in salmon, marine ecosystem models continue to project neutral or positive effects of ocean acidification on salmon (Reum et al. 2015).

Loss of adaptive capacity at climatic extremes

Population comparisons affirmed genetic variation and local adaptation in heat tolerance for trout (Chen et al. 2015; Garvin et al. 2015; Narum and Campbell 2015) and in environmental conditions generally for Chinook salmon (Hecht et al. 2015). However, less genetic diversity was found in bull trout populations exposed to high temperatures and high winter flooding, suggesting that the ability to adapt to climate change is already being eroded (Kovach et al. 2015b).

Because not all traits show genetic variability in heat tolerance even in the absence of strong selection on this trait, Munoz et al. (2015a) predicted that this constraint will cause population extinction. However, Mantua et al. (2015) pointed out that behavioral plasticity might prevent exposure to the conditions explored by Munoz et al. (2015a). Anderson et al. (2015) demonstrated that extinction risk could be minimized using conservation strategies that specifically aim to preserve existing genetic variability in thermal tolerance.

Selective fishing on older fish is a particular concern because under climate change, evolutionary drivers might favor an older age at return, as shown in Atlantic salmon (Piou et al. 2015). Management practices that oppose adaptation to climate change undermine species resilience, causing population decline.

Exotic predators and prey spread in the Columbia Basin

Salmon populations persist by balancing growth from prey consumption with mortality from predators. In the Columbia Basin, invasive plankton species now dominate reservoirs (Emerson et al. 2015) and the estuary (Bowen et al. 2015). Chinook salmon eat these species, although they are not preferred prey (Adams et al. 2015).

Evidence continues to show declines of native pteropods in the southern CCS due to ocean acidification (Bednarsek and Ohman 2015). Although the link between pteropod abundance and salmon survival is generally weak, Doubleday and Hopcroft (2015) found a correlation between pteropod abundance and pink salmon survival in the Gulf of Alaska.

In freshwater, smallmouth bass is a warm-water predator expected to pose an increasing threat to Chinook salmon. Until now, mechanistic models of bass range limits have not been available; however, Lawrence et al. (2015) developed a model that can now be used to identify specific life stages that limit bass range.

Salmon populations: northern advances and southern declines

Some exciting changes were revealed by new observations in the Arctic: all Pacific salmon species are increasing in areas historically unfavorable for them (Logerwell et al. 2015). Phenological changes in migration (Kovach et al. 2015a; Sergeant et al. 2015; Stich et al. 2015) and spawn timing (Lyons et al. 2015) have been observed as well, but only some of these trends are in the direction expected from regional climate trends. The evidence shows that local heterogeneity can outweigh climate drivers in both the direction and rate of population response.

Declines in Puget Sound Chinook salmon populations over 20 years reflect numerous drivers, but are attributed in part to increasing variability in stream flow by (Ward et al. 2015). In southern Europe, global range limits have contracted for brown trout due in part to thermal constraints over the last century (Larios-Lopez et al. 2015).

Projected range contractions in the California Current System

A new bioclimatic envelope analysis of major fish distributions predicts significant range contractions and local extinctions at the southern extent of the CCS (Cheung et al. 2015). Salmon prefer colder regions of the CCS, and therefore are expected to contract their range.

NOAA Fisheries Climate Science Strategy

NOAA Fisheries released its science strategy to manage for climate change (Link et al. 2015). This strategy involves building infrastructure, tracking trends, detecting early warning signs, developing mechanistic understanding, and robust management solutions for a changing climate.

In conclusion, unprecedented heat exposures were observed in the Columbia River in 2015, along with prolonged drought in California and extraordinarily high ocean temperatures (the blob). Preliminary observations indicate severe negative consequences for endangered Redfish Lake sockeye, endangered Sacramento River winter-run Chinook and Oregon coho populations. These observations provide evidence that climate change will present enormous challenges for salmon. Climate change is advancing rapidly and will likely accelerate in coming decades (Roberts et al. 2015). New information about negative effects of freshwater acidification on salmon and loss of adaptive capacity in climate-stressed populations of bull trout increase concern about the ongoing resilience of salmon in the PNW and California.

Contents

Objective and Methods

The goal of this review was to identify literature published in 2015 that is most relevant to prediction and mitigation of climate change impacts on Columbia River salmon listed under the Endangered Species Act. Because almost anything that affects salmon is altered in some way by changes in temperature, stream flow, or marine conditions, a large amount of literature related to this topic was necessarily excluded.

In our literature search, we elected to focus on peer-reviewed scientific journals included in the *Web of Science* database, although we occasionally included highly influential reports outside that database. We sought to capture the most relevant papers by combining climatic and salmonid terms in search criteria. This excluded studies of general principles demonstrated in other taxa or within a broader context. In total, we reviewed over 600 papers, 170 of which were included in this summary.

Literature searches were conducted in June 2016 using the Institute for Scientific Information (ISI) *Web of Science* indexing service. Each set of search criteria involved a new search, and results were compared with previous searches to identify missing topics. We used specific search criteria that included a publication year of 2015, plus:

1) A topic that contained the terms climate,[1] temperature, streamflow, flow, snowpack, precipitation, **or**[2] PDO, **and** a topic that contained salmon, *Oncorhynchus*, or steelhead, but **not** aquaculture or fillet
2) A topic that contained climate, temperature, precipitation, streamflow **or** flow **and** a topic containing "Pacific Northwest"
3) A topic that contained the terms marine, sea level, hyporheic, **or** groundwater **and** climate, **and** salmon, *Oncorhynchus*, **or** steelhead
4) Topics that contained upwelling **or** estuary **and** climate **and** Pacific
5) Topics that contained ocean acidification and salmon, *Oncorhynchus* or steelhead
6) Topics that contained upwelling **or** estuary **or** ocean acidification **and** California Current**,** Columbia River, Puget Sound or Salish Sea
7) A topic that contained prespawn mortality

This review is presented in two major parts, with the first considering changes to the physical environmental conditions that are both important to salmon and projected to change with climate. Such conditions include air temperature, precipitation, snowpack, stream flow, stream temperature, and ocean conditions. We describe projections driven by global climate model (GCM) simulations, as well as historical trends and relationships among these environmental conditions. In the second part, we summarize the literature on responses of salmon to these environmental conditions, both projected and retrospective, in freshwater and marine environments.

---

[1] The wildcard (*), was used to search using "climat*" to capture all forms of the word "climate."
[2] Boolean operators used in the search are shown in boldface.

Physical Processes of Climate Change

Annual Observations from 2015

Globally, nationally, and regionally, 2015 was a record-breaking year in climate. At the Mauna Loa Observatory station in Hawaii, the longest-running record of atmospheric CO_2 exceeded 400 ppm for the first time, and global average concentration was 399.4 ppm. The Antarctic ozone hole was the largest observed since 1990.

Enhanced by a strong El Niño, global annual surface temperature was the warmest ever for the second year in a row, exceeding the pre-industrial average by over 1°C for the first time. Heat records were broken on every continent. In the Arctic, land surface was 2.8°C warmer than when records began in 1900. Sea ice maximum was the smallest ever recorded (7% below the 1981-2010 average), and Arctic sea surface temperatures were up to 8°C above average. New records were also set in global ocean heat content and sea level. Over 50% of the Greenland ice sheet experienced melting at the surface, with net mass loss in alpine glaciers for the 36th consecutive year. In the Northern Hemisphere, snow cover was the second lowest on record (49 years), and the permafrost reached record high elevation at 20 m.

Tropical storm activity was very high, both in terms of total number of named storms and number of most intense storms. An intensified hydrological cycle drove floods worldwide; in the U.S., May 2015 was the wettest month ever (121-year record). Nonetheless, groundwater storage was low, based on the Gravity Recovery and Climate Experiment satellite observations (14-year record), and 14% of the world experienced "severe" drought.

Retrospective Climate Trends

Reduced snowfall in the Pacific Northwest

A study of snowfall across the U.S. from 1930 to 2007 found that trends differed by region depending on location in relation to major storm tracks, but that the frequency of heavy (above average) snowfall has decreased in the PNW and California. Annual variation in snowfall is correlated with large-scale atmospheric circulation patterns such as the Pacific decadal oscillation (PDO) in winter, the Pacific North American pattern (PNA), and the Oceanic Niño index (ONI) in Niño region 3.4 (Kluver and Leathers 2015).

Reduced snowfall has impacted glaciers in the PNW. Glacial retreat on the Olympic Peninsula has been stunning, culminating in the loss of 82 glaciers for a reduction in combined area of 34% from 1980 to 2009 (Riedel et al. 2015). Glacial meltwater is an important contributor to streamflow during low flow periods in some basins: in the Hoh Basin, up to 30% of total runoff comes from glaciers. Marcinkowski and Peterson (2015) used mountain hemlock tree rings to reconstruct increases and decreases in glacial mass from North Cascades glacier over the past 350 years. They found that recent years have shown rapid declines in glacial mass, but that glaciers in this region are not at an all-time low, which occurred in the 1940s.

They found that local glacial history was consistent with that of larger geographic regions, and reflected forcing from large-scale climate drivers such as the PDO and El Niño southern oscillation (ENSO). These long-term analyses are enormously helpful, because short-term time series often cannot detect recent trends due to high interannual variability. This problem was demonstrated by an analysis of 15 years of snowfall data in the Oregon Cascades (Kostadinov and Lookingbill 2015).

Variable effects of increased temperature

Temperature patterns in the conterminous U.S. were analyzed for different metrics over various time periods, but all showed dramatically warmer temperatures in recent years, particularly in relation to extreme hot and cold events (Mutiibwa et al. 2015). In the number of days over 90°C, the frequency and area covered have dramatically increased. There were no years in which 5% of the U.S. was over 90°C for extended periods from 1979 to 2005. However, 5 years from 2006-2012 surpassed this record, with nearly half of the U.S. (47%) experiencing at least 90 d over 90°C in 2012. Warming occurred fastest in springtime. Spring temperatures were positively correlated with ENSO in the PNW, but the correlation coefficient was negative elsewhere in the country.

A study of recent extreme heat waves in the Central Valley in California further resolves their characteristics and attributes the increase in severity to increasing greenhouse gases (Mera et al. 2015).

As heat waves become more frequent, a particular type of drought might become more problematic; that is, flash drought caused by high temperatures as opposed to low precipitation. These flash droughts occur when soil moisture dries out very quickly because of a heat wave. Flash droughts are primarily a concern for agriculture, but will influence fish through increased irrigation demands and altered runoff patterns. Despite concern about future increases, trends during 1916-2012 show decreasing drought in the PNW, largely because of increasing precipitation (Mo and Lettenmaier 2015).

Since 1979, decreasing trends in drought were also detected using the Palmer drought severity index in the PNW (Ficklin et al. 2015). The relative importance of temperature and precipitation in causing drought in the PNW is similar. The regional trend does tend to obscure spatial heterogeneity that is important for local planners. Duncan et al. (2015) showed how the regional trend played out locally across the PNW.

Stream temperatures have been increasing over the past half century following regional climate trends. However, Reiter et al. (2015) document that regulations imposing buffers on forest harvest have reduced the amount of stream warming in buffered areas compared to un-buffered areas.

California drought of 2012-2014: extreme, but not unprecedented

Analyses of the 2012-2014 California drought supported previous reports. Some aspects of the 2014 drought broke historical records (Williams et al. 2015), but extreme droughts of this or greater magnitude have been observed in the recent and ancient past, and are driven primarily by natural variability in precipitation (Diaz and Wahl 2015; Mann and Gleick 2015; Mao et al. 2015; Williams et al. 2015). Nonetheless, Mao et al. (2015) found that anthropogenic warming has caused declines in snowpack and total spring runoff, which contributed to the California drought and accounted for 8-27% of the drought anomaly. In brief, anthropogenic warming makes the combination of dry and warm years more likely, increasing the negative impacts of drought (Diffenbaugh et al. 2015).

State-wide trends in climate indicators in Idaho

In an effort to make climate change information more useful to a wider audience, Klos et al. (2015) assembled an interdisciplinary group conducted a survey across Federal and State Agencies, private citizens and NGOs to identify the primary concerns about climate change impacts in Idaho. Water availability, the risk of extreme drought, changes in plant productivity and wildfire risk were the top concerns.

Based on these concerns, Klos et al. (2015) collected data on a set of biophysical indicators, such as temperature, flow/precipitation/snowpack indices, plants/salmon/bird phenologies, and forest area burned, focusing on 1975-2010 time period. This start period was selected to avoid the significant trend over time due to the historical regime shift between PDO phases that occurred in 1976.

Ecological indicators include the date of upstream adult sockeye migration at Lower Granite Dam from 1975 to 2011. It is not clear exactly why they chose sockeye instead of more robust Chinook populations. This period includes essentially no natural anadromous run because this population was functionally extinct and reduced to captive brood stock in most of this period, and is missing data altogether for many years. They did not find a significant trend in this indicator. Other indices did show significant trends: rising mean annual air temperature, lengthening growing season, earlier dates for lilac blooming and mountain bluebird egg-laying, and more forest area burned.

Non-significant but positive trends occurred in increasing spring precipitation, earlier peak streamflow, decreased April 1 snowpack, and longer fire season. No detectable trends were found in total annual streamflow, timing of sockeye migration, mean annual stream temperature, and start of fire season. An interesting point in this paper is the comparison of the perceived importance of an indicator and how closely that indicator is linked to climate (i.e., complexity of the process involved). Water-related indices outweighed temperature-related indices likely because water is already a limiting resource in Idaho, whereas temperature is not a tightly tied to specific use. Fire and biological viability metrics are complicated by many influences other than climate, but are seen as potentially causing direct harm, and hence worthy of greater research to separate out different influences.

Complex dynamics control fog in Southern California

Large climate drivers profoundly affect conditions in the California Current and upwelling, which in turns influences coastal fog. Fog in southern California has a complex relationship with the PDO and ENSO, showing that a historically strong correlation has disappeared in recent years (Witiw and LaDochy 2015). Other important influences on fog include pollution levels, heat island effects, and upwelling, each with waxing and waning roles in different decades, complicating any future projections.

Projected Climate Change Scenarios

Terrestrial projections

Increased heavy precipitation**—**Atmospheric rivers are narrow air currents that accumulate large amounts of water vapor across the Pacific Ocean and carry much of the rain that falls along the west coast of North America. Global circulation models project a northward shift in major wind patterns. Warmer air in general holds more water vapor. When these processes are combined, they have implications for the frequency and intensity of storms caused by atmospheric rivers. A series of papers that explored these dynamics appear to form a consensus on this matter (Gao et al. 2015; Payne and Magnusdottir 2015; Radic et al. 2015; Warner et al. 2015).

Schoof (2015) compiled a new set of daily precipitation projections that has been completed for the entire U.S. The number of heavy precipitation events is likely to go up along the whole coast, especially in winter. Similar to previous results, the PNW is expected to become wetter from fall through spring and possibly slightly drier in summer. Slightly shorter rainy periods are expected west of the Cascades, with little change in dry or wet spell duration in most of the interior. California is projected to have more dry days, but not a significant change in total precipitation outside the winter season (Dec-Feb). To produce these results, Schoof (2015) applied a relatively uncommon statistical downscaling method to output from Earth-system and atmosphere-ocean GCMs from the Coupled Model Intercomparison Project (CMIP5).

Increased flooding and hydrologic regime change—Winter storms cause major damage to human infrastructure and present concerns for salmon. A new set of simulated extreme runoff events examined spatial heterogeneity in risk across the PNW (Najafi and Moradkhani 2015). An ensemble average prediction was made from eight GCM/regional climate model (RCM) combinations, followed by the variable infiltration capacity (VIC) hydrological model.

The ensemble projection showed increases in extreme runoff during winter and spring in 90% of grid cells. The entire region west of the Cascades showed increased extreme runoff events from fall through spring. Snow-dominated regions such as the Salmon River Basin, the ridge of the Cascades, and the Canadian portion of the Columbia River showed more extreme events in summer.

The largest floods along the west coast are often caused by rain-on-snow events. Safeeq et al. (2015) projected a 30-40% increase in peak flows at high elevations within Washington State. Historically, most rain-on-snow events occurred in the Olympic and Cascade Mountain Ranges, as well as in the Blue Mountains. As the climate warms, areas that are now solidly snow-dominated, such as the upper Columbia River in Washington, will become more transitional and display more of these events.

Taking a different approach to identification of the PNW watersheds most sensitive to warming, Vano et al. (2015b) explored differences in runoff depending on whether warming occurred in winter or summer. In rain-dominated basins, runoff was directly dependent on precipitation in both winter and summer, and relative seasonal sensitivity did not change with climate change. With snow-dominated basins, changes in winter had a delayed effect on runoff that did not occur until the spring snowmelt.

If a basin converts from snow-dominated to transitional or from transitional to rain-dominated, winter runoff increases, and summer runoff decreases, resulting in a differential seasonal response. Vano et al. (2015b) identified watersheds that are likely to undergo a hydrological regime change with 3°C warming, based on this discrepancy. Regime-changing watersheds span the ridge of the Cascades and central Idaho.

Vano et al. (2015b) also found that the region most sensitive to both temperature and precipitation change is the Salmon River Basin. This basin had the greatest projected decline in annual runoff with warming of 1°C vs. increased runoff with a precipitation increase of 1%. The response to temperature was greater when warming was applied in summer vs. winter, whereas the response to precipitation was more sensitive in winter.

Much of the rest of Washington and Oregon and the Snake River Plain showed very little response to increased summer precipitation. Impacts from warming tend to be greater in summer, whereas the impacts from precipitation change tend to be greater in winter. Vano et al. (2015b) identified watersheds that are likely to undergo a regime change with 3°C warming, e.g., from snow-dominated to transitional, or from transitional to rain-dominated, based on the discrepancy in sensitivity to cool- vs. warm-season warming. These span the ridge of the Cascades and central Idaho.

Focusing in more detail on regime change in the Salmon River Basin, Tennant et al. (2015) show how watersheds at different elevations respond to warming. They project that a 3°C temperature increase will result in a 40% loss of snow-covered area, as the snowline increases from 1,980 to 2,440 m.

Vano et al. (2015a) conducted a separate sensitivity analysis to explore streamflow in selected basins within more specific seasonal periods. In the snow-dominated Upper Columbia Basin, they found that spring runoff (Apr-Jun) increased with up to 4°C warming because snow remained despite an earlier freshet. Summer flows (Jun-Aug) in the Willamette were much more sensitive to change in precipitation than temperature because snow had little effect in this rain-dominated basin.

In the transitional Yakima basin, irrigation demands span three seasons, impacting flows from April to September, and flows are similarly sensitive to both temperature and precipitation. Over the full range of GCM scenarios to date, declines in flow during high-demand periods are predicted in the Willamette and Yakima Basins. In the Upper Columbia Basin, increases in spring runoff are seen as more snow melts earlier in the season.

Thorne et al. (2015) used a process-based model (the basin characterization model) to (1) ask what is the magnitude of historical and projected future change in the hydrology of California's watersheds; (2) test the spatial congruence of watersheds with the most historical and future hydrologic change; and (3) identify watersheds with high levels of hydrologic change under drier and wetter future climates. Watershed change was analyzed for climatic water deficit, April 1st snowpack, recharge, and runoff. They developed a normalized index of hydrologic change that combined the four variables, and identified which watersheds show the most spatial congruence of large historical change and continued change under the two futures. Of the top 20% of all watersheds (1028), 591 in the Sierra Nevada Mountains and Northwestern ecoregions have high spatial congruence across all time periods. Among watersheds where change accelerates in the future, but not historically, a majority are congruent between both climate models, predominantly in the Sierra Nevada, Cascade Ranges and the Northwestern ecoregions.

Hydropower production forecasts**—**Reduced snowpack, more intense storms and drier summers will affect hydropower generation across the country. Kao et al. (2015a) assessed power production for 132 federal dams and projected a median loss of -2 TW hours in annual power generation capacity of. At local BPA installations, the change in annual mean runoff and hence power generation was projected to decrease by 8-10% within the next decade, with impacts reduced by 2040. However, summer production was projected to drop 40-50% by 2040.

Interannual variation was similar in the projections compared to the 20-year historical baseline period (1989-2008). To generate these projections, Kao et al. (2015a) used output from the community climate system model version 3 (CCSM3) under the A1B[3] emissions scenario. They downscaled this output to 25 km resolution using the International Centre for Theoretical Physics regional climate model (RegCM2). Hydrological projections are based on the variability infiltration capacity model (VIC) and the WaterWatch runoff-based assessment approach.

Pacific Northwest Stream Flows Correlated with the PDO—One concern for salmon is that unfavorable environmental conditions can impact multiple life stages, leading to larger cumulative effects than might have been expected based on the sum of individual life-stage impacts. Large-scale climate phenomena such as the PDO were already known to correlate with terrestrial precipitation patterns, but a new study further explores the relationship with seasonal indices of the PDO and sea-surface temperature (SST) across the U.S. Sagarika et al. (2015) compared SST in winter with spring and summer streamflow across seasons in the PNW and found positive correlations in the PNW and negative correlations in California. These correlations were statistically significant during the cold phase of the PDO, but not the warm phase.

Increased fires promote shifts toward warmer-climate vegetation—Riparian areas are greatly influenced by vegetation in the surrounding landscape, both locally and regionally. Sheehan et al. (Sheehan et al. 2015) simulated vegetation for the Northwest U.S. using results from 20 different CMIP5 models downscaled using the multivariate adaptive constructed analogs (MACA) algorithm. They project a shift from conifer to mixed forest in the western part of the region, woodier vegetation under fire suppression scenarios in the eastern plains and plateau, and loss of subalpine communities altogether at higher elevations. Fires became much more frequent, with large fires in the western subregion driven by warmer and drier conditions. They discuss the shifts in drivers and controls on fire and vegetation throughout the region.

Zooming in on the Willamette Basin, Turner et al. (2015) projected much higher fire frequency, entailing a shift from evergreen, needle-leaf forest to a mixture containing more broadleaf trees over 20-50% of forested area. A generally more disturbed and open forest landscape is expected.

British Columbia is projected to experience a longer growing season and consequently more vegetation growth under a warmer climate, with the greatest change expected in the coastal mountains (Holmes et al. 2015).

---

[3] A "balanced" emissions scenario that assumes rapid economic growth and a reliance on alternate energy sources in addition to fossil fuels. See the IPCC special report *Emissions Scenarios* at www.ipcc.ch/index.htm (October 2016).

Increasing stress on water supplies—A hotter drier climate will stress water supply for humans as well as wildlife, leading to more problems with water scarcity (Mateus et al. 2015). Mateus et al. (2015) explored the impact of climate change projections on the importance of human water demand vs. climate factors in shaping water availability across a the transitional Santiam Basin watershed in Oregon. Because agricultural and urban withdrawals are generally located at lower elevations, variation in demand has a larger impact on water scarcity at lower than higher elevations.

Vano et al. (2015a) also explored vegetation responses in the Columbia River Basin. They found that differences among basins in fire frequency changed the response to temperature and precipitation. On the Oregon and Washington coasts and in the western Cascades, vegetation changed in response to temperature increases but was fairly insensitive to precipitation changes. In contrast, vegetation in the Upper Columbia Basin was more sensitive to precipitation. Nonetheless, the majority of GCMs predicted declines in productivity in all areas for both the 4.5 and 8.5 RCP scenarios.

Similar trends projected for British Columbia and Alaska—An expert review of projected impacts from climate change in the Canadian and Alaskan coastal rainforests was conducted by Shanley et al. (Shanley et al. 2015). They used 5 GCMs and two emissions scenarios (RCP 4.5 and 8.5), downscaled by the ClimateWNA modeling software. They stratified results by alpine, subalpine, and lowland forest zones, as well as by geographic province and discuss possible implications for salmon as well as vegetation and wildlife. Their conclusions are similar to those discussed previously—some cool, limited regions might experience higher salmon productivity, but in other regions, negative impacts are expected for more vulnerable salmon life stages. Reductions in snowmelt-dominated watersheds will expose more eggs to scour, and changes in temperature might shift migration and spawn timing. They emphasize the importance of maintaining diverse life histories for resilience to climate change.

In the Arctic, warming will occur much faster than at temperate latitudes. Nilsson et al. (2015) review the types of extreme precipitation and temperature events that will likely ensue.

Ocean projections

Intensification of upwelling—Upwelling is a very strong correlate of early marine survival in salmon, especially for Californian stocks. Two key papers explored the implications from GCM for upwelling in the California Current. Neither study supported the Bakun (1990) hypothesis that warmer ocean-land temperature gradients would intensify upwelling. Both studies projected more intense winds at higher latitudes, but a dampened response at lower latitudes. Upwelling is therefore likely to become stronger, start earlier, and last longer in the northern CC ecosystem (Wang et al. 2015).

However, Wang et al. (2015) cautioned that projections for the California Current were more uncertain than those for other eastern boundary systems. Processes other than alongshore winds drive dynamics of the CCS, and observed decadal fluctuations in upwelling are not fully resolved by these models (Di Lorenzo 2015). Thus projections should still be considered exploratory for these very important processes.

The impact of upwelling on fish survival depends not only on intensity, but also the nutrient concentrations within upwelled water. Jacox et al. (2015b) explore how ENSO affects both vertical transport strength and nutrient supply and develops a new index of upwelling efficacy for primary productivity. They explore the teleconnections driving these responses and find similar processes at work in comparisons of ENSO and the PDO.

Jacox et al. (2015a) used a regional ocean model to evaluate the roles of wind, surface heat flux, and basin-scale climate variability in regulating the upwelled nitrate supply in the California Current. A strong positive trend in nitrate flux from 1980-2010 was driven almost exclusively by enhanced equatorward winds, negating a weak negative trend associated with increased surface heat flux.

Ocean acidification and hypoxia—Recent observational data from the Arctic Basin show that continental shelf seas in the Arctic will become undersaturated with respect to aragonite (Beaufort Sea, 2001; Chukchi Sea, 2033; Bering Sea, 2062, Mathis et al. 2015). Mean annual aragonite concentrations were evaluated at approximately 30-year intervals from north to south. However, biological impacts might occur before these threshold years. The Chukchi and Beaufort Seas are expected to pass outside the range of their respective historical variability in undersaturation by the 2020s, and the Bering Sea and Pacific-Arctic Region by ~2050.

Projected ocean acidification rates have moved from global means to subregions to individual habitats. Takeshita et al. (2015) demonstrated habitat-specific signatures of pCO_2 within the California Current. They compared surf zone, kelp forest, submarine canyon edge, and shelf break in the upper 100-m of the Southern California Bight. They found that while habitats differed in their buffering capacity, the mean and variance in pCO2 increased in all habitats, with the fastest rate of increase occurring in the deepest habitat.

Hypoxia typically accompanies low pH. At present, hypoxia occurs along the Oregon/Washington coastline seasonally, but these waters are expected to shoal, with hypoxia persistence lengthening under future climates. A study of the effects of hypoxia on local fish larvae found only small effects, although densities of larvae overall were lower under more hypoxic conditions (Johnson-Colegrove et al. 2015).

Siedlecki et al. (2015) explored the physical mechanisms that cause hypoxia along the coast, comparing the cause of local recirculation patterns within a broad area experiencing high respiration rates. They found also that the Columbia River plume lowers O_2 levels, causing a slight increase in hypoxia in areas affected by the plume. Bacterial community changes, it turns out, act as an early warning sign of impending hypoxic conditions. Spietz et al. (2015) found that bacteria community composition changes at much higher levels of dissolved oxygen than those typically causing negative impacts on fish. They studied these responses in the seasonally hypoxic area of Hood Canal, Washington.

Rising temperatures, sea level, and storminess lead to harmful algal blooms and coastal damage—Two impacts of climate change in western Washington and Oregon that are especially concerning for people are the predicted increases in harmful algal blooms and coastal damage. Moore et al. (2015b) projected a 30-day increase in the number of days favorable for harmful algal blooms in Puget Sound by 2050. This increase is driven primarily by warmer temperatures increasing the maximum growth rate of the dinoflagellate *Alexandrium*, which produces these toxic blooms. Along the outer coast, rising sea level and storm intensification will increase total water levels and erosion damage. Baron et al. (2015) and Cheng et al. (2015) focus on Tillamook County, Oregon to quantify this impact and explore a mapping technique that will be useful for coastal planners.

Climate Model Comparisons/Improvements

There is extensive work to compare modeling methods and document improvements and ongoing model development. Most of this work is beyond the scope of our review, but we note a few relevant examples. A new earth system model, BioEarth, is being developed for the Columbia Basin. BioEarth couples GCM output with a regional climate model through hydrologic impacts, dynamic vegetation, and carbon cycling. They introduce a final step involving anthropogenic feedbacks with a reservoir operations model (ColSim) and agricultural impacts using NEWS (Adam et al. 2015). This model is designed for basin-wide decision making.

Several studies documented that dynamical downscaling methods better capture spatial variation in precipitation than statistical downscaling. Jang and Kavvas (2015) dynamically downscaled all of northern California, whereas Walton et al. (2015) developed a hybrid dynamical/statistical method focused specifically on Los Angeles, CA.

Effects of Climate Change on Pacific Salmon

Historical Trends

Northward range shifts

Although most effects of climate change for Pacific salmon in the Northwest are negative, some environments may become newly habitable as the climate warms. Chinook and coho, in particular, are historically rare north of the Bering Strait. After a detailed habitat assessment of the western Beaufort and Chukchi Seas by Logerwell et al. (2015), evidence of a northward range expansion is now available. They report that Chinook salmon were caught in both areas, which is highly unusual. A few sockeye were also caught, presumably enroute to the Mackenzie River, where they are known to spawn. Pink and chum salmon are not unusual for this region, but they were especially abundant in the Chukchi Sea, suggesting recent warming may have been beneficial for these species.

Our ability to detect salmon range shifts, including contractions, within the PNW is limited by sampling techniques. We monitor certain populations closely, but spawner counts are labor-intensive and not possible for all populations. A systematic and broad-scale sampling regime would significantly improve our ability to detect range shifts. New methods using environmental DNA allow sampling over a large area, covering many species very quickly and inexpensively. Laramie et al. (2015) explore methodological questions about environmental DNA surveys for Chinook salmon in the Methow River Basin.

Population declines

A population dynamics model of 21 Puget Sound Chinook salmon populations explored the importance of various factors associated with declines from 1984 to 2005. On average, these populations declined until 1995, recovered slightly, and have been relatively stable at moderately low abundance in recent years. Ward et al. (2015) developed a hierarchical Ricker stock-recruit model that included ocean covariates of the PDO and North Pacific upwelling, flow metrics (mean winter flow, flow variability, and date of peak flows), and unexplained trends.

They found the strongest estimated climatic driver was variability of winter flows. There was an additional negative trend not explained by the covariates. Whether populations increased or decreased did not differ with hydrological regime (i.e., snowmelt vs transitional vs rainfall), but about half of the populations in each category increased. Variance in population growth did not increase over time, but actually decreased slightly.

Ward et al. (2015) attributed the mechanism by which flow variability reduces population growth rate to the relationship between spawn location in fall (toward river centers under low-flow conditions) with the risk of egg scour during peak winter flows (higher in river centers). Mean flows alone did not have a negative impact, presumably because fish spawned in more protected locations outside the thalweg.

Climate change predictions do indicate a high likelihood of greater annual variability in flows (lower low flow and higher winter flow), and more intense winter storms, which would also increase the variability in winter flow. This paper suggests this variability itself might be a core problem, not just the lows and highs directly.

Pteropods are especially sensitive to ocean acidification. Work published in 2015 documents levels of shell dissolution and reduced occurrence at depth along gradients in aragonite saturation levels in the southern California Current (Bednarsek and Ohman 2015). As undersaturated water continues to shoal, habitat for pteropds is likely to be reduced. Du et al. (2015) described the phytoplankton community in northern California Current in relation to upwelling. Doubleday and Hopcroft (2015) studied the plankton community in the Gulf of Alaska and found that pteropod abundance near smolt release sites was correlated with pink salmon survival.

Phenological trends: shifts in migration and spawn timing

Shifts in migration timing continue to be observed in additional populations and species each year. Three papers on Alaskan salmon demonstrate shifts in migration timing. In southeast Alaska, pink, chum, and coho display trends toward earlier migration across various time periods, depending on the species and population (Kovach et al. 2015a). However, most southeastern Alaskan sockeye populations showed trends toward delayed migration.

Coho showed the strongest and most consistent trends across populations, with a ~2 week shift over 30-year time series. However, local factors appear to have had greater effects than the general climate trend, causing highly diverse responses across coho populations. Walsworth and Schindler (2015) analyzed a Chignik River coho population in the Aleutians that showed a significant trend toward earlier migration between 1922 and 2013. Annual variation in migration timing was also correlated with the PDO.

A study of Atlantic salmon smolt timing across sites in the Penobscot River, Maine, showed the relationship of environmental variability compared with anthropogenic factors, such as hatchery practices and dam operations. (Stich et al. 2015) found a significant temperature effect on the initiation timing of migration, where timing differed by 5 d across the thermal range observed. Both temperature and flow affected movement rate (Stich et al. 2015).

Although most research is conducted at the species level to capture individualistic climatic constraints, species interactions limit range as well. Phenological mismatch occurs when predators and prey shift their timing at different rates, disrupting the food web. Sergeant et al. (2015) found that this is not a problem for Dolly Varden in Auke Creek, Alaska, where annual variation in salmon migration timing has been tracked closely.

Long-term trends in spawn timing were also noted in Lake Trout and Yellow Perch in Lake Michigan and Lake Superior (Lyons et al. 2015). Trends in water temperature were consistent with the perch response, but the link between temperature and Lake Trout phenology was not clear.

Collapse of Snake River sockeye run in 2015

Severe losses of adult sockeye in summer 2015 provided a striking example of the ramifications of increased water temperatures for salmon (NOAA Fisheries 2016). Endangered Snake River sockeye, in particular, suffered considerable mortality during their upstream migration. Early in the migration season, sockeye encountered record high temperatures in the mainstem Columbia River. By the second week of July, water temperature consistently exceeded 23°C at water quality monitoring sites at Bonneville and The Dalles Dams, and 25°C in the top meter at McNary Dam. These high temperatures persisted, producing a mean July temperature of 22.4°C at both Bonneville and The Dalles. Preliminary results showed only 14% of PIT-tagged Snake River sockeye survived from Bonneville to McNary Dam, with a record low 26 out of 679 tagged fish (4%) detected at Lower Granite Dam.

Nearly all of these survivors avoided the hottest temperatures by migrating in June rather than July. Also, none of the survivors had a history of transportation during the smolt migration, which appears to have delayed effects on the adult migration upstream. Columbia River sockeye survived at a higher rate than Snake River sockeye at all temperatures, presenting interesting questions for further research.

Record low egg-to-fry survival rates for Central Valley winter-run Chinook salmon for Brood Year 2014

Poytress (2016) summarized historical juvenile winter-run Chinook salmon passage at Red Bluff Diversion Dam and showed that brood year 2014 represented the lowest estimate of juvenile winter Chinook production since 1996. The estimated egg-to-fry survival rate, based on the brood-year 2014 winter Chinook fry-equivalent juvenile production index was 5.9%. This was the lowest estimated survival rate in 18 years of monitoring.

Martin et al. (In press) tested a lab-derived relationship between incubation water temperature and winter-run Chinook salmon egg survival rates against field data and found that it significantly underestimated field-derived estimates of thermal mortality. They used a biophysical model based on mass-transfer theory to show that the discrepancy was due to the differences in water flow velocities between the lab and the field. They found support for these predictions across more than 180 fish species, suggesting that flow and temperature mediated oxygen limitation is a general mechanism underlying the thermal tolerance of embryos. They also showed that the temperature-dependent mortality rate for winter-run Chinook salmon eggs was higher in 2015 than it was in 2014 (back-to-back record high years for temperature-dependent mortality rates).

Flow and temperature trends in the Fraser River Basin

Padilla et al. (2015) completed an updated analysis of flow and temperature in the Fraser River Basin. Interannual variability in flow during July and August increased throughout the basin from 1980 to 2005. Fall flow showed mixed responses in different sub-basins. Temperatures were most correlated with flows in July, slightly less so in August, and much less frequently in September. Variability in temperature was best predicted by whether the river was regulated.

Projected Ecological Impacts

Range shifts of all marine species

When attempting to predict range shifts for a large number of species, scientists often take a bioclimatic-envelope approach. This method used climatic correlates with the present range of each species to map future ranges on an altered climate gradient. Cheung et al. (2015) projected range shifts for 28 species in the California Current by 2050 under the A2 emissions scenario using this technique. They projected high invasion rates in the northern Bering Sea, and high local extinction rates in southern California.

Cheung et al. (2015) projected range centroids would shift by a mean of 30 km/decade. Salmon are among the species with the strongest preference for cold temperatures and thus show stronger responses than average as the California Current shifts to more warm-water species. The CCS ecosystem showed a net loss of species, with local extinction rates of over 30%, especially off Baja California.

Failure of an evolutionary rescue effect

Temperature affects many aspects of salmon physiology. Genetic variability in physiological tolerance of various traits might allow populations to adapt evolutionarily in response to a warming climate, facilitating persistence in a warming world. However, not all traits show variability in heat tolerance, so any one of these traits might limit adaptive potential.

In an experiment on juvenile Chinook salmon in British Columbia, Muñoz et al. (2015a) found limited variability in the upper thermal limit for heart arrhythmias. They extrapolated that this constraint would cause a 17-98% chance of "catastrophic loss" (presumably species-level extinction) by 2100. Mantua et al. (2015) responded to this paper, pointing out that behavioral plasticity would likely allow juveniles to avoid these high temperatures. Furthermore, geographic variability in temperature across the range of Chinook salmon will likely prevent extinction of the entire species. Munoz et al. (2015b) replied that physiological constraints are still highly limiting, and knowledge of evolutionary potential is crucial for understanding risks from climate change.

Genetic diversity must be present in order for populations to adapt. Selection over time tends to erode this variability, which is one reason evolutionary rates decline over time. In one concerning study, bull trout genetic diversity (i.e., allelic richness) was shown to be lower in habitats with higher temperatures and more winter flooding. These results suggest that trout populations may have less evolutionary potential to respond to further change in specific environmental characteristics (Kovach et al. 2015b).

Many salmon grow more slowly during their years at sea when the ocean is relatively warm. Piou et al. (2015) explored the consequences of poor ocean growth rates for Atlantic salmon in the context of a full population-dynamic and evolutionary model. They predicted that under several climate change scenarios, fish would mature at an older age to compensate for poor growth rates. Selection would favor an earlier threshold for maturation due to high mortality in the additional ocean year from both natural causes and fisheries. In their simulations, populations declined due to this additional mortality. Fishery selection for older salmon inhibited the adaptive response.

Vulnerability of other trout

Several analyses explored the vulnerability of trout species to climate change in the PNW. Bull trout in the Wenatchee River Basin was especially sensitive to habitat connectivity and wildfire size. Hence, Falke et al. (2015) concluded that land management would determine the net response to climate change. Penaluna et al. (2015) reported that coastal cutthroat trout in northwestern Oregon showed an inconsistent direction of response to climate change across streams because of complex interactions with local habitat features.

Bioenergetic models assess the amount of prey consumption necessary for fish to grow under various thermal conditions. Kao et al. (2015b) compared the energetic demands of Chinook, steelhead, and lake trout in Lakes Michigan and Huron under climate change scenarios for 2043-2070. After updating model parameters to reflect new data, they concluded that Chinook salmon will need the largest increase in prey consumption (10%) to maintain positive growth rates relative to the other species. Other species were able to maintain current growth rates without increasing consumption.

Research on additional stressors

Freshwater and ocean acidification**—**Increasing CO_2 concentrations in both freshwater and marine environments are also an important concern, especially noteworthy because of our lack of information about the direct effects of lower pH on salmon. Community models that focus on trophic interactions in complex food webs tend to predict net positive effects on salmon (Reum et al. 2015).

However, the first study to expose extensive negative effects of exposure to projected pCO_2 levels in Pacific salmon was published this year. Ou et al. (2015) studied the effects of various levels of pCO_2, including a fluctuating treatment on developmental stages of pink salmon. They found statistically significant declines in body length, yolk conversion efficiency, and total mass in the high pCO_2 treatment compared with the control. They also found significantly inhibited predator avoidance behavior and olfaction. Fivelstad et al. (2015) described declines in specific growth rate as a function of pCO_2 in Atlantic salmon, providing additional evidence for negative effects on salmon growth.

Ocean acidification poses a direct threat to calcifying species. The consequences of decline in these species for species higher in the food web is an area of active research. Reum et al. (2015) applied a new modelling approach, *qualitative network models* to explore community responses to ocean acidification in Willapa Bay, Oregon. While this approach did not include any direct effects of acidification on salmon, Chinook salmon responded positively to the altered food webs that occurred in all of their scenarios.

Invasive species**—**Impacts of climate change in montane streams include not only direct physiological constraints such as those from lethal temperatures, but also more complex dynamics mediated through species interactions. Even high temperature constraints are in practice typically lower in the field than in the laboratory (Martin et al. In press). This is partly because of species interactions—namely disease agents that become more virulent and abundant at high temperatures and that may be further concentrated by low flows and fish crowding.

Changes in food webs are also a natural consequence of climate change through differences among species in physiological tolerance and bioenergetic demand. These inherent differences in species' climate niches is exacerbated by species introductions and stocking fish.

For salmon in the Columbia River Basin, threats from increasing predation by the warm water-preferring non-native, introduced smallmouth bass is a management concern. Smallmouth bass is a particular concern in the John Day River Basin, which supports a Chinook population at the upper end of the spatial distribution. This population was feeding at the maximum consumption rate expected and constitutes one of the last remaining wild populations of Chinook salmon with minimal hatchery interference. Since bass were introduced in 1971 for recreational fishing, it has been expanding its range in the basin.

Lawrence et al. (2015) helped to elucidate thermal limitations on the upstream limits of bass distribution by developing a bioenergetic model that identifies the mechanism of the range limit. Lawrence et al. (2015) identify the range limit as the point where age-0 bass cannot grow enough over summer to store sufficient reserves to survive winter, i.e., to reach a minimum size of ~55 mm. This growth limitation depends directly on temperature, because of fish bioenergetic parameters. Their model provides a more useful means for projecting bass range shifts because it can account for changes in productivity (food availability) separately from temperature changes.

Introduction of fish into fishless lakes has a different impact on the food web, and MacLennan et al. (2015) illustrated how this interspecific dynamic can also alter the impacts of rising temperatures. MacLennan et al. (2015) showed that warmer temperatures increase zooplankton biomass and species turnover in lakes stocked with rainbow trout, but not in fishless lakes. They argue that this is because trout remove large invertebrates that otherwise regulate zooplankton populations.

Several studies focused on declines in native species and preponderance of invasive species in the Columbia River Basin. The Asian calanoid copepod, *Pseudodiaptomus forbesi*, was introduced to the Columbia River estuary approximately 15 years ago. This species now dominates the late-summer zooplankton community in the estuary (Dexter et al. 2015) and in Columbia and Snake River reservoirs (Emerson et al. 2015). *P forbesi* has a diet similar to native copepods (Bowen et al. 2015). Chinook consumed *P. forbesi* at rates equal rate to that of native copepods in single-prey experiments, but preferred native copepods in multi-prey taste tests (Adams et al. 2015).

Temperature, hypoxia, contaminants and parasites—Several studies addressed interactions between multiple stressors, such as heat stress combined with hypoxia (Anttila et al. 2015) and heat stress combined with hypoxia and heavy metals (Sappal et al. 2015). Physiological processes often responded to these stressors in opposite directions; thus, the combination of stressors was sometimes less than their additive effects.

For example, warm acclimation actually reduced sensitivity to hypoxia in Atlantic salmon (Anttila et al. 2015), and the stimulatory metabolic effects of copper were counteracted by inhibitory effects of hypoxia in rainbow trout (Sappal et al. 2015). Higher temperature, however, increased sensitivity to the combination of copper and hypoxia (Sappal et al. 2015). In their review of the literature on interacting effects of combinations of elevated CO_2 (lower pH) and metals, Ivanina and Sokolova (2015) emphasized the complexity of physiological responses to multiple stressors. Nilsen et al.

(2015) demonstrated the widespread contamination of sediment in the Columbia River Basin by documenting contaminant levels in larval Pacific lamprey, which may be contributing to the decline of that species.

Parasite loads and susceptibility of fish to parasite burdens often depends on temperature, as explained in a review by Lõhmus and Björklund (2015). The complex life cycles and rapid co-evolution between many parasites and their hosts make simple projections difficult. Although very small shifts in temperature can have very large effects on fish mortality rates, as demonstrated by simple models in this paper, there are also many potential mitigating factors. Such factors include changes in other predators or hosts of the parasite or different rates of phenological change in parasite and host that could dampen these responses.

Dam and reservoirs—Dams can both increase and decrease climate change resilience. Cool-water releases from the hypolimnion level of stratified reservoirs is used to cool waters downstream from dams, which would otherwise be lethally hot for salmon (e.g., Shasta Dam and Dworshak Dam). On the other hand, dams block access to upstream habitat that might provide a thermal refuge from high summer temperatures (e.g., Willamette River, Columbia River). Quinones et al. (2015) quantify the various costs and benefits of dam removal for 24 Californian dams. They identified four dams on the Klamath River that would have the most benefit for salmon conservation.

Dams also can exacerbate thermal barriers to passage. High temperature exposure is an important problem already on the Columbia and Willamette Rivers (Keefer and Caudill 2015; Keefer et al. 2015). Keefer and Caudill (2015) describe temperature maxima inside fishways of dams and cumulative thermal exposure of migrating adult Chinook and steelhead. Keefer et al. (2015) also found that fish were exposed to extremely high temperatures in the Willamette River, a location where pre-spawn mortality is very high.

Continuing research in correlates of salmon survival

Numerous studies explored how climatic factors are correlated with marine survival of Pacific salmon. These included:

- Duration of the smolt migration for Japanese chum (Morita and Nakashima 2015)
- Ocean entry timing for Puget Sound steelhead (Moore et al. 2015a)
- North Pacific Gyre Oscillation for coho and Chinook (Kilduff et al. 2015; Mantua 2015)
- Northern copepod anomalies for Redfish Lake sockeye (Tucker et al. 2015)
- Spring phytoplankton bloom for pink salmon (Malick et al. 2015)
- Competition between pink and sockeye salmon (Ruggerone and Connors 2015).

Bakun et al. (2015) reviewed the effects of climate change on upwelling ecosystems including the California Current and considered the interactive effects of increased upwelling, stratification, current patterns and ocean acidification. They conclude that major direct effects on pelagic fishes are unlikely, but there will be a likely shift toward more subtropical marine communities along the coast. They also raise a concern about temporal food resource mismatches for salmon as a result of shifts in the seasonality of upwelling.

Other studies improved our understanding of basic ecology of juvenile Chinook and coho salmon in the California Current: location and body size (Teel et al. 2015; Weitkamp et al. 2015) and prey selection (Daly and Brodeur 2015). Daly and Brodeur (2015) describe Chinook salmon diet between 1981 and 2011. In warm years, increased consumption did not compensate fully for increased metabolic costs. Despite eating more food that had relatively high energy density, fish were smaller and thinner in warm years, with fewer adult returns. Hertz et al. (2015) further explored salmon feeding habits with isotopic analysis, which showed results similar to those of the stomach analysis in diet breadth and diversity across different developmental stages and geographical regions. More information on juvenile Chinook salmon location and size also came to light (Teel et al. 2015; Weitkamp et al. 2015).

Numerous papers described correlations between freshwater temperature and/or flow and salmon survival. These included spawner-spawner ratios for Yukon Chinook (Neuswanger et al. 2015) and Atlantic salmon (Penaluna et al. 2015), juvenile survival in Atlantic salmon (Hvidsten et al. 2015), smolt migration survival of Sacramento River late-fall Chinook (Michel et al. 2015; Zimmerman et al. 2015), and adult pre-spawn survival of Willamette River Chinook (Benda et al. 2015; Keefer et al. 2015).

Literature Cited

Adam, J. C., and coauthors. 2015. BioEarth: Envisioning and developing a new regional earth system model to inform natural and agricultural resource management. Climatic Change 129(3-4):555-571.

Adams, J. B., S. M. Bollens, and J. G. Bishop. 2015. Predation on the Invasive Copepod, Pseudodiaptomus forbesi, and Native Zooplankton in the Lower Columbia River: An Experimental Approach to Quantify Differences in Prey-Specific Feeding Rates. Plos One 10(11).

Anderson, S. C., J. W. Moore, M. M. McClure, N. K. Dulvy, and A. B. Cooper. 2015. Portfolio conservation of metapopulations under climate change. Ecological Applications 25(2):559-572.

Anttila, K., and coauthors. 2015. Warm acclimation and oxygen depletion induce species-specific responses in salmonids. Journal of Experimental Biology 218(10):1471-1477.

Bakun, A. 1990. Global Climate Change and Intensification of Coastal Ocean Upwelling. Science 247(4939):198-201.

Bakun, A., and coauthors. 2015. Anticipated Effects of Climate Change on Coastal Upwelling Ecosystems. Current Climate Change Reports 1(2):85-93.

Baron, H. M., and coauthors. 2015. Incorporating climate change and morphological uncertainty into coastal change hazard assessments. Natural Hazards 75(3):2081-2102.

Bednarsek, N., and M. D. Ohman. 2015. Changes in pteropod distributions and shell dissolution across a frontal system in the California Current System. Marine Ecology Progress Series 523:93-103.

Benda, S. E., G. P. Naughton, C. C. Caudill, M. L. Kent, and C. B. Schreck. 2015. Cool, Pathogen-Free Refuge Lowers Pathogen-Associated Prespawn Mortality of Willamette River Chinook Salmon. Transactions of the American Fisheries Society 144(6):1159-1172.

Blunden, J., and D. S. Arndt, editors. 2016. State of the Climate in 2015, volume 97.

Bond, N. A., M. F. Cronin, H. Freeland, and N. Mantua. 2015. Causes and impacts of the 2014 warm anomaly in the NE Pacific. Geophysical Research Letters 42(9):3414-3420.

Bowen, A., G. Rollwagen-Bollens, S. M. Bollens, and J. Zimmerman. 2015. Feeding of the invasive copepod Pseudodiaptomus forbesi on natural microplankton assemblages within the lower Columbia River. Journal of Plankton Research 37(6):1089-1094.

Chen, Z. Q., and coauthors. 2015. Selection for upper thermal tolerance in rainbow trout (Oncorhynchus mykiss Walbaum). Journal of Experimental Biology 218(5):803-812.

Cheng, T. K., D. F. Hill, J. Beamer, and G. Garcia-Medina. 2015. Climate change impacts on wave and surge processes in a Pacific Northwest (USA) estuary. Journal of Geophysical Research-Oceans 120(1):182-200.

Cheung, W. W. L., R. D. Brodeur, T. A. Okey, and D. Pauly. 2015. Projecting future changes in distributions of pelagic fish species of Northeast Pacific shelf seas. Progress in Oceanography 130:19-31.

Daly, E. A., and R. D. Brodeur. 2015. Warming Ocean Conditions Relate to Increased Trophic Requirements of Threatened and Endangered Salmon. Plos One 10(12).

DART. 2016. Columbia River Data Access in Real Time. Data publicly available at www.cbr.washington.edu/dart/dart.html (Jan 2014).

Dexter, E., S. M. Bollens, G. Rollwagen-Bollens, J. Emerson, and J. Zimmerman. 2015. Persistent vs. ephemeral invasions: 8.5 years of zooplankton community dynamics in the Columbia River. Limnology and Oceanography 60(2):527-539.

Di Lorenzo, E. 2015. Climate science: the future of coastal ocean upwelling. Nature 518(7539):310-311.

Di Lorenzo, E., and N. Mantua. 2016. Multi-year persistence of the 2014/15 North Pacific marine heatwave. Nature Clim. Change 6(11):1042-1047.

Diaz, H. F., and E. R. Wahl. 2015. Recent California Water Year Precipitation Deficits: A 440-Year Perspective*. Journal of Climate 28(12):4637-4652.
Diffenbaugh, N. S., D. L. Swain, and D. Touma. 2015. Anthropogenic warming has increased drought risk in California. Proceedings of the National Academy of Sciences of the United States of America 112(13):3931-3936.
Doubleday, A. J., and R. R. Hopcroft. 2015. Interannual patterns during spring and late summer of larvaceans and pteropods in the coastal Gulf of Alaska, and their relationship to pink salmon survival. Journal of Plankton Research 37(1):134-150.
Du, X. N., W. Peterson, and L. O'Higgins. 2015. Interannual variations in phytoplankton community structure in the northern California Current during the upwelling seasons of 2001-2010. Marine Ecology Progress Series 519:75-87.
Duncan, L. L., D. Perrone, J. H. Jacobi, and G. M. Hornberger. 2015. Drought planning and management: using high spatial resolution as part of the solution. Environmental Science & Technology 49(5):2639-2647.
Emerson, J. E., S. M. Bollens, and T. D. Counihan. 2015. Seasonal dynamics of zooplankton in Columbia-Snake River reservoirs, with special emphasis on the invasive copepod Pseudodiaptomus forbesi. Aquatic Invasions 10(1):25-40.
Falke, J. A., and coauthors. 2015. Climate change and vulnerability of bull trout (Salvelinus confluentus) in a fire-prone landscape. Canadian Journal of Fisheries and Aquatic Sciences 72(2):304-318.
Ficklin, D. L., J. T. Maxwell, S. L. Letsinger, and H. Gholizadeh. 2015. A climatic deconstruction of recent drought trends in the United States. Environmental Research Letters 10(4).
Fivelstad, S., and coauthors. 2015. Growth and physiological models for Atlantic salmon (Salmo salar L.) parr exposed to elevated carbon dioxide concentrations at high temperature. Aquaculture 436:90-94.
Gao, Y., and coauthors. 2015. Dynamical and thermodynamical modulations on future changes of landfalling atmospheric rivers over western North America. Geophysical Research Letters 42(17):7179-7186.
Garvin, M. R., G. H. Thorgaard, and S. R. Narum. 2015. Differential Expression of Genes that Control Respiration Contribute to Thermal Adaptation in Redband Trout (Oncorhynchus mykiss gairdneri). Genome Biology and Evolution 7(6):1404-1414.
Hecht, B. C., A. P. Matala, J. E. Hess, and S. R. Narum. 2015. Environmental adaptation in Chinook salmon (Oncorhynchus tshawytscha) throughout their North American range. Molecular Ecology 24(22):5573-5595.
Hertz, E., and coauthors. 2015. Continental-scale variability in the feeding ecology of juvenile Chinook salmon along the coastal Northeast Pacific Ocean. Marine Ecology Progress Series 537:247-263.
Holmes, K. R., N. C. Coops, T. A. Nelson, F. M. A. Fontana, and M. A. Wulder. 2015. Indicators of vegetation productivity under a changing climate in British Columbia, Canada. Applied Geography 56:135-144.
Hvidsten, N. A., and coauthors. 2015. Water discharge affects Atlantic salmon Salmo salar smolt production: a 27 year study in the River Orkla, Norway. Journal of Fish Biology 86(1):92-104.
Ivanina, A. V., and I. M. Sokolova. 2015. Interactive effects of metal pollution and ocean acidification on physiology of marine organisms. Current Zoology 61(4):653-668.
Jacox, M. G., S. J. Bograd, E. L. Hazen, and J. Fiechter. 2015a. Sensitivity of the California Current nutrient supply to wind, heat, and remote ocean forcing. Geophysical Research Letters 42(14):5950-5957.
Jacox, M. G., J. Fiechter, A. M. Moore, and C. A. Edwards. 2015b. ENSO and the California Current coastal upwelling response. Journal of Geophysical Research-Oceans 120(3):1691-1702.
Jang, S., and M. L. Kavvas. 2015. Downscaling global climate simulations to regional scales: statistical downscaling versus dynamical downscaling. Journal of Hydrologic Engineering 20(1).

Johnson-Colegrove, A., L. Ciannelli, and R. D. Brodeur. 2015. Ichthyoplankton distribution and abundance in relation to nearshore dissolved oxygen levels and other environmental variables within the Northern California Current System. Fisheries Oceanography 24(6):495-507.
Kao, S. C., and coauthors. 2015a. Projecting changes in annual hydropower generation using regional runoff data: an assessment of the United States federal hydropower plants. Energy 80:239-250.
Kao, Y. C., C. P. Madenjian, D. B. Bunnell, B. M. Lofgren, and M. Perroud. 2015b. Temperature effects induced by climate change on the growth and consumption by salmonines in Lakes Michigan and Huron. Environmental Biology of Fishes 98(4):1089-1104.
Keefer, M. L., and C. C. Caudill. 2015. Estimating thermal exposure of adult summer steelhead and fall Chinook salmon migrating in a warm impounded river. Ecology of Freshwater Fish:n/a-n/a.
Keefer, M. L., and coauthors. 2015. Thermal exposure of adult Chinook salmon in the Willamette River basin. Journal of Thermal Biology 48:11-20.
Kilduff, D. P., E. Di Lorenzo, L. W. Botsford, and S. L. H. Teo. 2015. Changing central Pacific El Ninos reduce stability of North American salmon survival rates. Proceedings of the National Academy of Sciences of the United States of America 112(35):10962-10966.
Klos, P. Z., and coauthors. 2015. Indicators of Climate Change in Idaho: An Assessment Framework for Coupling Biophysical Change and Social Perception. Weather Climate and Society 7(3):238-254.
Kluver, D., and D. Leathers. 2015. Regionalization of snowfall frequency and trends over the contiguous United States. International Journal of Climatology 35(14):4348-4358.
Kostadinov, T. S., and T. R. Lookingbill. 2015. Snow cover variability in a forest ecotone of the Oregon Cascades via MODIS Terra products. Remote Sensing of Environment 164:155-169.
Kovach, R. P., S. C. Ellison, S. Pyare, and D. A. Tallmon. 2015a. Temporal patterns in adult salmon migration timing across southeast Alaska. Global Change Biology 21(5):1821-1833.
Kovach, R. P., and coauthors. 2015b. Genetic diversity is related to climatic variation and vulnerability in threatened bull trout. Global Change Biology 21(7):2510-2524.
Laramie, M. B., D. S. Pilliod, and C. S. Goldberg. 2015. Characterizing the distribution of an endangered salmonid using environmental DNA analysis. Biological Conservation 183:29-37.
Larios-Lopez, J. E., J. M. T. de Figueroa, C. Alonso-Gonzalez, and B. N. Sanz. 2015. Distribution of brown trout (Salmo trutta Linnaeus, 1758) (Teleostei: Salmonidae) in its southwesternmost European limit: possible causes. Italian Journal of Zoology 82(3):404-415.
Lawrence, D. J., D. A. Beauchamp, and J. D. Olden. 2015. Life-stage-specific physiology defines invasion extent of a riverine fish. Journal of Animal Ecology 84(3):879-888.
Link, J. S., R. Griffis, and S. Busch, editors. 2015. NOAA Fisheries Climate Science Strategy. U.S. Dept. of Commerce, NOAA Technical Memorandum NMFS-F/SPO-155.
Logerwell, E., and coauthors. 2015. Fish communities across a spectrum of habitats in the western Beaufort Sea and Chukchi Sea. Progress in Oceanography 136:115-132.
Lõhmus, M., and M. Björklund. 2015. Climate change: what will it do to fish-parasite interactions? Biological Journal of the Linnean Society 116(2):397-411.
Lyons, J., and coauthors. 2015. Trends in the Reproductive Phenology of two Great Lakes Fishes. Transactions of the American Fisheries Society 144(6):1263-1274.
MacLennan, M. M., C. Dings-Avery, and R. D. Vinebrooke. 2015. Invasive trout increase the climatic sensitivity of zooplankton communities in naturally fishless lakes. Freshwater Biology 60(8):1502-1513.
Malick, M. J., S. P. Cox, F. J. Mueter, and R. M. Peterman. 2015. Linking phytoplankton phenology to salmon productivity along a north-south gradient in the Northeast Pacific Ocean. Canadian Journal of Fisheries and Aquatic Sciences 72(5):697-708.

Mann, M. E., and P. H. Gleick. 2015. Climate change and California drought in the 21st century. Proceedings of the National Academy of Sciences of the United States of America 112(13):3858-3859.
Mantua, N. J. 2015. Shifting patterns in Pacific climate, West Coast salmon survival rates, and increased volatility in ecosystem services. Proceedings of the National Academy of Sciences of the United States of America 112(35):10823-10824.
Mantua, N. J., L. G. Crozier, T. E. Reed, D. E. Schindler, and R. S. Waples. 2015. CORRESPONDENCE: Response of chinook salmon to climate change. Nature Climate Change 5(7):613-615.
Mao, Y., B. Nijssen, and D. P. Lettenmaier. 2015. Is climate change implicated in the 2013- 2014 California drought? A hydrologic perspective. Geophys. Res. Lett. 42:2805-2813.
Marcinkowski, K., and D. L. Peterson. 2015. A 350-year reconstruction of the response of South Cascade Glacier to interannual and interdecadal climatic variability. Northwest Science 89(1):14-33.
Martin, B. T., and coauthors. In press. Phenomenological vs. biophysical models of thermal stress in aquatic eggs. Ecology Letters.
Mateus, C., D. D. Tullos, and C. G. Surfleet. 2015. Hydrologic sensitivity to climate and land use changes in the Santiam River Basin, Oregon. Journal of the American Water Resources Association 51(2):400-420.
Mathis, J. T., J. N. Cross, W. Evans, and S. C. Doney. 2015. Ocean Acidification in the Surface Waters of the Pacific-Arctic Boundary Regions. Oceanography 28(2):122-135.
Mera, R., and coauthors. 2015. Climate change, climate justice and the application of probabilistic event attribution to summer heat extremes in the California Central Valley. Climatic Change 133(3):427-438.
Michel, C. J., and coauthors. 2015. Chinook salmon outmigration survival in wet and dry years in California's Sacramento River. Canadian Journal of Fisheries and Aquatic Sciences 72(11):1749-1759.
Mo, K. C., and D. P. Lettenmaier. 2015. Heat wave flash droughts in decline. Geophysical Research Letters 42(8):2823-2829.
Moore, M. E., and coauthors. 2015a. Multi-population analysis of Puget Sound steelhead survival and migration behavior. Marine Ecology Progress Series 537:217-232.
Moore, S. K., J. A. Johnstone, N. S. Banas, and E. P. Salathe. 2015b. Present-day and future climate pathways affecting Alexandrium blooms in Puget Sound, WA, USA. Harmful Algae 48:1-11.
Morita, K., and A. Nakashima. 2015. Temperature seasonality during fry out-migration influences the survival of hatchery-reared chum salmon Oncorhynchus keta. Journal of Fish Biology 87(4):1111-1117.
Munoz, N. J., A. P. Farrell, J. W. Heath, and B. D. Neff. 2015a. Adaptive potential of a Pacific salmon challenged by climate change. Nature Climate Change 5(2):163-166.
Munoz, N. J., A. P. Farrell, J. W. Heath, and B. D. Neff. 2015b. Reply to 'Response of chinook salmon to climate change'. Nature Climate Change 5(7):615-615.
Mutiibwa, D., S. J. Vavrus, S. A. McAfee, and T. P. Albright. 2015. Recent spatiotemporal patterns in temperature extremes across conterminous United States. Journal of Geophysical Research-Atmospheres 120(15):7378-7392.
Najafi, M. R., and H. Moradkhani. 2015. Multi-model ensemble analysis of runoff extremes for climate change impact assessments. Journal of Hydrology 525:352-361.
Narum, S. R., and N. R. Campbell. 2015. Transcriptomic response to heat stress among ecologically divergent populations of redband trout. Bmc Genomics 16.
Neuswanger, J. R., M. S. Wipfli, M. J. Evenson, N. F. Hughes, and A. E. Rosenberger. 2015. Low productivity of Chinook salmon strongly correlates with high summer stream discharge in two Alaskan rivers in the Yukon drainage. Canadian Journal of Fisheries and Aquatic Sciences 72(8):1125-1137.
Nilsen, E. B., W. B. Hapke, B. McIlraith, and D. Markovchick. 2015. Reconnaissance of contaminants in larval Pacific lamprey (Entosphenus tridentatus) tissues and habitats in

the Columbia River Basin, Oregon and Washington, USA. Environmental Pollution 201:121-130.
Nilsson, C., L. E. Polvi, and L. Lind. 2015. Extreme events in streams and rivers in arctic and subarctic regions in an uncertain future. Freshwater Biology 60(12):2535-2546.
NOAA Fisheries. 2016. 2015 adult sockeye salmon passage report. Available at http://www.westcoast.fisheries.noaa.gov/publications/hydropower/fcrps/2015_adult_sockeye_salmon_passage_report.pdf.
Ou, M., and coauthors. 2015. Responses of pink salmon to CO2-induced aquatic acidification. Nature Climate Change 5(10):950-+.
Pacific Fishery Management Council. 2016. Preseason report 1 stock abundance analysis and environmental assessment Part 1 for 2016 ocean salmon fishery regulations. Regulation identifier number 0648-BF56. Available at http://www.pcouncil.org/wp-content/uploads/2016/03/Preseason_Report_I_2016_FINAL03012016.pdf.
Padilla, A., K. Rasouli, and S. J. Dery. 2015. Impacts of variability and trends in runoff and water temperature on salmon migration in the Fraser River Basin, Canada. Hydrological Sciences Journal-Journal Des Sciences Hydrologiques 60(3):523-533.
Payne, A. E., and G. Magnusdottir. 2015. An evaluation of atmospheric rivers over the North Pacific in CMIP5 and their response to warming under RCP 8.5. Journal of Geophysical Research-Atmospheres 120(21):11173-11190.
Penaluna, B. E., and coauthors. 2015. Local Variability Mediates Vulnerability of Trout Populations to Land Use and Climate Change. Plos One 10(8).
Piou, C., M. H. Taylor, J. Papaix, and E. Prevost. 2015. Modelling the interactive effects of selective fishing and environmental change on Atlantic salmon demogenetics. Journal of Applied Ecology 52(6):1629-1637.
Poytress, W. R. 2016. Brood-year 2014 winter Chinook juvenile production indices with comparisons to juvenile production estimates derived from adult escapement. Report of U.S. Fish and Wildlife Service to U.S. Bureau of Reclamation, Sacramento, CA.
Quinones, R. M., and coauthors. 2015. Dam removal and anadromous salmonid (Oncorhynchus spp.) conservation in California. Reviews in Fish Biology and Fisheries 25(1):195-215.
Radic, V., A. J. Cannon, B. Menounos, and N. Gi. 2015. Future changes in autumn atmospheric river events in British Columbia, Canada, as projected by CMIP5 global climate models. Journal of Geophysical Research-Atmospheres 120(18):9279-9302.
Reiter, M., R. E. Bilby, S. Beech, and J. Heffner. 2015. Stream temperature patterns over 35 years in a managed forest of Western Washington. Journal of the American Water Resources Association 51(5):1418-1435.
Reum, J. C. P., and coauthors. 2015. Evaluating community impacts of ocean acidification using qualitative network models. Marine Ecology Progress Series 536:11-24.
Riedel, J. L., and coauthors. 2015. Glacier status and contribution to streamflow in the Olympic Mountains, Washington, USA. Journal of Glaciology 61(225):8-16.
Roberts, C. D., M. D. Palmer, D. McNeall, and M. Collins. 2015. Quantifying the likelihood of a continued hiatus in global warming. Nature Clim. Change advance online publication.
Ruggerone, G. T., and B. M. Connors. 2015. Productivity and life history of sockeye salmon in relation to competition with pink and sockeye salmon in the North Pacific Ocean. Canadian Journal of Fisheries and Aquatic Sciences 72(6):818-833.
Rykaczewski, R. R., and coauthors. 2015. Poleward displacement of coastal upwelling-favorable winds in the ocean's eastern boundary currents through the 21st century. Geophysical Research Letters 42(15):6424-6431.
Safeeq, M., G. E. Grant, S. L. Lewis, and B. Staab. 2015. Predicting landscape sensitivity to present and future floods in the Pacific Northwest, USA. Hydrological Processes 29(26):5337-5353.
Sagarika, S., A. Kalra, and S. Ahmad. 2015. Interconnections between oceanic-atmospheric indices and variability in the US streamflow. Journal of Hydrology 525:724-736.
Sappal, R., and coauthors. 2015. Effects of copper, hypoxia and acute temperature shifts on mitochondrial oxidation in rainbow trout (Oncorhynchus mykiss) acclimated to warm

temperature. Aquatic Toxicology 169:46-57.
Schoof, J. T. 2015. High-resolution projections of 21st century daily precipitation for the contiguous US. Journal of Geophysical Research-Atmospheres 120(8):3029-3042.
Sergeant, C. J., J. B. Armstrong, and E. J. Ward. 2015. Predator-prey migration phenologies remain synchronised in a warming catchment. Freshwater Biology 60(4):724-732.
Shanley, C. S., and coauthors. 2015. Climate change implications in the northern coastal temperate rainforest of North America. Climatic Change 130(2):155-170.
Sheehan, T., D. B. Let, and K. Ferschweiler. 2015. Projected major fire and vegetation changes in the Pacific Northwest of the conterminous United States under selected CMIP5 climate futures. Ecological Modelling 317:16-29.
Siedlecki, S. A., and coauthors. 2015. Seasonal and interannual oxygen variability on the Washington and Oregon continental shelves. Journal of Geophysical Research-Oceans 120(2):608-633.
Spietz, R. L., C. M. Williams, G. Rocap, and M. C. Horner-Devine. 2015. A dissolved oxygen threshold for shifts in bacterial community structure in a seasonally hypoxic estuary. Plos One 10(8).
Stich, D. S., M. T. Kinnison, J. F. Kocik, and J. D. Zydlewski. 2015. Initiation of migration and movement rates of Atlantic salmon smolts in fresh water. Canadian Journal of Fisheries and Aquatic Sciences 72(9):1339-1351.
Takeshita, Y., and coauthors. 2015. Including high-frequency variability in coastal ocean acidification projections. Biogeosciences 12(19):5853-5870.
Teel, D. J., B. J. Burke, D. R. Kuligowski, C. A. Morgan, and D. M. Van Doornik. 2015. Genetic Identification of Chinook Salmon: Stock-Specific Distributions of Juveniles along the Washington and Oregon Coasts. Marine and Coastal Fisheries 7(1):274-300.
Tennant, C. J., B. T. Crosby, and S. E. Godsey. 2015. Elevation-dependent responses of streamflow to climate warming. Hydrological Processes 29(6):991-1001.
Thorne, J. H., R. M. Boynton, L. E. Flint, and A. L. Flint. 2015. The magnitude and spatial patterns of historical and future hydrologic change in California's watersheds. Ecosphere 6(2):24.
Tucker, S., and coauthors. 2015. Coastal Distribution and Consequent Factors Influencing Production of Endangered Snake River Sockeye Salmon. Transactions of the American Fisheries Society 144(1):107-123.
Turner, D. P., D. R. Conklin, and J. P. Bolte. 2015. Projected climate change impacts on forest land cover and land use over the Willamette River Basin, Oregon, USA. Climatic Change 133(2):335-348.
Vano, J. A., J. B. Kim, D. E. Rupp, and P. W. Mote. 2015a. Selecting climate change scenarios using impact-relevant sensitivities. Geophysical Research Letters 42(13):5516-5525.
Vano, J. A., B. Nijssen, and D. P. Lettenmaier. 2015b. Seasonal hydrologic responses to climate change in the Pacific Northwest. Water Resources Research 51(4):1959-1976.
Walsworth, T. E., and D. E. Schindler. 2015. Coho salmon escapement and trends in migration timing to a data-poor river: estimates from a Bayesian hierarchical model. Canadian Journal of Fisheries and Aquatic Sciences 72(12):1807-1816.
Walton, D. B., F. P. Sun, A. Hall, and S. Capps. 2015. A hybrid dynamical-statistical downscaling technique. part I: development and validation of the technique. Journal of Climate 28(12):4597-4617.
Wang, D. W., T. C. Gouhier, B. A. Menge, and A. R. Ganguly. 2015. Intensification and spatial homogenization of coastal upwelling under climate change. Nature 518(7539):390-394.
Ward, E. J., J. H. Anderson, T. J. Beechie, G. R. Pess, and M. J. Ford. 2015. Increasing hydrologic variability threatens depleted anadromous fish populations. Global Change Biology 21(7):2500-2509.
Warner, M., C. F. Mass, and E. P. Salathé. 2015. Changes in winter atmospheric rivers along the North American west coast in CMIP5 climate models. J. Hydrometeorology 16:118-128.
Weitkamp, L. A., and coauthors. 2015. Stock-Specific Size and Timing at Ocean Entry of Columbia River Juvenile Chinook Salmon and Steelhead: Implications for Early Ocean

Growth. Marine and Coastal Fisheries 7(1):370-392.
Williams, A. P., and coauthors. 2015. Contribution of anthropogenic warming to California drought during 2012–2014. Geophysical Research Letters 42(16):6819-6828.
Witiw, M. R., and S. LaDochy. 2015. Cool PDO phase leads to recent rebound in coastal southern California fog. Erde 146(4):232-244.
Zimmerman, M. S., C. Kinsel, E. Beamer, E. J. Connor, and D. E. Pflug. 2015. Abundance, Survival, and Life History Strategies of Juvenile Chinook Salmon in the Skagit River, Washington. Transactions of the American Fisheries Society 144(3):627-641.