Endangered Species Act
Federal Columbia River Power System
2010 Annual ESA Progress Report: Section 2

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

Under Reasonable and Prudent Alternative (RPA) action 2, the Bonneville Power Administration (BPA), U.S. Army Corps of Engineers (Corps), and Bureau of Reclamation (Reclamation), collectively referred to as the Action Agencies, submit an annual progress report that describes the status of implementation for the previous calendar year. Section 2 describes this progress for each RPA action. Section 3 includes a list of all projects implemented in 2010 along with their associated RPA subactions.

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Hydropower Implementation Reports, RPA Actions 4–33

This document reports on actions taken during calendar year 2010. The Hydropower RPA actions are intended to be implemented over the term of the Biological Opinion (BiOp). Although many of these actions were under way or being implemented during 2010, some will be implemented later in the BiOp period. For hydro operations, actions are reported by water year (October through September) rather than calendar year because this is more meaningful.

Table 1. Hydropower Strategy Reporting

RPA Action No.	Action	Annual Progress Report
Hydropower Strategy 1		
4	Storage Project Operations	Prepare an annual year-end review.
5	Lower Columbia and Snake River Operations	Prepare an annual year-end review.
6	In-Season Water Management	Annual progress reports will describe Federal Columbia River Power System (FCRPS) operations for the fish passage season. There is no other physical or biological monitoring or reporting.
7	Forecasting and Climate Change/Variability	Annual progress reports will include a summary of the annual forecast review and any new, pertinent climate change information or research.
8	Operational Emergencies	Annual progress reports will describe any emergency situations and actions taken per the emergency protocols. There is no other physical or biological monitoring or reporting.
9	Fish Emergencies	Annual progress reports will describe any fish emergency situations and actions taken. There is no other physical or biological monitoring or reporting.
10	Columbia River Treaty Storage	Annual progress reports will describe actions taken to provide 1 million acre-feet (maf) of storage in treaty space. There is no other physical or biological monitoring or reporting.
11	Non-Treaty Storage (NTS)	Annual progress reports will describe actions taken to refill non-treaty storage (NTS) space. There is no other physical or biological monitoring or reporting.
12	Non-Treaty Long-Term Agreement	Annual progress reports will describe actions taken to develop long-term and/or annual agreements that affect lower Columbia River flows during the April through August period. There is no other physical or biological monitoring or reporting.
13	Non-Treaty Coordination with Federal Agencies, States, and Tribes	Annual progress reports will describe actions to coordinate NTS agreements. There is no other physical or biological monitoring or reporting.

Table 1. Hydropower Strategy Reporting

RPA Action No.	Action	Annual Progress Report
14	Dry Water Year Operations	Annual progress reports will describe 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	Annual progress reports will describe actions taken to implement Endangered Species Act (ESA) commitments. There is no other physical or biological monitoring or reporting.
16	Tributary Projects	Status of the consultations for Reclamation's tributary projects will be provided in the annual progress reports.
17	Chum Spawning Flows	Annual progress reports will describe in-season water management actions taken during the water year, which includes part of the previous calendar year.
18	Configuration and Operational Plan for Bonneville Project	Annual progress reports will describe status of the actions taken in the Configuration and Operational Plan (COP) and the results of the associated research, monitoring, and evaluation (RME).
19	Configuration and Operational Plan for The Dalles Project	Annual progress reports will describe the status of the actions taken in the COP and the results of the associated RME.
20	Configuration and Operational Plan for John Day Project	Annual progress reports will describe the status of the actions taken in the COP and the results of the associated RME.
21	Configuration and Operational Plan for McNary Project	Annual progress reports will describe the status of the actions taken in the COP and the results of the associated RME.
22	Configuration and Operational Plan for Ice Harbor Project	Annual progress reports will describe the status of the actions taken in the COP and the results of the associated RME.
23	Configuration and Operational Plan for Lower Monumental Project	Annual progress reports will describe status of the actions taken in the COP and the results of the associated RME
24	Configuration and Operational Plan for Little Goose Project	Annual progress reports will describe the status of the actions taken in the COP and the results of the associated RME.
25	Configuration and Operational Plan for Lower Granite Project	Annual progress reports will describe the status of the actions taken in the COP and the results of the associated RME.
26	Chief Joseph Dam Flow Deflector	Annual progress reports will describe the status of the flow deflector construction. Note: This construction project was completed in spring 2009.
27	Turbine Unit Operations	Annual progress reports are developed by BPA.

Table 1. Hydropower Strategy Reporting

RPA Action No.	Action	Annual Progress Report
Hydropower Strategy 2		
28	Columbia and Snake River Project Adult Passage Improvements	Annual progress reports will describe the status of the actions taken.
Hydropower Strategy 3		
29	Spill Operations to Improve Juvenile Passage	Spill operations are reported annually.
30	Juvenile Fish Transportation in the Columbia and Snake Rivers	Annual progress reports will provide the number of fish collected and transported in an annual report each February.
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.
Hydropower Strategy 4		
32	Fish Passage Plan (FPP)	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.

Hydropower Strategy 1 (RPA Actions 4–27)

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 Federal Columbia River Power System (FCRPS) storage projects were operated in accordance with the 2010 Water Management Plan (WMP) (ACOE, BPA, and Reclamation 2010 WMP), at *http://www.nwd-wc.usace.army.mil/tmt/documents/wmp/2010/final/wmp_final_20091231.pdf*, which was developed in the fall 2009 with full regional coordination.[1] The 2010 operations were under court

[1] The Regional Forum process was developed in 1995 and has been employed ever since by NOAA Fisheries and other regional entities to implement ESA provisions for protection and recovery of listed salmon species. Members of the Regional Forum include: state and tribal sovereigns with management authority over fish and wildlife resources and water quality in the Columbia River basin; and federal agencies with regulatory or action authority in the Columbia River, including NOAA Fisheries, USFWS, BPA, Corps, EPA, and Reclamation. Other agencies and regional interests, such as the Northwest Power and Conservation Council, the Idaho Power Company and the Mid-Columbia Public Utility Districts, may also attend. The Regional Forum consists of several technical workgroups such as the Technical Management Team (TMT), the System Configuration Team (SCT), the Studies Review Work Group (SRWG), and the Fish Passage Operations and Maintenance (FPOM) workgroup. As used in this document,

order, as in 2009. In accordance with the adaptive management provisions of the 2008 BiOp, the WMP was developed to meet RPA hydro actions identified in the 2008 FCRPS BiOp and the 2000 and 2006

"the region" or "regional coordination" generally refers to the Regional Forum technical subgroup appropriate for the issue at hand.

U.S. Fish and Wildlife Service (USFWS) BiOps (USFWS 2000, 2006). The WMP incorporates operations consistent with the 2010 Spring and Summer Fish Operations Plans (FOPs) and the respective court orders. Details of the operations of the projects are shown in Figures 1 through 4 and described below. Further discussion of these operations is included in the minutes of the Technical Management Team (TMT) "2010 Year End Review Session" (Columbia River Regional Forum TMT) at *http://www.nwd-wc.usace.army.mil/tmt/agendas/2010/1208_Minutes.pdf*.

Dworshak Dam

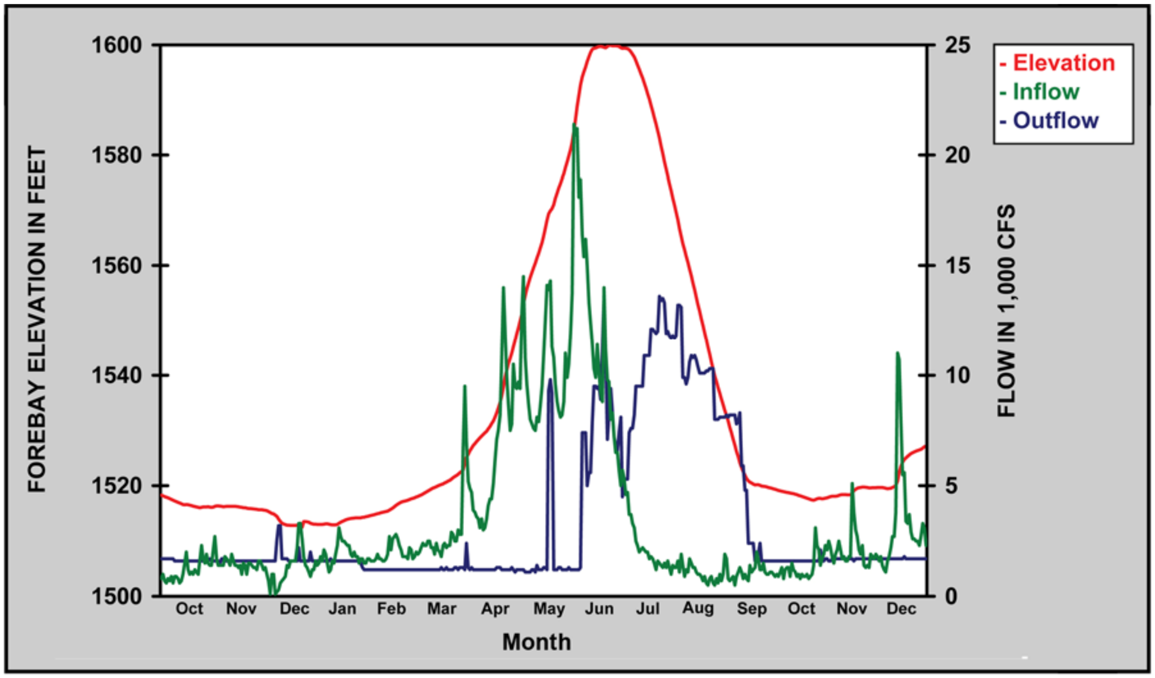


Figure 1. Dworshak Dam Inflow, Outflow, and Forebay Elevation from October 1, 2009, through December 31, 2010.

From October 2009 through mid-May 2010, Dworshak Dam released approximately 1,200 to 1,600 cubic feet per second (cfs), except for some minor unit testing. Dworshak Dam began January 2010 at elevation 1,513 feet, well under flood control elevations. From May 20-23, 2010, the project released near full powerhouse at the request of the Salmon Managers to augment flows in the lower Snake River for smolt migration. The project then returned to near minimum discharge to ensure meeting refill targets, due to low inflows and a below average water supply forecast (WSF).

Dworshak Dam was operated to meet standard flood control criteria during the winter and spring flood control season and, due to dry conditions and low inflows, stayed at or below the flood control rule curve, despite near minimum outflow.

The project began April 2010 at elevation 1,525.4 feet and filled to 1,546.4 feet by the end of the month as modest rises in inflow were seen during the month. The May 2010 forecast for the May-to-July inflow volume was 1,980 thousand acre-feet (kaf), which was 58 percent of average. During April and May 2010, the inflows averaged 6,350 cfs and 10,020 cfs, respectively. From early to mid-June 2010, unusually strong rain events boosted inflows, and Dworshak Dam reached full levels (maximum elevation of 1,600.0 feet) on June 25, 2010. June 2010 inflow averaged 12,590 cfs and outflow averaged 6,430 cfs.

The reservoir began drafting on July 5, 2010 to provide temperature and flow augmentation for the lower Snake River. Summer temperature management was successful, maintaining Lower Granite Dam tailwater temperatures below 68 degrees Fahrenheit; the maximum Lower Granite Dam tailwater temperature recorded in 2010 was 67.8 degrees Fahrenheit. By August 31, 2010, the reservoir was drafted to elevation 1,535.7 feet. September 2010 operations followed the Nez Perce 200 kaf operational plan for 2010, with orderly prescribed stepdowns to a flow of 1,600 cfs on September 20, 2010, when the reservoir reached 1,520 feet.

From October to December 2010, Dworshak Dam released minimum flows between 1,600 and 1,700 cfs, except during brief periods of turbine testing following normal maintenance activities. Dworshak Dam ended December 2010 at elevation 1,513.1 feet, with flood control elevation being 1,527.2 feet.

Libby Dam

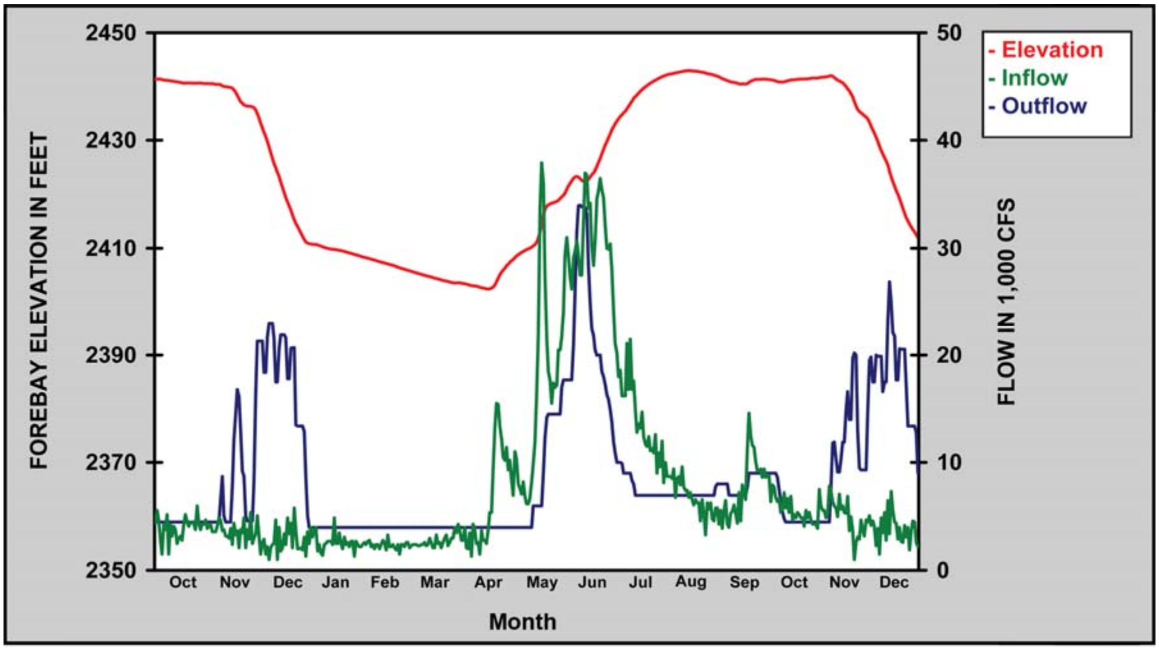


Figure 2. Libby Dam Inflow, Outflow, and Forebay Elevation from October 1, 2009, through December 31, 2010.

After meeting an end of December 2009 flood control elevation target of 2,411.0 feet, Libby Dam released the minimum flow of 4,000 cfs (Figure 2) from January through May 14, 2010. Due to cool weather and below average snow pack, the project filled less than three feet in April 2010, ending that month at elevation 2,407.1 feet. Inflows averaged 6,123 cfs in April 2010 and 14,296 feet through May 23, 2010. A heat event during the third week of May 2010 spiked inflows above 30 thousand cubic feet per second (kcfs). Outflow was kept at 4 kcfs through May 14, 2010, then increased to the minimum bull trout flow of 6 kcfs on May 16, 2010, and was increased to a full variable outflow flood control procedures (VARQ) outflow of 14.5 kcfs on May 23, 2010. As of May 23, 2010, the project was at elevation 2,417.8 feet.

The calculated May 2010 WSF was 4,887 kaf, triggering a tier 2 Kootenai River white sturgeon operation of 800 kaf, consistent with the USFWS 2006 BiOp as clarified in 2008. As part of that operation, while taking into consideration other operational requirements, the Corps operates Libby Dam so as to best position the reservoir to spill up to 10 kcfs on top of full powerhouse outflows in May to June 2010 in order to provide experimental benefits to endangered sturgeon. In order to boost reservoir levels higher to provide gated spill, the Corps delayed the beginning of VARQ operations, storing an additional 260 kaf, as documented through a formal internal deviation review process and coordinated with the TMT. Libby Dam began June 2010 at elevation 2,419.4 feet, increased outflow to about 17.7 kcfs, and then increased outflows again for the sturgeon operation beginning on June 8, 2010. Following release of the required 800 kaf of water for the sturgeon operation the project drafted out the remaining volume that was stored by deviating earlier from the VARQ flows.

From July 1 through July 15, 2010, all remaining surplus storage was released and flows decreased to 7,000 cfs on July 15, 2010. The project maintained 7,000 cfs, the minimum flow for bull trout based on WSFs, for the remainder of July and August 2010. Libby Dam filled at a very slow rate into August 2010, reaching its highest elevation of the year on August 17, 2010, of 2,443.0 feet (noon reading). The July 2010 project outflow averaged 8,280 cfs. Inflows during July and August 2010 averaged 15,390 cfs and 7,080 cfs respectively. The project drafted slightly by the end of August 2010, declining to 2,442.1 feet.

For September 2010, the plan was to start with a slightly higher outflow and then decrease if needed to a flow of no less than 6,000 cfs, the minimum for bull trout. The project outflow was increased to 8,000 cfs on September 1, 2010, and then reduced to 7,000 cfs on September 9, 2010. Unusually strong rain events required ramping up to 9,000 cfs on September 20, 2010. Forecasts then suggested releases of approximately 12,000 cfs in order to reach the end of September 2010 target. A special session of the TMT convened to discuss the operation and potential biological impacts to the river reach below Libby Dam from projected flow fluctuations. In that session, a favored alternative was adopted to keep outflows at 9,000 cfs through September 2010 and maintain that outflow until elevation reached 2,439.0 feet, expected by October 9, 2010. The end of September 2010 elevation was 2,441.4 feet.

Due to inflows that continued to be higher than forecast, the Corps concluded, with input from the TMT, that the prudent operation would be to begin a gradual decrease toward 4,500 cfs. The project was operated at 4,500 cfs from October 13, 2010, through November 11, 2010, at which time outflow was increased for the fall flood control draft with attendant power operations. Based on the December 2010 Libby Dam WSF (6.3 million acre feet [maf]), the end of December flood control target was set at elevation 2,411 feet. In mid-December 2010, the Corps' Seattle District requested a slight relaxation from the end of the month elevation target, based on preliminary water supply estimates and current inflow conditions. The project ended December 2010 at 2,411.9 feet (midnight elevation). December 2010 inflows average 3.9 kcfs, and outflows averaged 18.2 kcfs.

Grand Coulee Dam

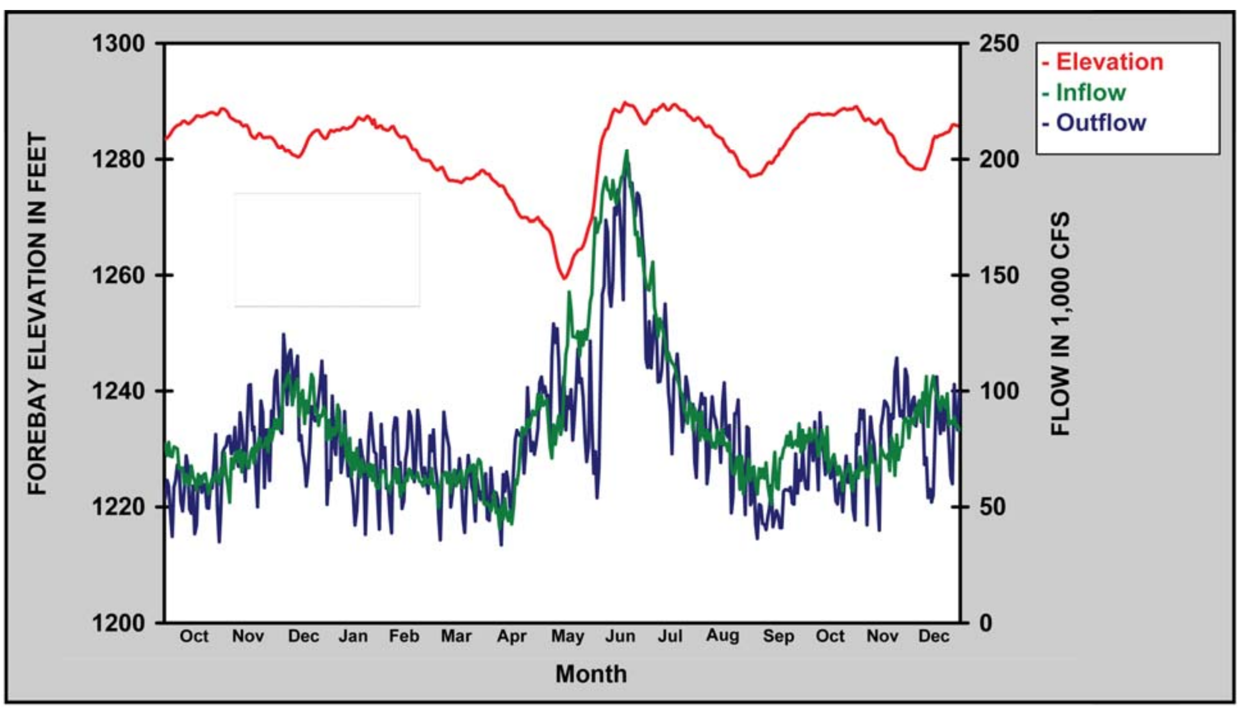


Figure 3. Grand Coulee Dam Inflow, Outflow, and Forebay Elevation from October 1, 2009, through December 31, 2010.

Grand Coulee Dam was operated during November and December 2009 to facilitate chum spawning below Bonneville Dam resulting in an 11.5-foot chum redd protection tailwater elevation. During January and February 2010, Grand Coulee Dam was operated to help maintain the chum redd protection tailwater of 11.5 feet below Bonneville Dam as well as the Vernita Bar protection flows of 60 kcfs below Priest Rapids Dam. Due to a low WSF, the decision was made by the TMT to transition, starting in March 2010, from meeting chum redd protection to just meeting the Vernita Bar protection flows and conserving as much water as practicable for the spring migration period. This was accomplished by gradually decreasing the required tailwater elevation below Bonneville Dam until flows were just sufficient to meet the Vernita Bar protection flows. Transition operations at Grand Coulee Dam were coordinated by the TMT. WSFs for the basin above Grand Coulee Dam for the April to September 2010 period were at 90 percent of average in January 2010, 76 percent of average in March 2010, 74 percent of average in April 2010, and 75 percent of average in June 2010. As a result of the low WSFs, flood control elevations were relatively high. Due to dry conditions and degrading water supply throughout the winter, Grand Coulee Dam storage was needed to help support the chum operation, and as a result, the project was drafted to elevation 1,275.2 feet on April 10, 2010, or about 8 feet below the April 10, 2010, elevation objective of 1,283.2 feet. Beginning April 20, 2010, it was decided at TMT to transition to use of storage at Grand Coulee Dam to help meet Priest Rapids flow objectives starting with 90 kcfs on April 20, 2010, and adjusting flows weekly until they reached 135 kcfs in early May 2010. Grand Coulee Dam was drafted to elevation 1,269.5 feet by April 30, 2010, which was close to 14 feet below the flood control elevation of 1,283.3 feet. Grand Coulee Dam continued to operate for Priest Rapids flow objectives until inflows increased in June 2010. Due to the low WSF, flood control did not draft Lake Roosevelt below elevation 1,255 feet. Drum gate maintenance was not performed and was deferred during 2010.

During May 2010, Grand Coulee Dam continued to be operated to help support coordinated flow objectives at Priest Rapids Dam. Beginning in June 2010, operations at Grand Coulee Dam transitioned to an operation of refilling Grand Coulee Dam while maintaining favorable flow conditions downstream. Due to abundant precipitation throughout the Columbia River basin and heavy runoff during early June 2010, Grand Coulee Dam filled to elevation 1,290 feet by June 21, 2010. As a result of over-generation in the lower river (high flows that resulted in excessive spill) generation was shifted from Grand Coulee Dam to lower Columbia and Snake river projects, resulting in spill at Grand Coulee Dam. During the refill, there were periods of high flows resulting in spill and elevated total dissolved gas (TDG) throughout the system. To minimize downstream spill and TDG production in the Columbia River, operations were coordinated through the TMT and in accordance with the 2010 Total Dissolved Gas Management Plan (ACOE 2010 Total Dissolved Gas Management Plan) at *http://www.nwd-wc.usace.army.mil/tmt/documents/wmp/2010/final/app4.pdf*. The rapid refill at Grand Coulee Dam during the first half of June 2010 helped reduce excessive flows and TDG levels downstream in the Columbia River.

Despite June 2010 rains and subsequent high flows, the July 2010 (April to August) WSF was still below 92 maf, resulting in a 12-foot end-of-August draft at Lake Roosevelt for flow augmentation. Grand Coulee Dam drafted during July and August 2010 to support the summer flow augmentation program and reached elevation 1,277.1 feet on August 31, 2010. The August 31, 2010 elevation target for Grand Coulee Dam was 1,277.3 feet, which included 0.7 feet released for the Lake Roosevelt Incremental Draft portion of Washington state's Columbia River Water Management Program. Pumping was reduced to Banks Lake during August, 2010, and Banks Lake reached an elevation of 1,565.1 feet on August 31, 2010.

Hungry Horse Dam

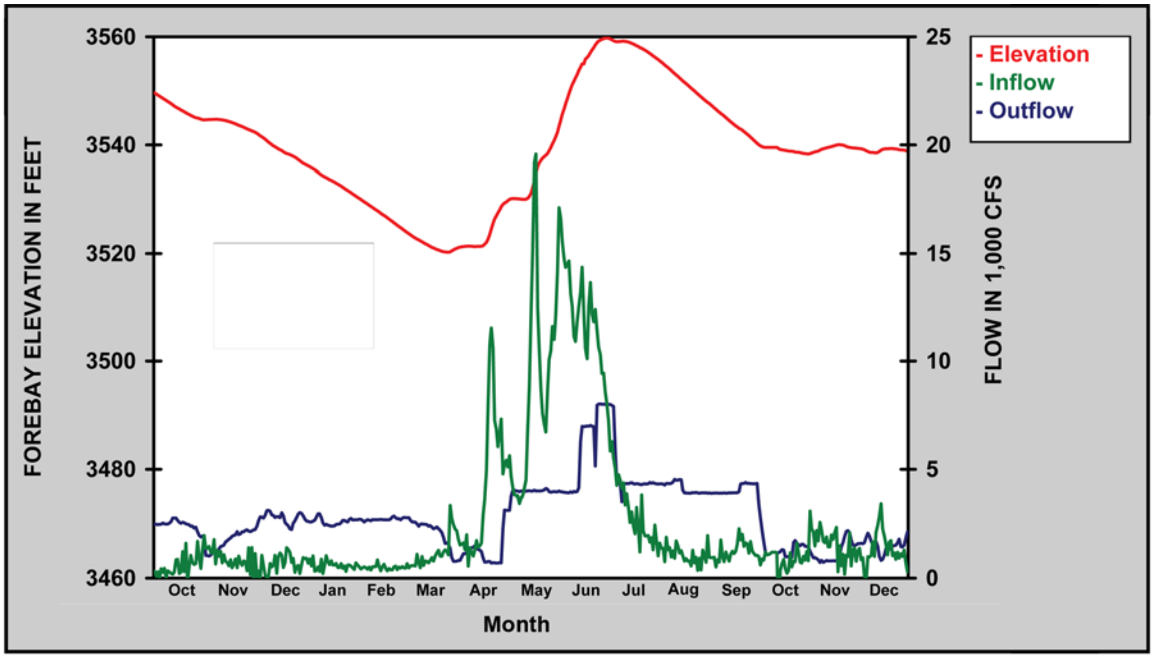


Figure 4. Hungry Horse Dam Inflow, Outflow and Forebay Elevation from October 1, 2009, through December 31, 2010.

Hungry Horse Dam was operated through the fall 2009 and throughout 2010 to maintain the minimum flow requirements in the Flathead River at Columbia Falls and in the South Fork Flathead River below Hungry Horse Dam. Minimum flows were for Endangered Species Act (ESA)-listed bull trout and were calculated from a sliding scale based on the Hungry Horse Dam inflow volume forecast. The calculated minimum flows from October 2009 to December 2010 are listed in Table 2. Fall minimum flows were based on WSF for 2009, and decreased throughout the winter as the forecast decreased.

Table 2. Minimum Flow requirements From October 2009-December 2010

Period	Hungry Horse Minimum Flow (cfs)	Columbia Falls Minimum Flow (cfs)
October 2009-December 2009	900	3500
January 2010	900	3500
February 2010	752	3411
March 2010-December 2010	616	3330

Hungry Horse Dam operations in 2010 followed VARQ flood control procedures. The WSF for Hungry Horse Dam inflow from May to September 2010 was at 90 percent of average in January 2010 and 73 percent of average by May 2010. Hungry Horse Dam was drafted to elevation 3,521.4 feet by April 10, 2010, due to minimum flow requirements at Columbia Falls, well below the April 10, 2010, elevation objective of 3,554.4 feet. Flows were increased to approximately 4 kcfs by early May 2010 to target refill and to shape the discharges into the spring migration period. Discharges were maintained at 4 kcfs until mid-June 2010 when flows were increased to around 8 kcfs to control the fill and to avoid spill. Spill was avoided at Hungry Horse Dam in 2010, thus limiting TDG production in the South Fork of the Flathead River to below Montana's standard of 110 percent. Changes in operations at Hungry Horse Dam followed ramping rates as prescribed in the 2000 BiOp (FWS 2000). Hungry Horse Dam refilled to elevation 3,559.8 feet on July 2, 2010, and then began drafting for summer flow augmentation.

As the 2010 WSF was in the lowest 20th percentile, Hungry Horse Dam targeted a September 30, 2010, elevation of 3,540 feet. Actual operations reached elevation 3,540.4 feet on September 30, 2010, and elevation 3,540 feet on October 2, 2010. Hungry Horse was operated to provide a stable flow during the summer flow augmentation period with an average flow from July through September 2010 of 4.2 kcfs.

Albeni Falls Dam

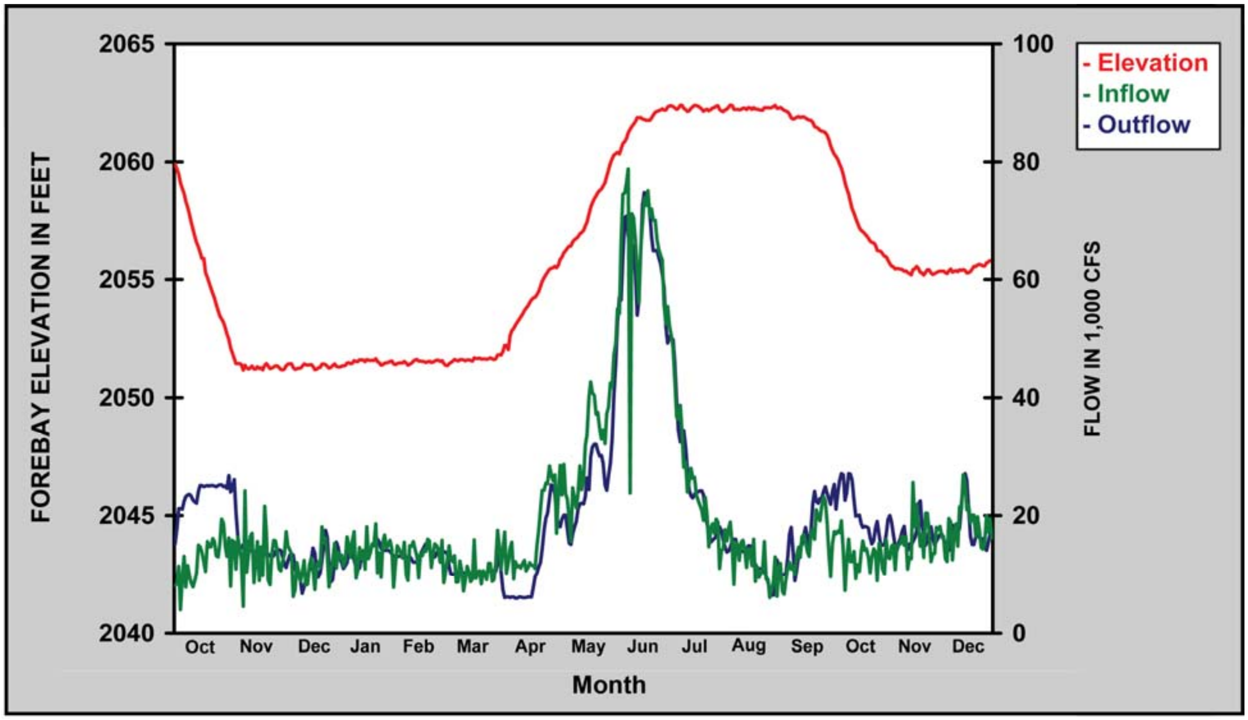


Figure 5. Albeni Falls Dam Inflow, Outflow and Forebay Elevation from October 1, 2009, through December 31, 2010.

The project was operated to standard flood control criteria (Figure 5). Through mid-September 2009, Albeni Falls Dam was operated within the summer operating range of 2,062.0 to 2,062.5 feet. The project began drafting toward its winter flood control elevation on September 15, 2009. Pursuant to a joint USFWS and Idaho Department of Fish and Game (IDFG) System Operations Request (SOR) the Albeni Falls Dam winter draft operation request was to reach 2,051 feet no later than November 15, 2009 and preferably by November 8, 2009. This operation was both for flood control and to accommodate spawning for kokanee (a primary food source for ESA-listed bull trout). The operational target range between 2,051.0 and 2,051.5 feet was reached on November 4, 2009. The project was then operated within a half-foot band until spawning was declared complete by IDFG. Beginning in January 2010 the lake was operated in a full one-foot range from 2,051.0 to 2,052.0 feet.

Spring refill began on April 1, 2010. Albeni Falls Dam reached the bottom of its normal summer operating range of 2,062.0 to 2,062.5 feet on June 25, 2010 and continued to operate in its summer range through early September 2010. The Albeni Falls Dam project started its fall draft on September 9, 2010. The TMT met on October 15, 2010, to discuss a SOR to draft the project to a winter elevation of 2,055 feet. This request was presented to the TMT on behalf of the USFWS and IDFG. In that meeting it was explained that the proposed elevation was likely to provide the greatest benefit to kokanee salmon spawning along the shores of Lake Pend Oreille. The group reached consensus and the Corps agreed to operate the project to reach elevation between 2,055 and 2,055.5 feet by about November 15, 2010. The range was reached by November 7, 2010. The project was then operated within a half-foot band until spawning was declared complete by IDFG on December 17, 2010, which allowed the project to begin operating in its full one-foot range between 2,055.0 and 2,056.0 feet with the minimum elevation to remain at 2,055.0 feet for the winter season.

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 2010 WMP included operations for these run-of-river projects. The projects were operated consistent with the WMP and the FOPs to 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. Further discussions of these operations are included in the minutes of the TMT "2010 Year End Review Session" (Columbia River Regional Forum TMT) at *http://www.nwd-wc.usace.army.mil/tmt/agendas/2010/1208_Minutes.pdf*.

The planned operations at Lower Monumental, Ice Harbor, Little Goose, and Lower Granite projects were to operate at minimum operating pool (MOP) from April 3, 2010 through August 31, 2010. As total river flow decreased in July 2010 and August 2010, the Ice Harbor pool elevation was increased on July 16, 2010, to 0.5 foot above MOP to provide minimum clearance over the Lower Monumental downstream navigation lock entrance sill for navigation. The same operation was implemented on August 5 2010, when the Little Goose pool elevation was increased 0.5 foot above MOP to provide minimum clearance over the downstream Lower Granite navigation lock entrance sill. These operations were coordinated with the TMT.

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 6, 7, and 8 show the observed outflow at McNary, Lower Granite, and Priest Rapids dams relative to the flow objectives.

In 2010, the Columbia River had a below average water year, with the January through September volume as measured at The Dalles Dam at 80 percent of average. The Snake River volume for the same period, as measured at Lower Granite, was 76 percent of average. May and June 2010 precipitation across the basin contributed significantly to higher June flows and a rising water supply, reversing a trend toward an extremely dry year rather than one just moderately below average. On the Columbia River mainstem, a preliminary flow spike occurred about mid-May 2010. Rain, combined with additional snow melt, caused increased outflow at The Dalles Dam during the first week of June 2010. Flows then steadily receded for the rest of the summer season. John Day Dam was operated at 262.5 to 264 feet from April 10 through September 30, 2010.

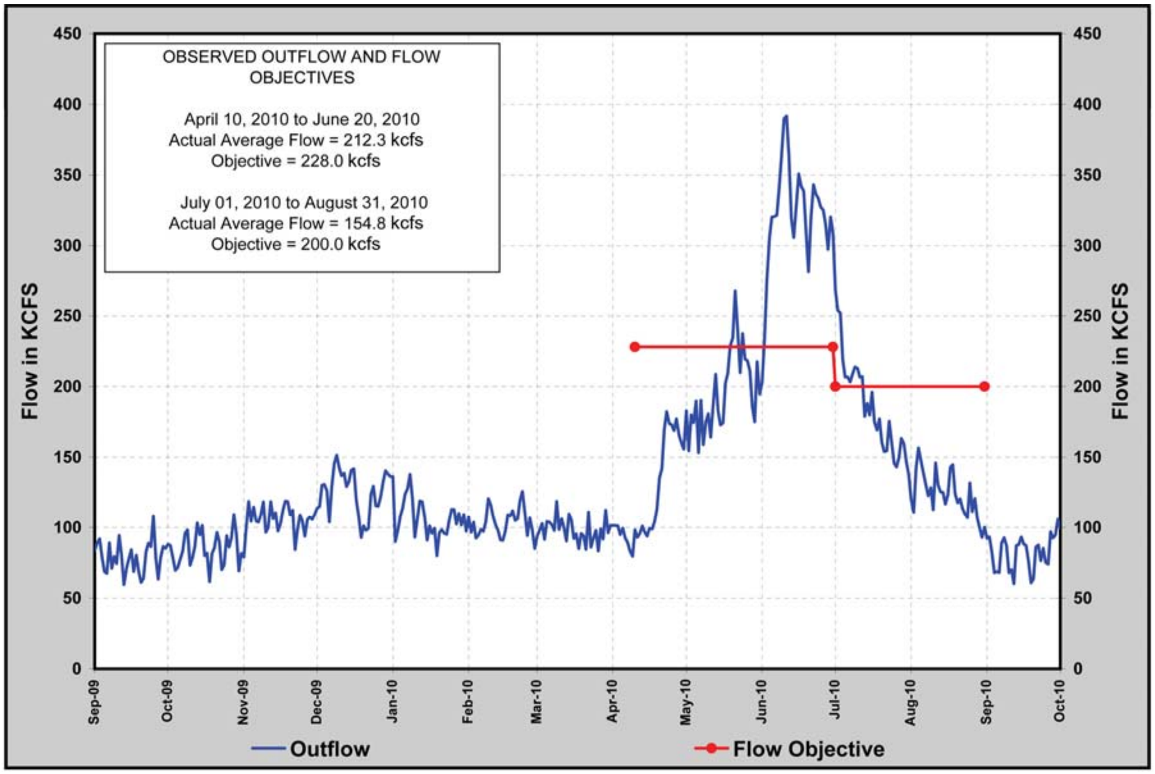


Figure 6. McNary Dam, Observed Outflow and Flow Objectives. The flow objectives are not achievable in all water conditions; rather they are used for pre-season planning and in-season water management to guide decision making.

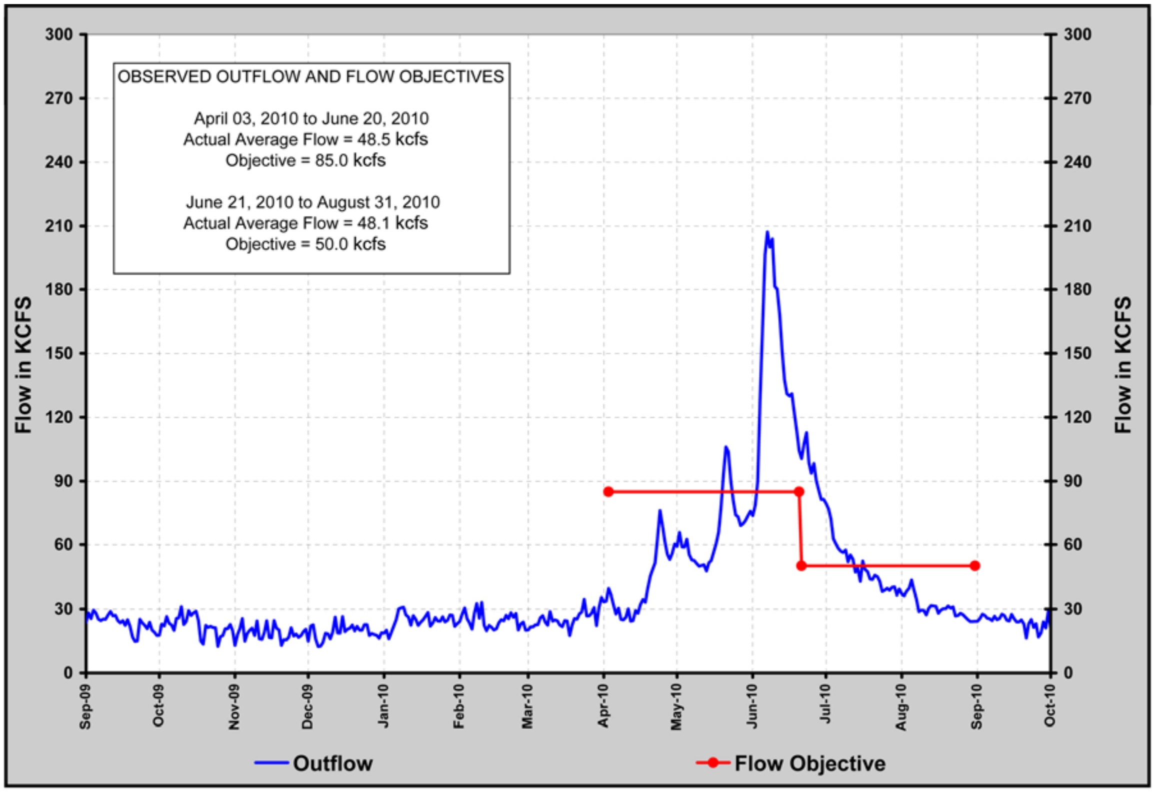


Figure 7. Lower Granite Dam, Observed Outflow and Flow Objectives. The flow objectives are not achievable in all water conditions; rather, they are used for pre-season planning and in-season water management to guide decision making.

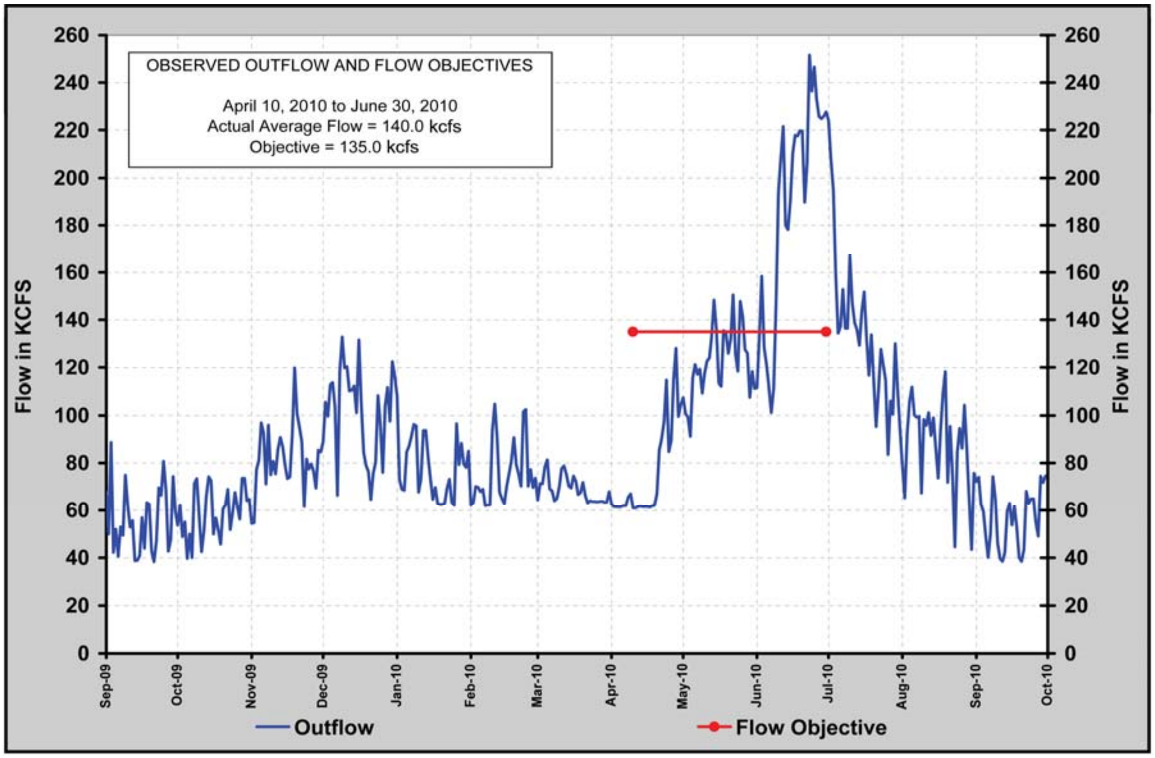


Figure 8. Priest Rapids Dam, Observed Outflow and Flow Objectives. The flow objectives are not achievable in all water conditions; rather, they are used for pre-season planning and in-season water management to guide decision making.

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 2010 operating season (October 1, 2009, through September 30, 2010) and the 2011 operating season (October 1, 2010, through September 30, 2011) were developed collaboratively with the region in accordance with the 2008 BiOp.

In fall 2009, the Action Agencies developed the WMP for the 2010 operating season. A draft of the 2010 spring/summer update to the 2010 WMP was released on March 1, 2010, and the final spring/summer update was released on May 15, 2010.

A draft of the WMP for the 2011 operating season was released on October 1, 2010, and the fall/winter update was released on November 1, 2010. The final WMP was released on December 31, 2010, and the final fall/winter update was released on December 31, 2010.

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 Action Agencies and Fish Accord partners formed the Columbia River Forecast Group (CRFG) to collaboratively implement this RPA action. The CRFG conducted five business and/or workshop meetings in 2010: March 19, May 13, August 4 (webinar), October 7, and December 10. The October and December 2010 meetings provided a forum to review the performance of the year's forecasts and to hear speakers on various topics related to water supply forecasting. The October 7 and December 10, 2010 workshops were attended by numerous agencies including the Natural Resources Conservation Service, Northwest River Forecast Center (NWRFC), National Oceanic and Atmospheric Administration (NOAA) Fisheries, Columbia River Inter-Tribal Fish Commission (CRITFC), BPA, Corps, Reclamation, Northwest Power and Conservation Council (NPCC), the Fish Passage Center (FPC), and BC Hydro and Power Authority.

In the October 7 meeting, representatives from multiple agencies provided a recap and review of their 2010 WSFs with an assessment of the performance of the procedures during the water year. Other presentations included an update by BPA on their effort to investigate potential sites for new snow pillow stations in Canada, and updates from Reclamation and the Corps on their ongoing study of the potential benefits of performing mid-month forecasts at Hungry Horse and Dworshak reservoirs.

The December 2010 meeting/workshop included a presentation from Reclamation summarizing the effects of using mid-month forecasts on the operation of Hungry Horse Reservoir which is described below. BC Hydro also provided two presentations. The first was titled "A Horse-Race Intercomparison of Process-Oriented Watershed Models for Operational River Forecasting," in which BC Hydro contracted with multiple entities for a "which model is the best" competition, where each entity used their own independent model to predict flow parameters at the same set of four unique projects. The results varied, but it confirmed that BC Hydro's internal model was robust and should continue to be supported. An additional BC Hydro presentation was "Multi-Thread Assessment of Hydroclimactic Change to Support Long-term Planning of Hydroelectric Resources," which was an analytical approach to using multiple (and sometimes divergent) climate change predictions for long-term planning certainty.

CRFG work accomplishments and ongoing studies in 2010 included the following:

- Improved the WSF equations for Libby Dam through evaluation of various climate indices. New WSF equations were developed for Libby Dam inflow during 2010. The analysis reviewed a wide pool of climate index variables, precipitation variables, and snow pillow sites, and it used advanced statistical methods to develop principal components regression models for producing monthly forecasts from November 1 to June 1, 2010. The new equations make seasonal use of the SOI (Southern Ocean Oscillation, the surface air pressure difference between Tahiti and Darwin, Australia), QBO (Quasi-Biennial Oscillation of equatorial stratospheric winds), and PNA (Pacific/North American wind pattern variations) climate variables along with four precipitation variables and up to nine snow pillow sites. The new equations provide improved forecasts (reduced errors) over the previous set of equations from 2004.
- Worked with Columbia River Treaty Hydrometeorological Committee to assess the benefits of additional snow pillows in the Columbia Basin in British Columbia. Assessment began with a geographic information system (GIS)-based analysis on snow course and snow pillow locations and elevations, compared to Parameter-Elevation Regressions on Independent Slopes Model (PRISM)-derived precipitation volume contributed per elevation band. This was augmented by

a statistical principal components analysis analysis of which snow stations are most influential in their contribution to runoff. BPA is developing a report that will include a list of recommended sites.

- Assessed the benefits of mid-month WSF updates. The effort entails looking at two test locations: Hungry Horse and Dworshak dams. Both efforts used multiple linear regression equations to hindcast mid-month forecasts going back to about 1980. At Dworshak Dam, the Corps determined that in roughly two-thirds of the cases the mid-month forecast points in the right direction, and one-third point in the wrong direction, although many of the ”trends” are not significant. Further work to analyze results is pending completion of the Corps’ system RES-SIM model. At Hungry Horse Dam, Reclamation determined there were minimal effects to operations from producing mid-month forecasts. Reclamation utilized a daily time-step operations model (Riverware) to simulate operations with and without the mid-month forecasts, and found that modeled operations were essentially the same in 25 out of the 30 years, with only minor changes in the other five years. Other conclusions were: impacts were not seen in most years because flood control was not forcing operations; impacts were limited to wet years with increasing or decreasing forecast trend; an increasing trend in March 2010 meant water was shifted earlier into late March from April 2010; an increasing trend after April meant shifting water into April from May 2010; an opposite effect was caused by a decreasing forecast; andany release changes would be further muted due to attenuation through downstream projects.
- Prepared an Annual Report (CRFG 2010) on the group’s activities that includes an appendix that will track WSF performance each year.

Climate Change Study

The Action Agencies collaborated to adopt climate change and hydrology datasets for their long-term planning activities in the Columbia River basin. This collaboration was coordinated through the River Management Joint Operating Committee (RMJOC), a subcommittee of the Joint Operating Committee that was established through a direct funding Memorandum of Agreement among the three agencies. In addition to adopting these datasets, the RMJOC agencies worked together to adopt a set of methods for incorporating these data into their longer-term planning activities.

The Action Agencies selected a subset of the Climate Impacts Group, University of Washington (CIG) climate change data sets resulting in 18 monthly future naturalized flow datasets and one historical condition. The 18 data sets included 12 Hybrid-Delta (HD) projections of future runoff of the Columbia River that reflected 30-year periods centered around 2020 (six scenarios) and 2040 conditions (six additional scenarios). The HD data sets represent a change in monthly distributions of temperature and precipitation over the study region sampled from a single climate projection. In addition to the HD method, six "transient" data sets were also selected, which use time-evolving temperature and precipitation data sets beginning in 1950 evolving through 2099.

The future climate change flow was provided at 13 locations in the Yakima, 12 in the Deschutes, and 28 in the Snake river subbasins. In addition to the climate change supply, WSFs reflecting the respective climate change projections for the HD and Transient scenarios were developed at key locations across the entire Columbia River basin. Each action agency started work to update their respective planning models as needed. Reclamation updated their Yakima River Planning Model (YPM), the Deschutes River Planning Model (DPM), and the Snake River Planning Model (SPM) to accept the new climate change supply inputs. Results and statistics were then generated at various locations. Time series of monthly flows were generated by Reclamation for the Yakima River at its mouth, the Snake River at Brownlee Reservoir, and the Deschutes River above Lake Billy Chinook to be used by the BPA and Corps as input to their regional planning models. Both agencies initiated modeling of the climate change projects for their own specific purposes.

The results of the work from the three agencies will be reported in three major reports as part of the *Climate and Hydrology Datasets for use in the RMJOC Agencies' Longer-Term Planning Studies* (BPA 2010) at *http://www.bpa.gov/power/pgf/HydrPNW.shtml*. The final results for Parts I and II were presented to the RMJOC Technical Team and other stakeholders on October 4, 2010, in Portland, Oregon.

A literature review of 2010 citations on the biological effects of climate change was provided by NOAA in August 2011 and is included as Attachment 1.

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.*

No operational emergencies occurred in 2010.

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.*

No fish emergencies occurred in 2010.

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:

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

The Columbia River Treaty Operating Committee Agreement on Operation of Treaty Storage for Non-Power Uses for December 11, 2009, through July 31, 2010 (Non-Power Uses Agreement) was executed on December 3, 2009. Under this agreement, 1 maf of flow augmentation water was stored in Mica Reservoir from late December 2009 through February 2010. All flow augmentation storage was released by July 31, 2010 under the Non-Power Uses Agreement. Treaty operations were coordinated during fall 2009 and spring 2010 stakeholder briefings.

A new non-power user agreement for 2010 was executed on November 3, 2010, which provides for one maf of flow augmentation water storage under the same terms as the prior agreement.

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.*

Significant progress was made in return of non-Treaty storage (NTS), with BPA and BC Hydro filling to nearly full by the end of December 2010. At the end of 2010, both the BPA and BC Hydro accounts were 99.2 percent of full, with only 8.7 ksfd each remaining to be filled. BPA and BC Hydro each filled about 24 ksfd between late September and the end of December 2010. (A "ksfd" is a thousand-second-foot-day, a volume of water sufficient to provide a flow of 1,000 cfs for a 24-hour period, or approximately 1983 acre-feet.).

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.*

Before approaching BC Hydro to negotiate a new long-term, NTS agreement, BPA has committed to the following:

- Substantial refilling of the U.S. NTS account
- The Dry Year Strategy Workgroup defining potential use of NTS in dry years
- Coordinating with federal agencies, states, and tribes under the BiOp
- Coordinating with tribes under the Fish Accords
- Establishing the collective U.S. interests in terms of such a new NTS agreement

As noted under RPA Action 11, during 2010, BPA and BC Hydro made significant progress toward refill of NTS accounts. BPA met with federal agencies, states, and Tribes to gather ideas and information regarding a new long-term NTS agreement at several meetings throughout the year beginning in June 2010. In July 2010, BPA and BC Hydro began discussion of potential terms for a new long-term NTS agreement.

A seasonal NTS agreement was negotiated in May 2010 between BPA and BC Hydro for shaping of Arrow outflows from May through early September 2010. During June 2010, a total of 100 ksfd was stored to reduce inflow to Grand Coulee Dam during the peak of freshet period. This storage was released from late August through early September. A short-term NTS agreement was also negotiated in October 2010, to allow use of NTS space. That agreement will conclude by the end of December 2011.

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.*

BPA met with federal agencies, states, and tribes throughout 2010, to solicit ideas and information regarding terms for a new NTS agreement. As discussions with BC Hydro proceeded toward development of a non-binding set of terms for negotiation, follow-up meetings were held to keep parties updated on progress.

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 Northwest River Forecast Center's (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:*

- *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.*
- *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.*
- *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.*
- *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.*

- *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.*
- *In very dry years, the Action Agencies will maximize transport for Snake River migrants in early spring, and will continue transport through May 31.*
- *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 the 20th percentile based on the NWRFC May final forecast for April through July 2010 runoff at The Dalles Dam, which equates to 72 maf. The 2010 water year met this BiOp definition for a dry year, as the May 2010 final forecast was 62 maf. Therefore, many dry-year operations were implemented in 2010, including the following: 1) Chum flows were relaxed during March to reduce their impact on spring flows, as described under RPA 17; 2) Although the BiOp's max transport operation for dry years was not implemented, low flow spill operations were implemented in accordance with the 2010 FOP and close coordination with TMT, as described under RPAs 29 and 30; 3) Lake Roosevelt was operated below the upper rule curve in May 2010 to maintain 135 kcfs at Priest Rapids Dam, as described under RPA 4; 4) A three-day pulse of flow was provided from Dworshak Dam in late May 2010 to aid the spring migration, as described under RPA 4; and 5) Reservoir summer refill and drafts were implemented as described in RPA 4. Due to abundant precipitation in the late spring, runoff conditions improved significantly in June 2010 and the actual April-August 2010 runoff volume at The Dalles Dam was 77 maf, exceeding the dry year trigger.

The dry year strategy technical workgroup held meetings on January 22 and February 26, 2010. Participants included Action Agencies, NOAA Fisheries, and representatives from the Confederated Tribes of the Colville Reservation (CTCR), CRITFC, Umatilla tribe, Montana, Oregon, Washington, and NPCC. Discussion included proposed operating alternatives (what actions to consider), when to initiate dry year operations (forecasting triggers), and how to perform the biological analysis of the proposed actions (Comprehensive Fish Passage Model [COMPASS] survival model, FPC survival model, and qualitative analyses). This group had already agreed on the overall study objectives and general study steps, and defined the first alternative for modeling in 2009. In 2010, BPA completed the hydro modeling of the first alternative and summarized the results. After reviewing the hydro modeling, the dry year group continued discussions of proposed operating alternatives and decided to defer further modeling until the negotiation with BC Hydro for non-Treaty water was completed. The dry year strategy technical workgroup met with the Corps and BPA representatives for non-Treaty water negotiations. The group provided input and discussed ideas about non-Treaty operations that would benefit dry years. The main input from the dry year strategy group to the non-Treaty negotiation was the desire to have more non-Treaty water released during the spring of dry years and allow refill of that water at a later time, such as the following spring, if/when flows are above average. Refer to RPA 13 for more detail on non-Treaty coordination.

The biological sub-group and COMPASS modeling group made additional progress in 2010 toward the development/expansion of COMPASS to include the mid-Columbia. The COMPASS model was configured for the mid-Columbia projects between McNary and Chief Joseph dams. These projects are considered mid-Columbia in hydro operations but are considered upper Columbia projects in fish passage modeling. The COMPASS modeling group also began compiling the survival data necessary to calibrate the model.

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:*

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

- *Continued development of fish passage strategies with less production of TDG,*
- *Update the SYSTDG model to reflect modifications to spillways or spill operations,*
- *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,*
- *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*
- *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*
- *Investigate alternatives to reduce total mass loading of TDG at Bonneville Dam while maintaining juvenile survival performance, and*
- *Continued operation of the Lower Snake River projects at MOP.*

The Dissolved Gas Monitoring Plan of Action was updated for 2010 and is included as Appendix B of the 2010 Dissolved Gas and Water Temperature Report (ACOE 2010 Dissolved Gas and Water Temperature Monitoring Report) at *http://www.nwd-wc.usace.army.mil/tmt/wqnew/tdg_and_temp/2010/app_b.pdf*.

Three efforts were implemented to further develop fish passage strategies and reduce TDG through structural and operational alternatives in 2010:

- Chief Joseph Dam: Preparation of the final post-construction spill test report was initiated in 2010.
- John Day Dam: Construction on the John Day Spill Bay 20 flow deflector was completed in March 2010.

The System Total Dissolved Gas (SYSTDG) model was used as a real-time decision support tool to manage spill at lower Columbia and Snake river projects. The model was updated to incorporate the spillway flow deflectors at Chief Joseph Dam and spill pattern changes that were implemented in 2010. TDG monitoring studies were conducted to measure the effects of The Dalles Dam spillwall and the John Day Dam spillway flow deflector, and the SYSTDG equations were updated based on these study findings. The Bonneville Dam second powerhouse (PH2) corner collector TDG production equation was updated. The Chief Joseph Dam TDG production equation was updated using the 2009 TDG monitoring study data.

After completion of the fish migration season, the Corps performed a statistical evaluation of the predictive errors based on observed TDG levels during the 2010 fish passage season to quantify the uncertainty of SYSTDG estimates and improve modeling accuracy and reliability. The results of this analysis are included as Appendix G of the 2010 Dissolved Gas and Water Temperature Monitoring Report at *http://www.nwd-wc.usace.army.mil/tmt/wqnew/tdg_and_temp/2010/app_g.pdf.* Wind forecast improvements were not incorporated into SYSTDG in 2010.

The CE-QUAL-W2 model was used from late June through early-September 2010 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.

The Corps awarded a contract to improve the existing model. Modifications included updating from version 3.2 to 3.6, making the pre-processing more user friendly with the Windows environment, and adding quality assurance/quality control (QA/QC) features. The combined result is a more efficient model execution with a shorter run-time.

The Action Agencies initiated discussions in May 2010 on the development of a CE-QUAL-W2 model for the Columbia River spanning the reach to include Grand Coulee to Bonneville dams. Reclamation and the Corps will work together during development of the model to ensure that the models appropriately interface in order to coordinate future models. In addition, exchange of information and data between the Action Agencies will be coordinated to maintain relative consistency in development of the models.

Reclamation will be responsible for the development of the Lake Roosevelt model from the Canadian border to the tailwater of Grand Coulee Dam. This model will provide boundary conditions (input) for the downstream reach (the Corps model). The Corps would cover the Columbia River from the tailwater of Grand Coulee Dam to Bonneville Dam.

Reclamation began bathymetry work (survey of topography beneath the Reservoir) at Lake Roosevelt at the end of September 2010. Due to the length of the Reservoir (150 miles) the work was divided into three phases. Surveyors completed two phases in the fall. Phase one covered the reservoir from the dam upstream to Seven Bays Marina (River Mile [RM] 40, upstream from the dam) including the Sanpoil and Spokane arms. Phase two included the upper end of the reservoir beginning at about mile 90 (about five miles upstream of Daisy) to just upstream of Onion Creek near the Canadian Border. Winter weather forced work on Phase three to be postponed until the late spring or early summer 2011.

Reclamation initiated data collection efforts to develop input information for the CE-QUAL-W2 model and initiated discussions with Portland State University (PSU) to assist in development of the model.

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 in-stream flow regime not considered in the FCRPS and Upper Snake River BA/Comprehensive Analysis.*

Reclamation is addressing ESA Section 7 consultations for the Yakima, Okanagan, and Tualatin project operations. Biological Assessments (BAs) have been submitted to NOAA Fisheries for all these projects.

NOAA Fisheries and USFWS suggested that Reclamation delay submission of Reclamation's 2000 BA supplement until issues associated with the Yakima Basin Workgroup/Basin Study are resolved so that potential actions from those efforts can be incorporated into the supplement, if appropriate.

NOAA Fisheries requested a time extension to complete work on the Okanogan Project BiOp, which was granted. During this period, Reclamation and NOAA Fisheries have been investigating the potential for refining the proposed action.

The Tualatin BA was submitted to NOAA Fisheries in 2009. The BiOp is scheduled for completion and delivery in 2012. Reclamation is currently collecting fish monitoring data in the basin which will be provided to NOAA Fisheries to help develop a BiOp.

RPA Action 17 – Chum Spawning Flows: *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.*

2009-2010 Operation

For chum tailwater readings, the official gauge is 0.9 mile downstream from Bonneville Dam's first powerhouse, 50 feet upstream from Tanner Creek (RM 144.5).

Chum operations were coordinated regularly through the TMT prior to the initiation of chum spawning and through the end of chum emergence. Chum operations were complicated by forebay constraints in place to facilitate the construction of the spillwall at The Dalles Dam. In response, the Action Agencies drafted a plan for operations during chum spawning season. Some of the conditions addressed in the plan included: 1) use of a new gauge installed near The Dalles Dam spillbay 23, to help with real-time surface elevation monitoring throughout the season; 2) modification of operating restrictions for spillwall construction to support more flexibility of the chum operations; and 3) specific guidance from the salmon managers on real-time management (timing, patterns) of excess water that might enter the system. Excess water was generally discharged at night, when chum tend not to spawn. In addition, the TMT developed contingency plans for managing chum operations that established a priority for actions to be taken to manage excess water if it could not be managed at night.

Beginning November 6, 2009, Bonneville Dam was operated at a tailwater elevation of no lower than 11.3 feet during all hours. During daylight hours (0600-1700 hours) the project maintained a tailwater elevation of 11.3 to 11.7 feet with a target of 11.5 feet. High inflows at times during November and December 2009 necessitated deviations to move excess water at night (from 1700 to 0600 hours). During these nighttime situations the Action Agencies were authorized to increase the tailwater elevation to 18.5 feet. Chum spawning operations ended on December 30, 2009, and the post-spawning and incubation operation began on December 31, 2009.

On February 23, 2010, the Action Agencies lowered the Bonneville tailwater target operation for chum to 11.3 feet. This decision to lower the tailwater minimum was based on WSFs that were significantly below average. On March 11, 2010, the action agencies gradually lowered the Bonneville tailwater minimum according to the following ramp down schedule: 1) March 15, 2010, operate to a minimum tailwater of 11.0 feet; 2) March 17, 2010, operate minimum tailwater of 10.8 feet; and 3) March 19, 2010, operate to a minimum tailwater of 10.5 feet. The chum operation ended on March 22, 2010, and the 10.5 feet minimum tailwater elevation was lifted and the project was able to operate within the normal operating tailwater criteria.

2010-2011 Operation

The 2010-2011 chum operation began on October 27, 2010. The Action Agencies issued the following guidance to Bonneville Dam to protect spawning chum: 1) Effective October 27, 2010, maintain a project tailwater elevation of no lower than 9.5 feet during all hours; 2) effective November 1, 2010, maintain a project tailwater of no lower than 11.3 feet during all hours, and maintain a project tailwater of 11.3 to 11.7 feet during daylight hours (0630-1700 hours) and 3) as needed to pass excess water, increase tailwater elevation up to 18.5 feet during evening hours (1700-0600 hours).

From December 13 to 16, 2010, the Action Agencies increased the tailwater to no lower than 12.1 feet (with a target of 12.3 feet) due to high inflows in coordination with TMT. On December 22, 2010, TMT members held a conference call to discuss the status of the chum spawning operation. The TMT discussed the impacts of a 48-hour higher tailwater elevation (due to excess precipitation in the system) on spawning chum. No redds were discovered spawning at higher elevations in response to this operation. NOAA Fisheries declared the end of chum spawning and initiation of the incubation operation on December 22, 2010. The incubation operation resulted in a tailwater elevation of 12.2 feet on all hours with no nighttime maximum tailwater elevation requirement. The chum operation ended on April 18, 2011, and the Action Agencies lifted the 12.2 feet minimum tailwater operation.

RPA Action 18 – Configuration and Operation Plan (COP) 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 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

- *Sluiceway modifications to optimize surface flow outlet to improve fish passage efficiency (FPE) and reduce forebay delay (2009).*
- *Minimum-gap turbine runner installation to improve survival of fish passing through turbines (2009)*

Bonneville Powerhouse II

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

- *Shallow BGS installation to increase Corner Collector efficiency and reduce forebay delay (prototype 2008)*

Bonneville Dam Spillway

- *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).*

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.

Several actions were undertaken at Bonneville Dam in 2010 to improve the survival of fish passing the project. These actions were completed as part of the Bonneville COP in working towards a final project configuration for full performance standard testing planned for 2011. Below is a summary of the actions and work completed in 2010.

- Sluiceway modifications, including increasing the width of the collection channel, shaping the sluiceway floor, removing the decommissioned juvenile bypass outfall and other components, and automating the sluiceway gates were completed during the 2009-10 winter work period. Survival through the modified sluiceway was evaluated as part of the single-release dam passage survival study conducted at Bonneville Dam in 2010. Single-release survival from sluiceway passage to the mouth of the Willamette River was estimated at 98 percent for yearling Chinook salmon, 96 percent for juvenile steelhead, and 94 percent for subyearling Chinook salmon.
- Installation of minimum gap runners (MGRs) was completed in 2010. Survival through Powerhouse I turbines was evaluated as part of the single-release dam passage survival study conducted at Bonneville Dam in 2010. Single-release survival from turbine passage to the mouth of the Willamette River was estimated at 99 percent for yearling Chinook, 90 percent for juvenile steelhead, and 97 percent for subyearling Chinook salmon.
- Injury rates of fish passing through the juvenile bypass system (JBS) have been higher than expected in recent years. Research to better understand the source and extent of these injuries was conducted during the 2008 and 2009 juvenile fish passage seasons. An alternatives report to evaluate potential solutions to the gatewell injury issue was initiated in 2009 and continued in 2010. In 2010, to minimize injury, turbine units were operated at the lower end of the ±1 percent peak efficiency range. This operation reduces flow into the gatewells, thereby reducing the injury to fish passing through the JBS. Survival through the bypass system was evaluated as part of the single-release dam passage survival study conducted at Bonneville Dam in 2010. Single-release survival from bypass system passage to the mouth of the Willamette River was estimated at 98 percent each for yearling Chinook, juvenile steelhead, and subyearling Chinook salmon.
- A prototype shallow draft Behavioral Guidance Screen (BGS) was installed in 2008 and evaluated in 2008, 2009, and 2010. During the spring 2008, Unit 11, the turbine at the Corner Collector (south) end of PH2, was taken offline due to mechanical failure. The unit remained offline through 2010 for evaluation. Pre- and post-BGS results are presented in Table 3. Due to the overall lower than expected guidance to the corner collector in addition to high operation and maintenance cost, the BGS was removed during the winter 2010-2011 in-water work period.

Table 3. Percent of yearling Chinook, steelhead, and subyearling Chinook passing from the Bonneville Dam PH2 forebay into the Corner Collector in 2004 and 2005 without the BGS compared to 2008-10 with the BGS. Results from 2004-05 are based on radio telemetry studies (Reagan et. al. 2006; Adams et al. 2006); 2008-10 results are based on acoustic telemetry studies (Faber et al. 2009; Faber et al. 2010, Ploskey et al. 2011).

Species	Percent of PH2 Salmonids that Passed through the Corner Collector			
	2004-05 (No BGS)	**2008 (With BGS)**	**2009 (With BGS)**	**2010 (With BGS)**
Yearling Chinook	40%	49%	40%	44%
Steelhead	70%	75%	59%	55%
Subyearling Chinook	40%	40%	52%	35%

- Single-release spillway and dam passage survival under two summer spill operations was estimated as part of the single-release dam passage survival study conducted at Bonneville Dam in 2010. The two summer spill operations were evaluated to determine a spill operation for future full performance standard testing planned to begin in 2011. Table 4 includes historical and 2010 spillway estimates of survival for subyearling Chinook salmon.

Table 4. Subyearling Chinook spillway survival rates from radio and acoustic telemetry studies at Bonneville Dam, 2004–2010. From Counihan et al. 2005a; Counihan et al. 2005b; Ploskey et al. 2007; Ploskey et al. 2008; Ploskey et al. 2009; Ploskey et al. 2011.

Year	Operation	Subyearling Chinook Spillway Passage Survival Rate
2004	48 kcfs Day / TDG Cap Night	88%
2005	75 kcfs Day / TDG Cap Night	91%
2006	75 kcfs Day / TDG Cap Night	86%
2007	85 kcfs Day / TDG Cap Night	93% (daytime survival estimate)
2008	85 kcfs Day / TDG Cap Night	97%
2010[1]	95 kcfs 85 kcfs Day /121 kcfs Night	92% 88%

[1] Survival estimates in 2010 were derived using a single-release survival model which includes mortality incurred from immediate dam passage and also mortality incurred from in-river passage down to the mouth of the Willamette River

Single-release survival from the face of Bonneville Dam to the mouth of the Willamette River was estimated in spring and summer 2010 (Table 5). Single-release estimates include mortality from dam passage, but also include mortality incurred from passage downstream from Bonneville Dam to the mouth of the Willamette River. Under full performance standard testing, survival will be estimated using a virtual paired-release model which partitions out mortality incurred only from dam passage, rather than passage from the Dam downstream to the mouth of the Willamette River. Dam passage survival estimates obtained using the virtual paired-release model are expected to be higher than the single-release survival estimates obtained in 2010 presented in Table 6.

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

Table 5. Single-release survival estimates and standard errors (SE) at Bonneville Dam in 2010 (Ploskey et al. 2011). Subyearling survival estimated under two spill operations (85 kcfs day / 121 kcfs night vs 95 kcfs 24-hours per day) were not statistically different. A pooled estimate is presented here.

Species	Dam Passage Survival (SE)
Yearling Chinook	95.2% (0.4)
Steelhead	94.5% (0.4)
Subyearling Chinook	95.8% (0.4)

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:*

- *Turbine operation optimization to improve overall dam survival (2011)*
- *Extended tailrace spill wall to increase direct and indirect survival of spillway passed fish (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.

In 2010, construction of The Dalles Dam spillwall was completed. The 700-foot spillwall was installed between spillbays 8 and 9 to help guide juvenile fish that pass the dam via the spillway away from shallow water predator habitat to the deeper main river channel for conveyance downstream, thereby improving overall dam survival to achieve the juvenile dam survival performance standards specified in the BiOp. Following spillwall construction, a full performance evaluation for both spring and summer juvenile salmonids was completed in 2010. Results from the first year of full performance standard testing indicated a marked improvement over the pre-spillwall configuration in dam survival of both spring and summer migrants (Table 6). Dam survival of yearling Chinook salmon exceeded the spring migrant performance standard of 96.0 percent at 96.4 percent. Dam survival of juvenile steelhead was slightly below the spring juvenile migrant performance standard of 96.0 percent at 95.3 percent however, elevated levels of avian predation occurred downstream of the dam during testing. Additional avian wires were installed following 2010 performance standard testing and it is anticipated that these additional wires will help further reduce avian predation and increase dam survival above the spring migrant performance standard of 96.0 percent. Finally, dam survival of subyearling Chinook salmon exceeded the summer juvenile migrant performance standard of 93.0 percent at 94.0 percent.

Table 6. Pre and post-spillwall dam survival of juvenile spring and summer migrants at The Dalles Dam. (Counihan et al. 2005; Carlson and Skalski, 2010.)

Metric	Yearling Chinook Salmon Pre-spillwall Post-spillwall 2005 2010		Steelhead Pre-spillwall Post-spillwall 2010		Subyearling Chinook Salmon Pre-spillwall Post-spillwall 2005 2010	
Dam Passage Survival (%) (95% CI)	93.3 (±2.1)	96.4 (±1.9)	na	95.3 (±1.9)	90.0 (±1.9)	94.0 (±1.8)

RPA Action 20 – Configuration and Operation Plan for John Day Project: *The Corps will consider all relevant biological criteria and prep**are, in coo**peration 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:*

- *Full-flow bypass and PIT-tag detection installation to reduce handing stress of bypassed fish (2007)*
- *Turbine operation optimization to improve overall dam survival (2011)*
- *Surface flow outlet(s) construction to increase FPE, reduce forebay delay and improve direct and indirect survival (prototype 2008 with final installation by 2013), and improve tailrace egress conditions.*

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.

Several actions were undertaken to improve the survival of fish passing the project. These actions were completed as part of the John Day COP in working towards a final project configuration for full performance standard testing. Below is a summary of the actions and work completed in 2010.

- Two prototype spillway weirs were relocated to spillbays 18 and 19 and evaluated for a third year to determine if surface spill near the powerhouse reduces turbine entrainment. Results are summarized in Table 7.

Table 7. Yearling Chinook, steelhead, and subyearling Chinook percent passage through John Day Dam turbines during pre-Spillway Weir (SW) years with 24-hour spill (Baseline) and SW tests in 2008 and 2009. (Beeman et al. 2006; Beeman et al. 2003; Hansel et al. 2003; Weiland et al. 2010; Weiland et al. 2009, Weiland et al. in prep).

Species	Percent of Fish Passing Through Turbines			
	Baseline (No SWs)	2008 (w/SWs)	2009 (w/SWs)	2010 (w/SWs)
Yearling Chinook	10-17%	7%	8%	4%
Yearling Steelhead	7-15%	3%	3%	2%
Subyearling Chinook	25-30%	17%	NA	12%

- An extended-length flow deflector (50 feet) was constructed in spillbay 20 to help reduce production of TDG and to improve the downstream egress of fish passing the dam.
- Installation of an improved avian deterrent wire array was completed prior to the 2010 juvenile outmigration season.
- Two spill treatments (30 percent and 40 percent spill) were tested to help determine a single spill operation for full performance standard testing planned to occur in 2011.

A single-release survival study was conducted during the spring and summer in 2010 at John Day Dam to evaluate the effect of these actions on overall juvenile dam passage survival. The single release survival model used estimates survival from the face of John Day Dam to the forebay of The Dalles Dam. Single-release survival estimates include mortality from dam passage, but also include mortality incurred from passage downstream from John Day Dam to The Dalles Dam. Under full performance standard testing, survival will be estimated using a virtual paired-release model which identifies mortality incurred only from dam passage, rather than passage from John Day Dam downstream to The Dalles Dam. Dam passage survival estimates obtained using the virtual paired-release model are expected to be higher than the single-release survival estimates obtained in 2010 presented in Table 8.

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

Table 8. Single-release dam survival estimates and standard errors (SE) for yearling Chinook, steelhead, and subyearling Chinook passing from the face of John Day Dam to the forebay of The Dalles Dam in 2010 under 30 and 40 percent spill operations (Weiland et al. in prep).

Species	Dam Survival 30% Spill (SE)	Dam Survival 40% spill (SE)	Pooled Dam Survival (30 and 40% spill)(SE)
Yearling Chinook	94.0% (0.7)	94.4% (0.7)	93.7% (0.5)
Steelhead	94.2% (0.8)	97.5% (0.5)	95.0 % (0.5)
Subyearling Chinook	91.9% (0.8)	91.4% (0.8)	90.8% (0.6)

RPA Action 21 – Configuration and Operational Plan for the 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:*

- *Turbine operation optimization to improve survival of fish passing through turbines (2013)*
- *Improve debris management to reduce injury of bypass and turbine passed fish (2011)*
- *Relocate juvenile bypass outfall to improve egress, direct, and indirect survival on bypassed fish (2011)*
- *Surface flow outlet installation to increase FPE, reduce forebay delay, and improve direct and indirect survival (temporary structure testing in 2007 and 2008 to develop a permanent system)*

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.

Several actions were undertaken to improve the survival of fish passing the project at McNary Dam in 2010. These actions were completed as part of the McNary COP process in working toward a final project configuration for full performance standard testing. Below is a summary of the actions and work completed in 2010.

- Work continued on development of the COP for McNary Dam. A biological background section was written, and the development of baseline values for modeling was initiated.
- A gatewell descaling evaluation under two turbine operating conditions was conducted in 2010 at McNary Dam. Results of this work suggest that no significant difference in juvenile fish descaling could be discerned between turbine operations points of 13,800 and 12,100 cfs.
- The frequency of screen cleaning was increased to a minimum of three times during each fish passage season (in addition to the preseason cleaning). This effort was initiated to minimize adverse impacts on fish condition from debris on trashracks and in the forebay.
- Efforts during 2010 were focused on developing the design of the juvenile bypass outfall relocation. Review of the 60 percent and 90 percent design documents was undertaken in collaboration with the Regional fish managers.

RPA Action 22 – Configuration and Operation Plan for the 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:*

- *Guidance screen modification to improve FGE (2010)*
- *Turbine operation optimization to improve survival of turbine passed fish (2011)*
- *Spillway chute and/or deflector modification to reduce injury and improve survival of spillway passed fish through the RSW (2009)*
- *Turbine unit 2 replacement to improve the survival of fish passing through turbines and reduce oil spill potential (2012)*

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.

Several actions were undertaken to improve the survival of fish passing the project at Ice Harbor Dam in 2010. These actions were completed as part of the Ice Harbor COP process in working toward a final project configuration for full performance standard testing. Below is a summary of the actions and work completed in 2010:

- Design of potential surface weir spillway chute modifications, including Passive Integrated Transponder (PIT) tag system integration, was completed in 2010.
- BPA and the Corps have agreed to support the design of test turbines optimized to improve survival and reduce juvenile fish passage injury at Ice Harbor Dam. The design of the test turbines is being developed in 2010 to incorporate both a fixed and adjustable runner.

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

RPA Action 23 – Configuration and Operation Plan for the 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:*

- *Primary bypass operations with PIT-tag detection installation to reduce handling stress of bypassed fish (2007)*
- *Juvenile bypass system outfall relocation to improve egress, direct and indirect survival on bypassed fish (2011)*
- *Turbine operation optimization to improve the survival of fish passing through turbines (2013)*
- *RSW installation to improve FPE, reduce forebay delay, and improve direct and indirect survival (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.

Action was undertaken to improve the survival of fish passing the project at Lower Monumental Dam in 2010. These actions were completed as part of the Lower Monumental COP process in working toward a final project configuration for full performance standard testing. Below is a summary of the work completed in 2010:

- Development of plans and specifications to relocate the juvenile bypass outfall to prepare the project for performance standard testing were initiated 2010.

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 Corpswill 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:*

- *Turbine operation optimization to improve the survival of fish passing through turbines (2014)*
- *Primary bypass operations with PIT-tag detection installation to reduce handling stress of bypassed fish (2008)*
- *Primary bypass outfall relocation to improve egress, direct and indirect survival on bypassed fish (2009)*
- *Surface spillway weir and deflector installation to improve FPE, reduce forebay delay and improve direct and indirect survival (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.

Several actions were undertaken to improve the survival of fish passing the project at Little Goose Dam in 2010. These actions were completed as part of the Little Goose COP process in working toward a final project configuration for full performance standard testing. Below is a summary of the actions and work completed in 2010.

- The draft Little Goose COP was reviewed by NOAA Fisheries and BPA in 2010.
- Construction of the bypass outfall was completed in early 2010, prior to the start of the juvenile migration season. The relocated outfall will release fish in an area with higher river velocities and consistent downstream flow during all operations. This is expected to decrease predation on the bypassed fish.

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

RPA Action 25 – Configuration and Operation Plan for the 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:*

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

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.

Several actions were undertaken to improve the survival of fish passing the project at Lower Granite Dam in 2010. These actions were completed as part of the Lower Granite COP process in working toward a final project configuration for full performance standard testing. Below is a summary of the actions and work completed in 2010:

- Alternatives and the associated biological evaluations for the Lower Granite COP were completed in 2010.
- A draft Engineering Design Report (EDR) on modifications to upgrade the juvenile fish facility (JFF) was completed in March 2010. Preliminary designs for overflow weirs to replace

collection channel orifices were completed. Modeling at the Corps' Engineering Research and Development Center (ERDC) was also conducted for the overflow weirs.

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 of the two-part alternative to reduce TDG downstream of Chief Joseph and Grand Coulee dams. A successful spill test was carried out in spring 2009 and no further testing is planned. Preparation of the final post-construction spill test report was begun in 2010 and will be finalized in 2011.

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 2010, 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).

Work continued to determine the safest operating point for fish passing through existing FCRPS turbines. Physical model studies and numerical model studies were conducted to further this understanding. The Corps completed a final report of rapid decompression effects on tagged and untagged fish, and it initiated a new study to determine whether effects of rapid decompression on tagged fish differ from the effects on untagged fish.

An alternatives study was continued in 2010 to assess the feasibility of directly capturing juvenile fish that have passed through a mainstem dam turbine. This method provides a means of directly assessing turbine mortality, including capturing the effects of rapid decompression.

The Turbine Survival Program (TSP) also initiated a turbine bead strike analysis at ERDC in early 2010 with the Bonneville Dam Powerhouse 1 model to qualify bead strike at 4 different turbine operational points including what is being referred to as "Best Geometry," which is approximately 1.3 kcfs outside the upper 1 percent turbine operating limit. The Corps and TSP team is in the process of completing an operational white paper that proposes the movement of the upper operating ranges to this best geometry point. This is being vetted through Fish Facility Design Review Workgroup (FFDRWG) and Fish Passage Operations and Maintenance (FPOM). Plans for turbine operations are included in Appendix C of the annual Fish Passage Plan (FPP) (ACOE 2010 Fish Passage Plan) at *http://www.nwd-wc.usace.army.mil/tmt/*. Turbine operations are reviewed annually and adapted for fish passage as needed.

Hydropower Strategy 2 (RPA Action 28)

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

- *John Day Dam*
  - *Adult ladder systems modifications to improve upstream adult passage conditions (2011).*
- *Ice Harbor Dam*
  - *Repair or replace north shore fishway auxiliary water supply (AWS) equipment as needed so that any two of the three pumps can meet flow criteria.*
- *Little Goose Dam*
  - *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).*
- *Lower Granite Dam*
  - *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 AWS (2012).*
  - *Adult fishway modification to improve upstream adult passage conditions impaired by temperature differentials (need will be determined by results of further research) (prototype 2011).*

- **Bonneville Dam** – The following actions were taken on the Bradford Island ladder system during the 2009-2010 winter work window:
  - Repaired A-branch diffusers
  - Repaired fish valve FV4-3
  - Refurbished count station crowder, including repair of structural integrity, sealing to reduce leakage and algal growth, and sandblasting and painting
  - Repaired hole in fish ladder floor at FG3-12
  - Removed wooden bulkhead in south collection channel

  Extension of the FV3-7 trashracks to prevent overtopping during high forebay elevations is planned for the winter 2011-2012 maintenance window.

- **The Dalles Dam** – The Corps, with its regional partners, continues to evaluate alternatives for a backup water supply alternative. Further efforts on the north ladder were deferred pending spillwall completion and testing. This will allow for evaluation of the effects of the new configuration on adult use of the north ladder.

- **John Day Dam** – The vast majority of fish ladders at Columbia and Snake river dams continue to perform well for adult salmon and steelhead. However, John Day Dam ladders were cited in RPA Action 28 as of concern with regard to historic problems with fish passage. These problems include adult fish dropping back out into the tailrace after entering the ladders, long passage times, fish jumping out of the ladder in the exit sections, and difficulties with fish counting related to fish delaying just above the count stations. At John Day north ladder, the main cause of these problems have been attributed to hydraulic issues at two separate locations; the count station exit section area and the lowest section of the ladder from the entrance to the transition pool.

  Applying lessons learned from the South Fish Ladder improvements, the Corps completed structural improvements to the upper section (including count station) at the John Day North Fish Ladder in spring 2010. Passage evaluations in 2010 suggest that the upper ladder modifications successfully resolved the chronic delay, jumping and turn-around problems observed in that section and plans are underway to complete improvements to the lower fishway by 2013.

- **Little Goose Dam** – Spill patterns were adjusted based on the previous year's research. However, passage delays did occur, prompting additional analysis and modeling late in 2010 (and 2011) and resulting in a new spill pattern and a decision to install a hoist to allow closure of the spillway weir and provide a more rapid response to future passage problems.
- **Lower Granite Dam Water supply for adult trap** – The water supply valve for the trap was replaced during the 2009-2010 winter maintenance period. At MOP, all six adult fish holding tanks can now be operated without causing any flow reduction to the AWS.
- **Lower Granite fishway temperature differentials** – An engineering alternative study was conducted that developed three alternatives, all of which were expensive. The study also determined that a pilot study with a simple prototype structure was not feasible. Future actions will include additional forebay temperature data collection, which could result in the alternative study being revisited.

Hydropower Strategy 3 (RPA Actions 29–31)

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

Spill operations for 2010 are reported in the 2010 Dissolved Gas and Water Temperature Report (ACOE 2010 Dissolved Gas and Water Temperature Monitoring Report) at *http://www.nwd-wc.usace.army.mil/tmt/wqnew/tdg_and_temp/2010/*. This report describes the Corps water quality and spill program for 2010. The report provides information consistent with the TDG waiver issued by Oregon and the criteria adjustment by Washington, and it 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 (GBT)
- Progress on implementing measures contained in the lower Columbia and lower Snake rivers TDG total maximum daily load (TMDL) documents.

The report focuses on the water quality monitoring of TDG and temperature at the 12 Corps dams in the Columbia River basin.

Spring Spill

During 2010, spring spills at the lower Columbia and Snake river projects were consistent with the 2010 Spring FOP ACOE 2010 Total Dissolved Gas Management Plan at *http://www.nwd-wc.usace.army.mil/tmt/documents/wmp/2010/final/app4.pdf*. Spring spill began April 3, 2010, and continued through June 20, 2010, at the lower Snake River projects. Spring spill began April 10, 2010, and continued through June 19, 2010, at McNary Dam, through June 30, 2010, at John Day and The Dalles dams, and through June 20, 2010, at Bonneville Dam.

The 2010 Spring 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. On two separate occasions in May 2010, adult spring Chinook passage was delayed. By taking the spillway weir out of service for approximately 24 hours and implementing a uniform spill pattern, the adult passage delay problem was remedied. In 2011, the Corps plans to organize a regional coordination trip to ERDC to identify a spill pattern that will more effectively pass both adult and juvenile fish. In addition, the Corps plans to install a gate hoist at the spillway weir so that spill patterns can be changed quickly to maximize in-season adaptive management options.
- **Lower Monumental Dam**: To the spill cap, 24 hours per day
- **Ice Harbor Dam**: Spill alternating between 30 percent of total project outflow 24 hours per day, or 45 kcfs during the day and up to the spill cap at night
- **McNary Dam**: 40 percent of total project outflow
- **John Day Dam**: 30 percent of total project outflow from April 10, 2010, through April 27, 2010, and alternating between 30 percent and 40 percent of total project outflow from April 27, 2010, through July 1, 2010
- **The Dalles Dam**: 40 percent of total project outflow
- **Bonneville Dam**: 100 kcfs

Daily average total river flows on the lower Columbia River, as measured at Bonneville Dam, from April 10 through August 31, 2010, ranged from 97 kcfs to 398 kcfs, averaging 199 kcfs. Daily average flow remained above 300 kcfs on the lower Columbia River, from June 4 through June 30, 2010 (with the exception of June 14 with 281 kcfs), with a peak of 398 kcfs on June 12, 2010. Flows began to taper off in early July 2010, dropping below 200 kcfs on July 14, 2010, and continued a steady recession until the end of August 2010 when flows reached 97 kcfs. On the lower Snake River, as measured at Ice Harbor Dam, total river daily average flow from April 1 through August 31, 2010 ranged from 22 to 216 kcfs, averaging 63 kcfs. Daily average flow increased above 120 kcfs on the lower Snake River from June 3 through June 16, 2010, with a peak of 216 kcfs on June 6. It was during this period that involuntary spill occurred at several lower Snake River dams. Total river flows continued to recede on the lower Snake River through July and August 2010, until total river flows reached 24 kcfs on August 28, 2010.

Summer Spill

During 2010, consistent with the Summer FOP, summer spill began June 21, 2010, and continued through August 31, 2010 at the lower Snake River projects. Summer spill on the lower Columbia River began June 20, 2010 at McNary Dam, July 1, 2010 at John Day and The Dalles dams, and June 21, 2010 at Bonneville Dam. Spill continued through August 31, 2010.

The 2010 FOP called for the following spill operations during the summer:

- **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 21 through July 11, 2010, spill alternating between 30 percent of the river flow 24 hours per day, or 45 kcfs during the day and up to the spill cap at night. From July 12 through August 31, 2010, 45 kcfs during the day and up to the spill cap at night.
- **McNary Dam**: Spill 50 percent of total project outflow

- **John Day Dam**: Alternating between 30 percent and 40 percent of total project outflow from July 1 through July 21, 2010, and spill 30 percent of total project outflow, 24 hours per day from July 21 through August 31, 2010
- **The Dalles Dam**: 40 percent of total project outflow
- **Bonneville Dam**: Spill alternating between 95 kcfs 24 hours per day and 85 kcfs during the day and 121 kcfs at night from June 16 through July 20, 2010. Spill 75 kcfs during the day and to the spill cap at night from July 21 through August 31, 2010.

TDG Instances

Fish passage spill operations may result in the generation of TDG supersaturation in the Columbia and lower Snake rivers at levels above 110 percent, the current state and federal water quality standards. The states of Washington and Oregon provide limited exceptions to these standards for juvenile fish passage spill. The Corps monitors TDG levels in the river and adjusts spill patterns and spill rates to stay within acceptable levels.

During the 2010 fish passage spill season, there were a total of 234 instances where TDG exceeded state standards as modified by waivers or criteria adjustment. There were 67 instances from voluntary spill and 167 instances from involuntary spill, measured in gauge-days.[2] This information is provided in the annual Dissolved Gas and Water Temperature Monitoring Report (ACOE 2010 Dissolved Gas and Water Temperature Monitoring Report) at *http://www.nwd-wc.usace.army.mil/tmt/wqnew/tdg_and_temp/2010/*.

Instances from voluntary spill:

- 0 - related to non-generating equipment (operation or mechanical failure)
- 7 - malfunctioning fixed-monitoring station gauges
- 60 - uncertainties associated with using best professional judgment, SYSTDG model, and forecasts

Instances from involuntary spill:

- 166 - high runoff flows and flood control efforts, BPA load requirements lower than actual powerhouse capacity, and involuntary spill
- 1 - outage of hydro power equipment

During the 2010 migration season, there were 555 instances in which TDG levels were higher than either the Oregon two-hour standard or Washington one-hour standards of 125 percent TDG; 553 of those instances were due to involuntary spill associated with high runoff. The other two instances resulted from special spill operations to pass debris that were coordinated through TMT. Debris spill operations can elevate TDG levels for a short period of time (usually from one to four hours) but are necessary to allow for safe access to juvenile fish passage systems.

Examination of data obtained from the FPC (under "Smolt Data" at *www.fpc.org*) showed that 13,624 juvenile fish were examined for GBT at Corps dams in 2010. Of the fish examined, 49 were found to have symptoms of GBT, none of the symptoms were severe. The symptoms occurred during high river flows.

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*

[2] [number of TDG gauges] x [number of days in spill season, April 3 through August 31, 2010]

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 2010 transportation program was conducted in accordance with NOAA Fisheries ESA Permit Number 1237 and the Juvenile Fish Transportation Program criteria in the 2010 Fish Passage Plan. The start dates for initiating transport operations were staggered at Snake River operating projects. Collection of juvenile fish for barge transport began April 23, 2010, at Lower Granite Dam, May 1, 2010, at Little Goose Dam, and May 4, 2010, at Lower Monumental Dam. 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, 2010 at Lower Monumental Dam and through October 31, 2010 at Little Goose and Lower Granite dams.

Fish at McNary Dam were bypassed from April 1 through July 14, 2010, and transported from July 15 to October 1, 2010. Before transport began, sampling operations occurred on an every-other-day basis beginning April 5, 2010, to support research and BPA-sponsored smolt monitoring activities, as well as to assess bypass system conditions.

Juvenile fish barged during 2010 were released at varying locations below Bonneville Dam as required in the permit. The ending date for the barging season in 2010 was August 16, 2010, for Snake River facilities and August 17, 2010, for McNary Dam. At Snake River facilities, trucks carried juvenile fish from August 16, 2010, through the end of the transport season. At McNary Dam, collected fish were trucked on even numbered days from August 6 through August 16, 2010, on days when barges were not available, then concurrently every-other day with Snake River trucking operations from August 18 through October 1, 2010. Trucked fish were released into the Bonneville Juvenile Monitoring Facility outfall flume. No early season (April) trucking took place in 2010.

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 sampled. At Snake River operating projects, the sampled fish were hand-counted and differentiated by species and the presence of adipose fins. A total of 3,645,277 juvenile fish were collected at Lower Granite Dam, with 247,129 of these fish bypassed to the river and 3,394,601 transported. At Little Goose Dam, 2,870,791 juvenile salmon and steelhead were collected in 2010. Of these, 140,719 were bypassed to the river, and 2,723,402 were transported. At Lower Monumental Dam, 1,065,007 juvenile salmon and steelhead were collected in 2010. Of these, 6,137 fish were bypassed, and 1,057,640 were transported. At McNary Dam, 4,331,732 juvenile salmon and steelhead were collected in 2010. Approximately 3,874,439 of the fish collected were bypassed to the river to meet fishery agency requirements, and 447,252 juvenile fish were transported.

A total of 11,912,807 juvenile salmon and steelhead were collected at all transport program locations in 2010, with 7,622,895 fish transported (64 percent) and 4,268,424 bypassed (36 percent). Of the fish transported, 7,447,369 were transported by barge (98 percent) and 175,526 were trucked (2 percent).

Table 9. Estimated Proportion of Non-Tagged Spring/Summer Chinook and Steelhead Smolts Transported in the Columbia and Snake Rivers in 2010.

Species	Percent Transported in 2010
Snake River Spring Chinook—Wild	38.2%

Species	Percent Transported in 2010
Snake River Spring Chinook—Hatchery	22.6%
Snake River Spring Steelhead—Wild	36.8%
Snake River Spring Steelhead—Hatchery	34.8%

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.

Various studies continued in 2010 to inform the Transportation Strategy COP, slated for completion in 2011. The data will be used to evaluate operational and construction alternatives to improve the transportation program. Significant among these were the following studies:

- **Transportation of Juvenile Salmonids on the Snake River, 2008: Final Report for the 2004 Fall Chinook Salmon Juvenile Migration** – In summer 2004, subyearling fall Chinook salmon were PIT-tagged at Lower Granite Dam, in contrast to 2001-2003 where fish were tagged at Lyons Ferry Hatchery and released in the Snake River 81 km above Lower Granite Dam at river kilometer 254. The study was designed to compare the smolt-to-adult return (SAR) of fish transported as juveniles from Lower Granite Dam with that of fish released to migrate in-river and not detected at any collector dam. However, recent data have shown that the method used to estimate numbers of non-detected yearling Chinook migrants cannot produce unbiased estimates of non-detected Snake River fall Chinook salmon. This method assumes equal probabilities of downstream detection among fish from each cohort after release. However, it is now known that a considerable proportion of fall Chinook overwinter within the migration corridor. Therefore, only SARs of fish with known migration histories are reported.

  The SARs (jacks through age-4 ocean fish) for subyearlings tagged in 2004 was 0.14 percent (95 percent CI, 0.02 to 0.26 percent) for transported, 0.10 percent (0.04-0.17 percent) for bypassed, and 2.22 percent (0.04 to 4.40 percent) for holdover groups. The SAR for fall transport index fish was 1.89 percent (1.35 to 2.42 percent). Transportation appeared to neither greatly harm nor help Snake River fall Chinook salmon. For the 2004 releases overall, the transported group had slightly higher SARs than the bypassed group, but the highest SARs were seen in holdover fish, or those that delayed migration. Fall transport index fish also had relatively high SARs.

- **Evaluating the responses of Snake and Columbia basin fall Chinook salmon to dam passage strategies and experiences –** The Corps continues to implement specific components of the regionally developed consensus proposal for evaluating transportation of fall Chinook salmon. Approximately 596,000 juvenile fall Chinook salmon (natural, surrogate, and production groups) were tagged in 2010 as part of this study. A region-wide workshop was held in May 2010 to begin the development of a method for analysis report that will outline how to analyze the adult return data. Future group meetings are continuing in order to develop and finalize a methods report with state, tribal, and federal input.

- The study, **Post-release performance of natural and hatchery subyearling fall Chinook salmon in the Snake and Clearwater rivers,** continued for 2010, and the 2009 report was completed. This study continues to document passage indices of subyearling fall Chinook salmon and make comparisons between natural fish and production and surrogate fish. Consistent with the 2005, 2006, and 2008 findings, post-release attributes measured on 2009 releases were more similar between Snake and Clearwater river natural and surrogate subyearlings than between natural and production subyearlings.

- **Fall Chinook salmon scale pattern analysis** – Scales from returning adults in 2007-2011 are being collected and analyzed to determine age at ocean entry for different groups of fall Chinook that were PIT-tagged as juveniles. This study will provide important information about the unique overwintering strategy of Snake River fall Chinook salmon relative to operational and environmental conditions.
- **A study to determine seasonal effects of transporting fish from the Snake River to optimize a transportation strategy** continued in 2010. The goal of this study is to identify periods and conditions when it is best to transport fish. Biotic and abiotic variables are collected to match weekly SARs of transport and in-river migrant steelhead and yearling Chinook salmon. Results of this study are still being compiled and analyzed. Generally, fish transported later in the season fare better than those transported early, and this study is attempting to identify the conditions that trigger this change in response.
- **Sockeye transportation pilot study –** Juvenile sockeye salmon from Idaho were PIT-tagged and used for an evaluation of the efficacy of a transportation study on sockeye salmon. This is discussed further under the discussion of RPA Action 52, subaction 5.

Hydropower Strategy 4 (RPA Action 32)

RPA Action 32 – Fish Passage Plan (FPP):

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.

The draft 2010 FPP was released in October 2009. The final FPP (*http://www.nwd-wc.usace.army.mil/tmt/documents/fpp/2010/*) was released in March 2010. 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.

As a result of adult fish mortalities associated with maintenance at Dworshak Dam in November 2010, the Corps made significant revisions to the procedures for routine turbine dewatering. These procedures are designed to minimize risks to fish during future maintenance activities. After coordination with regional sovereigns, the new procedures were incorporated into the 2011 FPP. For more information on this incident please see the incident report at *http://www.nwd-wc.usace.army.mil/tmt/documents/FPOM/2010/2011_FPOM_MEET/2011_JAN/DWO%20Draft%20Tube%20Mortality%20Report_2010%20Dec%2022.pdf*.

Hydropower Strategy 5 (RPA Action 33)

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.*

The BPA and Corps completed the 2010 Kelt Management Plan (KMP) and released it for comment in December 2010. The goal of kelt management actions is to improve survival and productivity of listed steelhead by allowing kelts to successfully survive and spawn in a subsequent year. The 2010 version of the KMP built upon the framework of the 2009 plan. It includes a review and synthesis of previous research on kelt migration studies through the hydrosystem as well as kelt reconditioning efforts. Beginning with the 2011 KMP, updates and research results will be reported in CRITFC's annual reports, and the focus will shift from planning to progress and adaptive management actions.

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

The BPA continued to fund CRITFC to prepare a master plan for kelt, and CRITFC has subcontracted portions of this project to the University of Idaho. The master plan, which will apply to reconditioning Snake River kelts, is part of a three-step technical review process required by NPCC for artificial propagation projects, particularly those that affect natural populations and involve construction of capital facilities. In addition, the master plan will focus on kelt collection and reconditioning at various locations, designed to hold fish over so they can spawn in a subsequent year.

Habitat Implementation Reports, RPAs 34–38

Table 10. Habitat Strategy Reporting, RPA Actions 34–38

RPA Action No.	Action	Annual Progress Report
Habitat Strategy 1		
34	Tributary Habitat Implementation 2007 to 2009 – Progress Toward 2018 Habitat Quality Improvement Targets	• Status of project implementation (including project milestones) through December of previous year for all 2007-2009 actions. • Report physical metrics for implementation achieved (e.g., miles of access, cfs of streamflow acquired, numbers of screens, miles or acres of habitat protected or enhanced, and miles of complexity enhanced) relative to the project objectives.

Table 10. Habitat Strategy Reporting, RPA Actions 34–38

RPA Action No.	Action	Annual Progress Report
35	Tributary Habitat Implementation 2010-2018 – Achieving Habitat Quality and Survival Improvement Targets	• Status of project implementation (including project milestones) through December of previous year for all actions identified in implementation plans. • Report physical metrics for implementation achieved (e.g., miles of access, cfs of streamflow acquired, numbers of screens installed, miles of acres of habitat protected or enhanced, and miles of complexity enhanced by benefited population(s)) relative to the total needed to complete the project and achieve the estimated survival benefits, by project.
Habitat Strategy 2		
36	Estuary Habitat Implementation 2007 to 2009	• Status of project implementation (including project milestones) through December of previous year for all 2007-2009 actions. • Report physical metrics for implementation achieved (e.g., number of acres protected/restored/enhanced; riparian miles protected) relative to the total needed to complete project and achieve the estimated survival benefits.
37	Estuary Habitat Implementation 2010-2018 – Achieving Habitat Quality and Survival Improvement Targets	• Status of project implementation (including project milestones) through December of previous year for all actions identified in implementation plans. • Report physical metrics for implementation achieved (e.g., number of acres protected, restored, enhanced; riparian miles protected) relative to the total needed to complete the project and achieve the estimated survival benefits, by project. • By Evolutionary Significant Unit (ESU), report progress toward ESU/Distinct Population Segment (ESU/DPS)-specific survival benefit. • Where ESU/DPS-specific survival benefits are not achieving the progress guidelines above, identify processes or projects in place to ensure achievements by the next comprehensive report.
38	Piling and Piling Dike Removal Program	• Status of project implementation (including project milestones) through December of previous year for all actions identified in implementation plans. • Report physical metrics for implementation achieved (e.g., number of pilings/pile dikes removed, habitat area restored) by project.

Habitat Strategy 1 (RPA Actions 34–35)

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 has been completed. The final report is found in the 2009 FCRPS Annual Progress Report (ACOE 2009 FCRPS) at *http://www.salmonrecovery.gov/BiologicalOpinions/FCRPS/BiopImplementation/BiOpImplementation2009.aspx*.

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

RPA Action 35 includes specifications for three-year implementation cycles between 2010 and 2018. Summary information for water quantity and quality, in-stream habitat complexity, riparian improvement and protection, and access actions completed through 2010 of the 2010-2012 implementation cycle is presented in Section 1 of this report. Metrics for actions completed in 2010 are summarized by population in Section 3, Attachment 2. Detailed information on the 2010 progress of individual projects and actions is presented in Section 3, Attachment 3, Tables 1 through 5. The projects and actions listed in Table 1 through 3 are BPA projects identified in the FCRPS BiOp 2010-2013 Implementation Plan at (*http://www.salmonrecovery.gov/Files/2010-2013%20FCRPS%20BiOp%20Implementation%20Plan%206%2010.pdf*). Tables 1 through 3 are organized by Evolutionarily Significant Unit (ESU) and Distinct Population Segment (DPS) and include project descriptions and habitat metrics that were completed in 2010. Projects may be reported multiple times if they benefit more than one species or more than one population. Many of the projects listed in Section 3, Attachment 3 represent multi-year contracts and ongoing accomplishments.

Reclamation has produced a number of additional reports that document tributary habitat accomplishments. These reports are listed in Section 3, Attachment 4; the reports can be accessed at *http://www.usbr.gov/pn/programs/fcrps/thp/index.html*.

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 2008FCRPS 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 are providing funding and technical assistance to improve habitat for more than 90 interior Columbia basin spring/summer Chinook and summer/winter steelhead populations, including most of the 18 priority and 38 non-priority populations listed in Table 5 of the 2008 FCRPS BiOp RPA.

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.

The Action Agencies provided funding and/or technical assistance to implement specific habitat projects listed in Appendix A of the 2010-2013 FCRPS BiOp Implementation Plan. The status on the progress of these projects for 2010 is presented in Section 3 of this annual progress report and in Section 1, Figures 13 to 17 and associated text.

The Action Agencies reviewed results from the expert panel workshops completed in 2010 and recognized that efforts need to be concentrated on some populations in order to reach RPA 35 Table 5 commitments by 2018 without compromising progress needed for populations already positioned for reaching 2018 commitments. For example, tributary assessments initiated in 2009 by Reclamation in close coordination with local partners in Catherine Creek, a tributary to the Grande Ronde River in Oregon, and the Yankee Fork of the Salmon River in Idaho are expected to be completed in 2011. As refined reach assessments are completed in 2012, they are expected to help identify, prioritize, and select habitat improvement actions that will focus on the highest biological benefits for proposals in the next implementation cycle based on objective, scientific analyses of physical and biological characteristics in these areas. To expedite progress for populations positioned for reaching 2018 commitments, BPA initiated a programmatic approach with comprehensive project planning, implementation, and management for upper Columbia salmon and steelhead populations through a BPA-funded project with the Upper Columbia River Salmon Recovery Board. The programmatic approach will allow greater flexibility to select the best actions available for implementation each year, provide opportunity for multi-year planning to address large-effort projects, and will sustain BiOp habitat implementation through various funding and solicitation cycles. It will also ensure thorough coordination with habitat improvements implemented through other funding entities.

- *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 last of the expert panel workshops for the 2010-2012 implementation cycle was completed in January 2010. All expert panels were provided the opportunity to review and comment on draft tables of their estimates of changes in habitat condition before they were finalized by the Action Agencies.

- *The expert panel will use methods consistent with the NWR v. NMFS Remand Collaboration Habitat Workgroup process.*

  The expert panels followed the Remand Collaboration Habitat Workgroup process to finalize changes in habitat limiting factors associated with the completed planned, replacement, and additional 2007-2009 habitat actions and to estimate changes in limiting factors for the planned 2010-2012 habitat actions.

- *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.*

  Projects and associated metrics that address key limiting factors identified in the expert panel process were included in the 2010-13 Implementation Plan. Quantitative habitat metrics completed in 2010 are presented in the project tables of Section 3 of this report.

- *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 expert panels identified changes in limiting factor habitat function associated with projects for each priority population in 2009 and 2010. The Action Agencies recorded the final information pursuant to guidance provided by the Remand Collaboration Habitat Workgroup. This information will be used in the 2013 and 2016 Comprehensive Evaluations to assess improvements to salmonid survival.

- *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 continue to fund and provide technical assistance for projects identified in the 2010-13 Implementation Plan. Quantitative habitat metrics completed in 2010 are presented in the project tables of Section 3 of this report. Benefits for all actions completed in the 2010-2012 cycle, including replacement projects and any projects carried over from 2007-2009, will be evaluated in the 2012 expert panel workshops.

- *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 will continue to cooperate with the NPCC to identify priorities and obtain Independent Scientific Review Panel (ISRP) review of projects.

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

  See RPA Action 57 action plan for 2010 progress on tributary habitat research, monitoring, and evaluation (RME).

- *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 considered by expert panel members in the 2009-2010 expert panel process suggest that habitat quality improvement estimates for 2007-2009 actions were reasonable.

b) *During 2010-2018, for non-bolded populations in Table 5 [of the 2008 FCRPS BiOp RPA], 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 provided funding and technical assistance for projects directed to non-bolded populations in RPA 35 Table 5. These projects were not implemented as replacement projects, per se. However, benefits from these projects may be used should the 2013 comprehensive evaluation indicate they are necessary for the Action Agencies to achieve equivalent major population group (MPG) or ESU survival benefits.

c) *For those lower Columbia populations above Bonneville Dam that have been significantly impacted by the FCRPS (CR chum, LCR coho, LCR Chinook, and LCR steelhead) the Action Agencies may provide funding and/or technical assistance for habitat improvement projects consistent with basin wide criteria for prioritizing projects, including Recovery Plan priorities.*

The Action Agencies provided funding to improve habitat for the lower Gorge population of lower Columbia River coho, Hood River populations of lower Columbia River Chinook and steelhead, and Wind River population of lower Columbia River steelhead. The habitat improvements were consistent with Recovery Plan priorities.

Table 5 of the 2008 FCRPS BiOp RPA

ESU	Major Population Group	Population	Estimated Percentage Habitat Quality Improvement of 2007- 2009 Actions	Total Estimated Percentage Habitat Quality Improvement of 2007-2018 Actions
Snake River Spring/Summer Chinook	Grand Ronde/Imnaha	**Catherine Creek**	**4**	**23**
		Lostine/Wallowa River	2	2 *
		Grand Ronde River upper mainstem	**2**	**23**
		Imnaha River mainstem	1	1 *
	Middle Fork Salmon River	Big Creek	1	1 *
	South Fork Salmon River	Secesh River	1	1 *
		South Fork Salmon River Mainstem	<1	<1 *
	Lower Snake	**Tucannon River**	**7**	**17**
	Upper Salmon River	East Fork Salmon River	1	1 *
		Lemhi River	7	7 *
		Pahsimeroi River	41	41 *
		Salmon River lower mainstem below Redfish Lake	1	1 *
		Salmon River upper mainstem above Redfish Lake	14	14 *

ESU	Major Population Group	Population	Estimated Percentage Habitat Quality Improvement of 2007- 2009 Actions	Total Estimated Percentage Habitat Quality Improvement of 2007-2018 Actions
		Valley Creek	1	1 *
		Yankee Fork	**10**	**30**
Upper Columbia Spring Chinook	Upper Columbia – Below Chief Joseph	**Entiat River**	**10**	**22**
		Methow River	**2**	**6**
		Wenatchee River	**1**	**3**
Middle Columbia Steelhead	Cascades Eastern Slope Tributaries	Deschutes River – eastside	1	1 *
		Deschutes River – Westside	<1	<1 *
		Fifteen mile Creek (winter run)	<1	<1 *
		Klickitat River	4	4 *
	John Day River	John Day River lower mainstem tributaries	<1	<1 *
		John Day River upper mainstem	<1	<1 *
		Middle Fork John Day River	<1	<1 *
		North Fork John Day River	<1	<1 *
		South Fork John Day River	1	1 *
	Umatilla and Walla Walla River	Touchet River	4	4 *
		Umatilla River	4	4 *
		Walla Walla River	4	4 *

ESU	Major Population Group	Population	Estimated Percentage Habitat Quality Improvement of 2007- 2009 Actions	Total Estimated Percentage Habitat Quality Improvement of 2007-2018 Actions
	Yakima River Group	Naches River	4	4 *
		Satus Creek	4	4 *
		Toppenish	4	4 *
		Yakima River upper mainstem	4	4 *
Snake River Steelhead	Clearwater River	**Lochsa River**	**6**	**16**
		Lolo Creek	**8**	**12**
		Selway River	**<1**	**<1**
		South Fork Clearwater River	**5**	**14**
Snake River Steelhead	Grand Ronde River	Grand Ronde River lower mainstem tributaries	<1	<1 *
		Grand Ronde River upper mainstem	4	4 *
		Joseph Creek (OR)	<1	<1 *
		Joseph Creek (WA)	4	4 *
		Wallowa River	<1	<1 *
	Hells Canyon	Hells Canyon		
	Imnaha River	Imnaha River		*
	Lower Snake	Asotin Creek	4	4 *
		Tucannon River	5	5 *
	Salmon River	**Lower Middle Fork mainstem and tribs (Big, Camas, and Loon Creeks)**	**1**	**2**
		East Fork Salmon River	2	2 *
		Lemhi River	3	3 *

ESU	Major Population Group	Population	Estimated Percentage Habitat Quality Improvement of 2007- 2009 Actions	Total Estimated Percentage Habitat Quality Improvement of 2007-2018 Actions
		Pahsimeroi River	9	9 *
		Salmon River upper mainstem	6	6 *
		Secesh River	**1**	**6**
		South Fork Salmon River	**<1**	**1**
Upper Columbia Steelhead	Upper Columbia River – below Chief Joseph	**Entiat River**	**6**	**8**
		Methow River	**2**	**4**
		Okanogan River	**12**	**14**
		Wenatchee River	**1**	**4**

* 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.

Habitat Strategy 2 (RPA Actions 36–38)

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.

Some projects scheduled for completion in 2007-2009 were delayed and 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. The Action Agencies will implement additional projects in 2010-2013 to provide survival benefits equivalent to those of the projects that proved infeasible. These additional projects will be selected and implemented in accordance with RPA 37.

The final report for this RPA Action is found in the 2009 FCRPS Annual Report (ACOE 2009 FCRPS) at: *http://www.salmonrecovery.gov/BiologicalOpinions/FCRPS/BiopImplementation/BiOpImplementation2009.aspx*.

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 2010-2013 the Action Agencies will provide funding for implementation of projects as needed to achieve the total FCRPS BiOp estuary survival benefits by 2018. Most projects implemented in the estuary are selected on an annual basis.

In 2010, the Action Agencies completed on-the-ground habitat actions on four projects in the estuary and continued planning and development of additional projects for future implementation (See Section 3, Attachment 5 for status of projects).

1. The Haven Island Restoration Project. This project restored much of the natural hydrologic connectivity to 80 acres of disconnected tidal floodplain islands within the Youngs River Estuary. The project reconnected 700 feet of historical tidal channels to the estuary by removing 500 feet of an existing levee, opened 800 feet of historical tidal channels by removing a tidegate, removed and controlled invasive plants, and planted approximately three acres with Sitka spruce and other on-site native shrubs/trees. This project has resulted in the restoration and enhancement of 80 acres of tidally influenced emergent wetlands within the Columbia River Estuary, including providing diverse off-channel habitat for juvenile salmonids.
2. Otter Point Restoration Project. This project is restoring tidal wetlands and improving salmon habitat for juvenile migrating salmon in the estuary. This project restored 28 acres of salmon habitat, intertidal wetlands, and historic landscape at a location within a national historic park. The first phase of the project was completed in 2010. Activities included: clearing, non-native plant species removal, channel excavation, large woody debris (LWD) mobilization, levee material preparation, and erosion control. The second phase will be completed in 2011 and will include breaching an existing levee to connect the intertidal channels to the Lewis and Clark River and construction of a new cross levee to protect adjacent landowners.
3. Sandy River Delta Project. The overarching goal of this project is recovery of naturally reproductive (self-maintaining) native floodplain forest – and associated ecosystem structure and functions – in the important salmon-bearing waters at the confluence of the Sandy and Columbia rivers. The focus of this project in 2010 was to plant and maintain native vegetation and remove invasive species on a total of 687 acres by applying herbicides to non-native species on 397 acres; maintain native vegetation on 152 acres; and plant native vegetation species on 355 acres. These actions will lead to improved bank stabilization and water quality, natural flood control, and a healthy riparian zone that once made the Sandy River Delta so productive for fish and wildlife.
4. Mirror Lake Restoration Project. This is a multi-year phased project to return the site, to the extent possible, to its pre-disturbance condition and to recover and sustain natural processes. Previous restoration efforts have addressed inadequate passage and loss of riparian forests and function. The focus of restoration efforts in 2010 was to address lack of instream habitat structure and complexity by adding LWD, placing 75 conifers with root balls. Prior to restoration, LWD abundance was extremely low. The 75 conifers with root balls increased LWD abundance directly as well as indirectly by helping to trap additional material. The placement of the LWD has improved one linear mile of stream complexity though pool scour and channel widening.

As part of an overall adaptive management strategy that assists the Action Agencies in identifying and responding to new information arising during implementation, the Action Agencies addressed the slower than expected pace in project implementation in the estuary by significantly increasing project development efforts. In 2010, the Action Agencies formulated and began implementing strategies for developing an expanded portfolio of high-quality projects in the estuary. They included:

- The Action Agencies worked collaboratively to produce joint project selection criteria. These criteria help guide selection of habitat projects to more effectively meet estuary targets/goals in the 2008 FCRPS BiOp.

- Continue to have all estuary projects reviewed and scored by the Expert Regional Technical Group (ERTG).
- Expedite Washington estuary Memorandum of Agreement (MOA) projects with high survival benefits. The Corps, BPA, and the Washington Department of Fish and Wildlife (WDFW) will identify and implement estuary restoration projects that provide the highest survival benefits.
- Identify and implement joint BPA/Corps projects (non-Washington MOA) that yield high survival benefits.
- Work with partners to identify large tracts of land on the Oregon and Washington shoreline that are suitable for implementation actions.
- Continue to explore the potential use or development of mitigation banks for restoration activities.

The Action Agencies continue to utilize the *Columbia River Estuary ESA Recovery Plan Module for Salmon and Steelhead* (NOAA 2011) to guide restoration and protection efforts through a collaborative process. In 2010, the Action Agencies continued development of a strategic approach to identifying restoration projects in the estuary using the Columbia River Estuary Ecosystem Classification (CREEC) being developed by the University of Washington and the U.S. Geological Survey (USGS). The Action Agencies began application of the completed river reaches of the CREEC in 2010. This strategic approach provides guiding principles based on salmonid ecology to identify potential sites with the highest value to salmon and steelhead. This is a collaborative effort between the Action Agencies and other regional interests, including the Lower Columbia River Estuary Partnership (LCREP), the states of Oregon and Washington, the Cowlitz Tribe, local restoration practitioners, and experts, including the Columbia River Estuary Study Taskforce (CREST), the Columbia Land Trust, watershed councils, and conservation districts.

- *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 2010, the Action Agencies continued to utilize LCREP's Science Workgroup, using its ecosystem criteria to help select restoration and protection projects in the lower Columbia River and estuary.

- *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 convened in 2009 and began evaluating federal projects for their survival benefit potential. The ERTG has five members, representing: the Oregon Department of Fish and Wildlife (ODFW); WDFW; NOAA Fisheries' Northwest Fisheries Science Center (NWFSC); the Department of Energy's Pacific Northwest National Laboratory; and the Skagit River System Cooperative. In 2010 the ERTG completed three key deliverables: project information templates, project scoring criteria, and a benefits calculator. These tools have allowed the Action Agencies to evaluate project benefits ("assigned survival benefit units") for individual projects by restoration action, and offer a common method from which to evaluate project benefit across projects.

- *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.*

  In 2010 the ERTG completed the project template for Lower Columbia River Estuary (LCRE) habitat restoration projects. Each project proposal is submitted to the ERTG in this template format, thus providing standardized terminology and descriptions for ecosystem stressors, habitats, processes, and functions. This information provides input to the scoring of projects.

- *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 RM&E to estimate the change in overall estuary habitat and resultant change in population survival.*

In 2010, the ERTG applied and modified the approach used in the FCRPS BA to assign survival benefits to federal projects. Improvements included refinements to the scoring criteria and development of a survival benefits calculator. The calculator allows for a more transparent, repeatable, and quantitative approach to assigning survival benefits. ERTG used the scoring criteria and calculator to assign draft survival benefits to fourteen federal projects. Improvements to the scoring criteria and calculator were vetted with project sponsors and other interested stakeholders.

- *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 scheduled for completion in 2010 were delayed or proved unfeasible. The delayed projects will be constructed in 2011-2013. As part of an overall adaptive management strategy that assists the Action Agencies in identifying and responding to implementation delays, the Action Agencies significantly increased project development efforts to increase on-the-ground projects and accelerate the pace of implementation in the estuary.

Late in 2010, ERTG began scoring projects implemented in 2007-2010 that were not included in the BA. Scoring for these projects is expected to be completed in 2011.

Replacement project selection will be based on input from expert panels, regional recovery planning groups, the NPCC, and NOAA Fisheries.

- *FCRPS RM&E 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.

- *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 find 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 2010, the Action Agencies actively engaged research agencies, consultants, LCREP's Science Workgroup, Anadromous Fish Evaluation Program (AFEP), the ERTG, and other sources regarding new scientific information. The Action Agencies have examined that information, and are not aware of any information that would indicate that habitat quality improvement estimates for projects completed in 2010 implementation cycle were "significantly overstated." The Action Agencies will continue to coordinate with LCREP's Science Workgroup and the ERTG regarding new scientific information. When available, new scientific information resulting from FCRPS RME will be applied to estimate benefits for projects implemented between 2010 and 2018.

RPA Action 38 – Piling and Piling Dike Removal Program:

To increase access to productive habitat and to reduce avian predation, the Action Agencies will develop and implement a piling and pile dike removal program.

- *In 2008, the Action Agencies will work with [the]Lower Columbia River Estuary Program develop a plan for strategic removal of structures that have lower value to navigation channel maintenance, present low-risk to adjacent land use, support increased ecosystem function, and are cost-effective.*

  A final draft pile structure program plan was presented to NOAA Fisheries in November 2008, and was reviewed in early 2009. This plan will be modified as new information becomes available.

- *Beginning in 2008 and 2009, the Action Agencies will begin implementation. Implementation will continue through 2018.*

  In 2010, the Corps contracted for a structural, hydraulic, and environmental analysis of Columbia River pile dikes to identify which pile dike structures are needed to support the Corps' navigation responsibilities, provide a preliminary analysis of habitat associated with each pile dike, and inventory "essential" and "non-essential" piling for maintaining the navigation channel. Non-essential pilings are considered candidates for removal or modification to improve habitat access for juvenile salmon as well as reduce avian predation. Essential pilings are candidates for "capping" to reduce avian predation. Field observations were completed in 2010. The final report, including findings and recommendations, is scheduled for completion in 2011.

Hatchery Implementation Reports, RPA Actions 39–42

Table 11. Hatchery Strategy RPA Action Reporting

RPA Action No.	Action	Annual Progress Report
Hatchery 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 (HSRG) 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.

Hatchery Strategy 1 (RPA Actions 39–40)

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 2010, the Action Agencies continued to fund mitigation hatcheries in accordance with existing programs and used the programmatic funding criteria developed in 2008 for funding decisions on mitigation programs for the FCRPS.

To implement RPA Action 39, NOAA Fisheries announced initiation of its ESA consultation process in a series of letters to Columbia basin hatchery operators and other interested parties. The process was initiated in September 2008 for upper Columbia hatchery programs, in March 2009 for programs in the Mid-Columbia Steelhead DPS, and in May 2009 for Snake River basin programs. Following each NOAA Fisheries announcement, the Action Agency-funded hatchery operators in these regions began updating the Hatchery and Genetic Management Plans (HGMPs) for their respective hatchery programs. In July 2009, the Action Agencies sent a letter to hatchery program operators that described a process for working collaboratively on development of HGMPs for consultation and transmitted the criteria for funding decisions on ongoing and new hatchery programs in the Columbia basin. Information from the reports of the recently completed USFWS Hatchery Review Team process and the Hatchery Scientific Review Group (HSRG) will guide and inform the development of program-specific HGMPs.

As of December 2010, updated HGMP drafts for most of the FCRPS hatchery programs (Tables 14, 15, 16) were either underway or completed and sent to NOAA Fisheries for review and comment.

<u>Upper Columbia</u>

Throughout 2010, hatchery program operators in the upper Columbia region continued to develop HGMPs for Action Agency-funded hatchery programs, based on processes set forth in 2008 and 2009. Action Agencies continued their reviews and commented on draft HGMPs during development.

NOAA Fisheries previously determined that the Leavenworth National Fish Hatchery (NFH) Spring Chinook program HGMP was sufficient for formal ESA Section 7 consultation, pending resolution of diversion flow issues. NOAA, hatchery operators, and Action Agencies agreed on flow issues in December 2010, paving the way for ESA consultation to move forward. In December 2010, NOAA Fisheries notified BPA that the HGMPs for the Yakama Nation Methow and Wenatchee Coho programs were sufficient for formal ESA Section 7 consultation. Final BiOps for these Leavenworth NFH and Yakama Nation programs are expected in 2011.

HGMPs for Winthrop hatchery programs were submitted in July 2009. Ongoing discussion in 2010 developed information for revised HGMPs for Winthrop spring Chinook salmon and summer steelhead programs. The HGMP for summer Chinook salmon at the Entiat NFH was informally found to have no major issues.

<u>Middle Columbia</u>

In December 2010, NOAA Fisheries notified BPA that the HGMPs for the Umatilla Spring Chinook, Fall Chinook, and Coho programs in the middle Columbia were sufficient for formal ESA Section 7 consultation. The HGMP for the Umatilla Summer Steelhead program has been submitted and pending determination as sufficient for formal ESA Section 10 consultation. Updated and completed HGMPs for the Yakima Spring Chinook, Yakima Fall-Summer Chinook, Yakima Coho and Touchet Endemic Summer Steelhead programs, sufficient for formal ESA consultation, are expected to be submitted to

NOAA Fisheries. BiOps for the aforementioned Umatilla, Yakima, and Touchet programs are expected in 2011.

Snake

As of December 2010, 25 of 29 draft HGMPs for the Snake region were completed by the hatchery operators and had been reviewed by Action Agencies; and NOAA Fisheries had provided review edits and comments to the operators for eight of the 25 draft HGMPs. At the end of 2010, the Action Agencies had not received four draft program HGMPs from the operators for review and comment: Lyons Ferry-Fall Chinook Acclimation Program, Nez Perce Hatchery Fall Chinook Program, Lookingglass Spring Chinook Program, and Nez Perce Hatchery Spring Chinook Program. Draft HGMPs for these four programs are expected to be completed and forwarded to the Action Agencies and NOAA Fisheries for review and comment by early-mid 2011. Revised and completed HGMPs for the Snake region programs sufficient for formal Section 7 or Section 10 consultations are expected in late 2011 and 2012.

Table 12. FCRPS-Funded Hatchery Programs in the Upper Columbia Region.

Program	Operator	Lead Action Agency	Basin
Leavenworth National Fish Hatchery (NFH) spring Chinook	USFWS	Reclamation	Wenatchee
Entiat NFH summer Chinook program	USFWS	Reclamation	Entiat
Upper Columbia steelhead kelt reconditioning	Confederated Tribes of the Colville Reservation (CTCR)[1] and Yakima Nation (YN)[2]	BPA	Okanogan, Entiat, Wenatchee
Winthrop NFH Methow Composite spring Chinook	USFWS	Reclamation	Methow
Winthrop NFH steelhead	USFWS	Reclamation	Methow
Methow coho	YN	BPA	Methow
Wenatchee coho	YN	BPA	Wenatchee

1/ Confederated Tribes of the Colville Reservation program is conducted in the Okanogan Subbasin

2/ The Yakama Nation upper Columbia kelt reconditioning program will probably be located in the Wenatchee subbasin near Dryden, Washington, and not at Entiat NFH as originally proposed. The Yakama Nation will be the operator, with funding from BPA, for this FCRPS BiOp/Columbia Basin Fish Accords project.

Table 13. FCRPS-Funded Hatchery Programs in the Mid-Columbia Region

Program	Operator	Lead Action Agency	Basin
Yakima Spring Chinook	YN	BPA	Yakima
Yakima Summer-Fall Chinook [1]	YN	BPA	Yakima

Program	Operator	Lead Action Agency	Basin
Yakima Coho	YN	BPA	Yakima
Yakima Steelhead Kelt Reconditioning	YN	BPA	Yakima
Touchet Endemic Steelhead	WDFW	BPA Lower Snake River Compensation Plan (LSRCP)	Walla Walla
Umatilla Spring Chinook	Oregon Department of Fish and Wildlife (ODFW) & Confederated Tribes of the Umatilla Indian Reservation (CTUIR)	BPA	Umatilla
Umatilla Fall Chinook [2]	ODFW & CTUIR	BPA and Corps	Umatilla
Umatilla Coho Chinook [3]	ODFW & CTUIR	BPA	Umatilla
Umatilla Summer Steelhead	ODFW & CTUIR	BPA	Umatilla
1/ Corps funds release of John Day mitigation fish (fall Chinook salmon) in the Yakima subbasin. 2/ Sub-yearling program funded by BPA, and Yearling program funded by the Corps 3/ BPA funds the operation of the CTUIR acclimation releases in the Umatilla subbasin; and Mitchell Act Funding covers the Bonneville and Cascade Hatcheries operations of the program.			

Table 14. FCRPS-Funded Hatchery Programs in the Snake River Region

Program	Operator	Lead Action Agency	Basin
Lyons Ferry Summer Steelhead	WDFW	BPA (LSRCP)	Lower Snake
Snake River Stock Fall Chinook (Lyons Ferry Hatchery) [1]	WDFW	BPA (LSRCP)	Lower Snake
Tucannon Summer Steelhead Endemic	WDFW	BPA (LSRCP)	Tucannon
Tucannon Summer Steelhead (Lyons Ferry)	WDFW	BPA (LSRCP)	Tucannon
NF Clearwater Summer Steelhead (B-Run-Clearwater Hatchery)	IDFG	BPA (LSRCP)	Clearwater
NF Clearwater Summer Steelhead (B-Run-Dworshak NFH)	USFWS	Corps	Clearwater
Clearwater River Basin Spring Chinook (Clearwater Hatchery)	IDFG	BPA (LSRCP)	Clearwater
S.F. Clearwater B-Run Steelhead (Clearwater Hatchery)	IDFG	BPA (LSRCP)	Clearwater

Program	Operator	Lead Action Agency	Basin
Clearwater Spring Chinook (NPTH-Hatchery)	Nez Perce Tribe (NPT)	BPA	Clearwater
Clearwater Fall Chinook (NPTH-Hatchery)	NPT	BPA	Clearwater
Cottonwood Creek Summer Steelhead (Wallowa Stock)	WDFW	BPA (LSRCP)	Grande Ronde
Grande Ronde Basin Summer Steelhead (Wallowa Hatchery)	ODFW	BPA (LSRCP)	Grande Ronde
Grande Ronde Endemic Spring Chinook Salmon Supplementation (Upper Grande Ronde River Spring/Summer Chinook Salmon Stock)	ODFW & CTUIR	BPA (LSRCP)	Grande Ronde
Grande Ronde Basin Catherine Creek Spring/Summer Chinook	ODFW & CTUIR	BPA (LSRCP)	Grande Ronde
Lostine Spring Chinook	ODFW, NPT & CTUIR	BPA (LSRCP)	Grande Ronde
Lookingglass Creek Spring Chinook	ODFW	BPA (LSRCP)	Grande Ronde
Little Sheep Creek Summer Steelhead	ODFW	BPA (LSRCP)	Imnaha
Imnaha Spring/Summer Chinook	ODFW	BPA (LSRCP)	Imnaha
Upper Salmon River B-Run Steelhead (Sawtooth- Magic Valley)	IDFG	BPA (LSRCP)	Salmon
Upper Salmon Spring Chinook (Sawtooth Hatchery)	IDFG	BPA (LSRCP)	Salmon
South Salmon Summer Chinook (McCall Fish Hatchery)	IDFG	BPA (LSRCP)	Salmon
Johnson Creek Summer Chinook (South Fork Salmon)	IDFG & NPT	BPA (LSRCP)	Salmon
Yankee Fork Summer Steelhead Streamside Incubation Supplementation	IDFG & Shoshone-Bannock Tribes SBT	BPA	Salmon
Yankee Fork Summer Steelhead Supplementation	IDFG & SBT	BPA	Salmon
Yankee Fork Chinook Supplementation	IDFG & SBT	BPA	Salmon
SF Salmon-Dollar Creek Summer Chinook (McCall FH-Eggbox)	IDFG & SBT	BPA	Salmon
E. Fork Salmon River Natural integrated Steelhead (Sawtooth)	IDFG	BPA (LSRCP)	Salmon
Little Salmon River A&B Run Steelhead (Niagara/Magic Valley)	IDFG	BPA (LSRCP)	Salmon
Pahsimeroi A-Run Steelhead (Niagara Springs)	IDFG	BPA (LSRCP)	Salmon
Upper Salmon River A-Run Steelhead (Sawtooth/ Magic Valley/Hagerman	IDFG	BPA (LSRCP)	Salmon

Program	Operator	Lead Action Agency	Basin
National)			
Rapid River Fish Hatchery Chinook (Rapid River and Little Salmon)	IDFG	BPA (LSRCP)	Salmon
Snake River Sockeye (Eagle Fish Hatchery)	IDFG	BPA (LSRCP)	Salmon

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.

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

The reprogramming of the John Day Mitigation Program has been the topic of ongoing coordination and negotiation for a number of years. The current effort, initiated in 2006, is to coordinate a regionally acceptable, detailed plan to accomplish the construction and operational modifications to the program to address a long-held objective to better provide for an in-place, in-kind mitigation concept.

In 2010, the Corps continued ongoing negotiations with *U.S. v. Oregon* parties to resolve key issues necessary to proceed with the evaluations and planning for the specific actions to achieve this objective and address the ESA issues associated with the current and potential future mitigation program. Funds were budgeted in 2010 to begin a study in FY 2011 to evaluate alternatives for improving the John Day Mitigation Program, including methods to reduce effects of Upriver Bright Chinook raised and released at Bonneville Hatchery, on lower Columbia River ESA-listed Chinook.

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

This action will be funded by BPA and implemented by the Lower Snake River Compensation Plan program office and WDFW, the LSRCP hatchery program operator for the Tucannon River steelhead supplementation program. For Tucannon steelhead, WDFW developed a revised HGMP to transition to local broodstock and submitted a summary of the proposed changes to the *U.S. v. Oregon* Production Advisory Committee for review. The proposal temporarily increases the current Tucannon River endemic stock summer steelhead smolt production from 50,000 to 75,000 fish annually.

As the program expands toward a production goal of 150,000 in the future, following needed facility modifications at the Lyons Ferry and Tucannon fish hatcheries, up to two-thirds of the annual production would be marked for harvest mitigation as part of the LSRCP mitigation program. The remaining one-third of the program would be used for supplementation in the Tucannon River. Production facilities, brood source, size and life history at release, and time of release would all remain the same as the current program.

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

This action will be funded and implemented by the LSRCP program office and WDFW. For Touchet steelhead, WDFW submitted a HGMP to NOAA Fisheries in June 2009 to align with NOAA Fisheries' request to consult on mid-Columbia stocks. The new HGMP is consistent with the current management plan and the *U.S. v. Oregon* agreement. At this time, the program remains the same (50,000 smolts annually) and continues to be evaluated. WDFW is in the process of conducting statewide review of steelhead hatchery programs and expects that a review of the Touchet program will be completed by the end of 2011. After that review, WDFW and co-managers will recommend the appropriate actions that should be taken for Touchet River steelhead.

- *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, that the measures are biologically and economically feasible and effective. Implementation of reforms will be prioritized and sequenced.*

The Winthrop NFH continued the program to evaluate longer-term (two-year) rearing of juvenile steelhead as part of a program to transition to a locally adapted steelhead broodstock in the Methow River. The program will continue for several more years and was expanded from 25,000 juvenile steelhead in 2008, to 40,000 in 2009, and to 50,000 in 2010. The release goal of 100,000 fish annually is still being met during the transition to locally adapted stock. Study plans were established with NOAA Fisheries to evaluate the survival benefits of the locally adapted broodstock.

Discussions regarding where and how to manage returning adult steelhead on the Methow River spawning grounds continued in 2010. Foghorn Dam is a likely place to intercept adult steelhead but is not a complete barrier to fish passage. A weir or other type of structure is being considered as a means to guide upstream migrating fish for collection and sorting. All hatchery-produced fish collected during hatchery activities in 2010 were removed from the system to reduce the proportion of hatchery-origin fish on the spawning grounds as much as possible.

Considerable progress was made in 2010 on hatchery upgrades. A project to remove and replace outdated structures and install new holding and rearing ponds for sorting and spawning adult fish was considered by the technical evaluation team and bids were solicited in 2010. An additional recommendation was for Winthrop NFH to reduce spring Chinook salmon production, thereby increasing steelhead capability. The hatchery transferred 160,000 spring Chinook salmon to the CTCR in 2010. Additionally, approximately 20,000 surplus spring Chinook salmon were donated to the Yakima, Colville, and Spokane tribes to further increase steelhead capacity.

Hatchery Strategy 2 (RPA Actions 41–42)

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 number 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. The progeny are raised in carefully managed hatcheries and released into their natural habitats using multiple release strategies, including smolt, fry, and parr releases; eyed-egg incubation boxes; and adult releases for volitional spawning. The Stanley Basin Technical Oversight Committee continues to provide guidance on the program. Since 1999, 3,193 adults from the program have returned to Redfish Lake in Idaho. In 2010, 1,355 adult sockeye salmon returned to Redfish Lake or the Sawtooth Hatchery weir on the upper Salmon River. This is the largest recorded annual return since 1956.

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.*

   In 2010, BPA project number 2000-019-00 (Tucannon River Spring Chinook Captive Brood), a one-generation safety-net program, was completed as planned. BPA continues to fund a supplementation hatchery program for Tucannon River spring/summer Chinook salmon through the LSRCP Direct Funding Agreement.

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 number 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 not been met for the upper Grande Ronde stock; this safety-net work continues to be funded under this project.

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 this safety-net program through BPA project number 1996-043-00 (Johnson Creek Artificial Propagation Enhancement project).

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).*

   BPA continued to fund this experimental captive rearing program through BPA project number 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.*

   It is not feasible to implement this action at this time because of a lack of adequate B-run steelhead population viability data. Once sufficient data are available (as determined by NOAA Fisheries) through the enhanced Snake River B-run steelhead population productivity and abundance monitoring called for in RPA Action 50.5, we will begin to work with NOAA Fisheries to develop the type of "trigger" described above. We estimate it may be several years before adequate data are available from the enhanced monitoring effort.

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.*

   When constructed and fully operational, BPA project number 2003-023-00 (Chief Joseph Hatchery) is expected to serve as the artificial production facility needed for this reintroduction program. This production will initially be contingent on the availability of within-ESU spring Chinook broodstock from the Methow River basin. Following final approval from the NPCC, major construction work began in February 2010. The hatchery is expected to be completed in late 2012.

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.*

In 2010, BPA began funding the Yakama Tribes to implement BPA project number 2008-458-00 (Upper Columbia Kelt Reconditioning project) that will develop a site plan and construct a steelhead kelt reconditioning facility.

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 implemented by the CTCR through BPA project number 2007-212-00 (Local Okanogan Steelhead Broodstock).

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 number 2007-401-00 (Kelt Reconditioning/Reproductive Success).

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.*

BPA continued to fund operation and maintenance for this action through the LSRCP Direct Funding Agreement.

6. *For Snake River Spring/Summer Chinook Salmon: For the Lostine and Imnaha rivers, contingent on a NOAA 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.*

As of December 2010, a proposed action and HGMP had not been completed for this program. Because funding of the action is contingent on a NOAA Fisheries-approved HGMP, BPA did not fund construction of the Northeast Oregon Hatchery Lostine and Imnaha spring/summer Chinook propagation facilities in 2010. It is possible that NOAA Fisheries may approve a HGMP for this program during the RPA Action 39 ESA consultation process for the Snake River basin in 2011.

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.*

Throughout 2010, BPA coordinated with IDFG and the state of Idaho to identify and begin the acquisition process for property meeting the criteria for a facility that would allow propagation of up to 1 million sockeye salmon smolts. In July 2010, the Springfield Hatchery property near Pocatello, Idaho, was acquired to help meet this BiOp action. The construction and operation of the new hatchery will be funded under BPA project number 2007-402-00 (Snake River Sockeye Captive Broodstock).

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.*

In 2010, the Action Agencies, together with state and federal fishery agencies, implemented a highly successful pilot project 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.

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.*

To create implementation efficiencies, in June 2010 the BPA project number 2001-053-00 (Reintroduction of Chum Salmon into Duncan Creek), was merged into BPA project number 2008-710-00 (Development of an Integrated Strategy for Chum Salmon Restoration in the Tributaries Below Bonneville Dam).

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.*

In 2010, BPA continued funding BPA project number 2008-710-00 (Development of an Integrated Strategy for Chum salmon Restoration in the Tributaries Below Bonneville Dam) to implement this action and the action to reintroduce chum salmon in Duncan Creek.

Predation Management Implementation Reports, RPA Action 43–49

Table 15. Predation Management RPA Action Reporting

RPA Action No.	Action	Annual Progress Report
Predation Management Strategy 1		
43	Northern Pikeminnow Management Program (NPMP)	Annual progress reports will describe actions taken, including: - Number of pikeminnow removals - Estimated reduction of juvenile salmon consumed - Average exploitation rate - Results of periodic program evaluations (including updates on age restructuring and compensatory responses)
44	Develop strategies to reduce non-indigenous fish	Beginning in 2010, annual progress reports will describe actions taken as a result of the workshop.
Predation Management Strategy 2		
45	Caspian Tern	Annual progress reports will describe actions taken toward the implementation of the Caspian Tern Management Plan.
46	Double-Crested Cormorant	Annual progress reports will describe actions taken if warranted.
47	Inland Avian Predation	Annual progress reports will describe actions taken if warranted.
48	Other Avian Deterrent Actions	Annual deterrent actions will not be reported.
Predation Management Strategy 3		
49	Marine Mammal Control Measures	Not applicable.

Predation Management Strategy 1 (RPA Actions 43–44)

RPA Action 43 – Northern Pikeminnow Management Program:

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 starting in 2004. To better evaluate the effects of the NPMP, BPA will increase the number of tagged fish. The Action Agencies will evaluate the effectiveness of focused removals of pikeminnow at The Dalles and John Day dams and implement as warranted. Additional scoping of other mainstem dams will be based upon evaluations and adaptive management principles with input from NOAA Fisheries, and other regional fisheries managers.

Since 1990, BPA has funded the Northern Pikeminnow Management Program (NPMP) to reduce the numbers of larger pikeminnow and improve survival of juvenile salmon. In 2004, after BPA increased the reward for the catch of this predator, the number of pikeminnow removed increased by 25 percent compared to prior years. The increased reward was made permanent in 2005 to sustain the higher catches. This resulted in the highest harvest rate of pikeminnow observed since the program began. The pikeminnow program has removed nearly 3.5 million northern pikeminnow from the Columbia River since 1990. Evaluation indicates that, as a result of the program, pikeminnow predation on juvenile salmon has declined 38 percent, saving 3 to 5 million juvenile salmon annually that would otherwise have been eaten by this predator.

The 2008 BiOp calls 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. In 2010, researchers continued to maintain higher tagging rates. This increase in tagging and resultant improvement in estimation is consistent with the 2008 BiOp and Independent Scientific Advisory Board (ISAB) recommendations in “The Northern Pikeminnow Management Program Justification, Performance, and Cost Effectiveness” (Hankin 2000) at *http://www.nwcouncil.org/library/2000/2000-16.pdf*.

Also in 2010, the exploitation rate on northern pikeminnow was 15.2 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 178,981 from the sport reward and dam angling fisheries. 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 2010 catch of 3,964 from the forebays and tailraces of The Dalles and John Day dams.

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.*

Actions resulting from a regional non-indigenous predation workshop in 2009 include projects implemented beginning in 2010 to address high–priority topic areas and critical uncertainties. Specifically, the Action Agencies implemented a project to document the food habits and physiological condition of smallmouth bass, pikeminnow, and walleye in three reservoirs of the Columbia River during the late summer and fall; and the influence of juvenile American shad on the health and well being of piscivores and their predation rates on juvenile salmonids during this time period. In late 2010, another project to scope the potential efficacy of localized removals of smallmouth bass for predation control was developed for contracting in 2011.

Predation Management Strategy 2 (RPA Action 45–48)

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 (RODs) adopting the Caspian Tern Management Plan. The National Marine Fisheries Service (NMFS) 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.

Implementation of the Caspian Tern Management Plan for the Columbia River Estuary continued in 2010 with construction of one new island prior to the nesting season. However, because 2010 was a dry year, three islands constructed late in 2009 were not available for use (i.e., were dewatered) during the 2010 nesting season (Table 16). As a result, tern nesting habitat on East Sand Island could only be reduced slightly, to 3.1 acres, for the 2010 nesting season.

With all islands available, the Corps expects to be able to reduce East Sand Island nesting habitat to two acres in subsequent years. Any additional acreage reduction at East Sand Island will not be possible until additional islands are constructed. Efforts are ongoing to develop nesting habitat in San Francisco Bay and in the Malheur Wildlife Refuge in Oregon. The ROD provides for the Corps to continue building islands at a 2:1 ratio to reduce East Sand Island tern nesting habitat to one acre.

Table 16. Status of Artificial Caspian Tern Nesting Islands for the 2010 Breeding Season. Productivity measured as offspring per nest.

Location	***Size (acres)***	***Completion Date***	***Social Attraction***	***Watered***	***Breeding Attempts***	***Productivity***
Fern Ridge Reservoir (OR)	1	Feb 08	Yes	Yes	0	0
Crump Lake (OR)	1	Mar 08	No	Yes	71	0
East Link Unit, Summer Lake Wildlife Area (OR)	0.5	Dec 08	Yes	Yes	29	0.1
Dutchy Lake, Summer Lake Wildlife Area (OR)	0.5	Feb 09	Yes	Yes	0	0
Sump 1B, Tule Lake NWR (CA)	2	Aug 09	No	No	-	-
Gold Dike Unit, Summer Lake Wildlife Area (OR)	0.5	Sep 09	No	No	-	-
Orems Unit, Lower Klamath NWR (CA)	1	Sep 09	No	No	-	-
Sheepy Lake, Lower Klamath NWR, (CA)	0.8	Feb 10	Yes	Yes	258	0.65

RPA Action 46 – Double-Crested Cormorants: *The FCRPS Action Agencies will develop a cormorant management plan encompassing additional research, development of a conceptual management plan, and implementation of warranted actions in the estuary.*

In 2010, the Action Agencies continued to evaluate potential management techniques for reducing losses of juvenile salmonids due to double-crested cormorant predation in the Columbia River estuary. Two techniques were tested to discourage nesting on East Sand Island. The first technique, human disturbance, was used on a discrete portion of the breeding colony area. The second technique was the placement of pond liner on a portion of the known nesting area.

The human disturbance technique was tested as a potential method to discourage double-crested cormorant nesting. Prior to the initiation of any breeding, a visual barrier (a fence of black plastic fabric, approximately 1.5 meters tall) was erected to isolate a small section of the easternmost end of the cormorant colony. Disturbances ceased as soon as evidence of egg laying was observed.

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 2010, the Action Agencies and the USFWS continued development of an avian management plan for Corps-owned lands and associated shallow water habitat upriver of Bonneville Dam. Two workshops on potential research and management actions for both the nesting habitat and dam components were held in 2010. Development of the plan continued through regional collaboration with a decision on warranted actions to be made pending completion of a multi-year synthesis report covering 2004-2009 Research, Monitoring and Evaluation (RME) activities. A full draft of the Inland Avian Predation Management Plan for regional review is now planned for completion in the third quarter of 2012. The multi-year synthesis report was scheduled to be completed in early 2011, and a subsequent benefits analysis is due in September 2011 and will be made available upon completion at *http://www.birdresearchnw.org* (Title: Impacts of Avian Predation on Salmonid Smolts from the Columbia and Snake Rivers: 2004-2009 Synthesis Report).

RPA Action 48 – Other Avian Deterrent Actions:

The Corps will 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 FPP.

Other avian deterrent actions, such as longer-term hazing and wire arrays, were implemented in accordance with the FPP (*http://www.nwd-wc.usace.army.mil/tmt/documents/fpp/2010*) as called for in RPA Action 48.

Evaluations of the effectiveness of the new wire array in the John Day Dam tailrace in conjunction with the ongoing harassment program led to plans for modifications to the John Day and The Dalles tailwater arrays in 2010, with construction planned to be finished in early 2011. At John Day Dam, the new array and boat hazing in the tailrace resulted in a 76 percent reduction of smolt consumption by California gulls from 2009 to 2010 (Zorich et al. in prep).

Predation Management Strategy 3 (RPA Action 49)

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 2010, the Corps implemented and evaluated a variety of sea lion deterrents, from physical barriers to non-lethal harassment (Stansell et al. 2010). Sea lion exclusion devices (SLEDs) were installed at

Bonneville Dam's 12 primary fishway entrances to prevent sea lions from entering the fishways. SLEDs were installed by January 29, 2010, at all operating main fishway entrances. The Powerhouse 1 and "B" branch entrances were not installed until after January 29, 2010, as the fishway was out of service for maintenance until March 2010. The SLEDs feature 15.38-inch (39.05-centimeter) gaps that are designed to allow fish passage. The SLEDs were removed in June 2010. Floating orifice gates (FOGs) were also equipped with SLED-like barriers. Acoustic deterrent devices, which emit a 205-decibel sound in the 15 kHz range, were installed at fishway entrances in January 2010, and removed in May 2010.

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. Dam-based harassment by USDA agents began in March 2010 and was conducted daily through the end of May 2010. Harassment involved a combination of acoustic, visual, and tactile non-lethal deterrents, including above-water pyrotechnics (cracker shells, screamer shells, or rockets), rubber bullets, rubber buckshot, and beanbags.

In part supported by BPA, CRITFC conducted boat-based harassment along with ODFW and WDFW from December 2009 through May 2010. Boats operated from the Bonneville Dam tailrace (RM 146) downstream to navigation marker 85 (RM 139). The Corps granted boats access to the Bonneville Dam Boat Restricted Zone (BRZ), but given concerns about human and fish safety, harassment was not allowed within 30 meters of dam structures or within 50 meters of fishway entrances. The use of "seal bomb" deterrents was prohibited within 100 meters of fishways, collection channels, or fish outfalls for the PH2 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 crews from ODFW, WDFW, and CRITFC on all sea lion harassment activities at Bonneville Dam to ensure safety and increase the effectiveness of harassment efforts.

RME Implementation Reports, RPA Actions 50–73

The following section provides information on the RME actions implemented by the Action Agencies in 2010. In many cases, Action Agency projects identify actions that were funded and initiated prior to the completion of the 2008 BiOp, or were initiated as part of a previous BiOp. This section of the report highlights examples of how projects contracted in 2010 fulfilled the RPAs, while Section 3 provides the full list of projects.

Table 17. RME Strategy Reporting

RPA Action No.	Action	Annual Progress Report
RME Strategy 1		
50	Fish Population Status Monitoring	Status of project implementation (including project milestones) through December of the previous year for all actions identified in Attachment B.2.6-1 or subsequent implementation plans.
51	Collaboration Regarding Fish Population Status Monitoring	Status of project implementation (including project milestones) through December of the previous year for all actions identified in implementation plans.
RME Strategy 2		

Table 17. RME Strategy Reporting

RPA Action No.	Action	Annual Progress Report
52	Monitor and Evaluate Fish Performance within the FCRPS	Status of project implementation (including project milestones) through December of the previous year for all actions identified in implementation plans.
53	Monitor and Evaluate Migration Characteristics and River Condition	Status of project implementation (including project milestones) through December of the previous year for all actions identified in implementation plans.
54	Monitor and Evaluate Effects of Configuration and Operation Actions	Status of project implementation (including project milestones) through December of the previous year for all actions identified in implementation plans.
55	Investigate Hydro Critical Uncertainties and Investigate New Technologies	Status of project implementation (including project milestones) through December of the previous year for all actions identified in implementation plans.
RME Strategy 3		
56	Monitor and Evaluate Tributary Habitat Conditions and Limiting Factors	Status of project implementation (including project milestones) through December of the previous year for all actions identified in implementation plans.
57	Evaluate the Effectiveness of Tributary Habitat Actions	Status of project implementation (including project milestones) through December of the previous year for all actions identified in implementation plans.
RME Strategy 4		
58	Monitor and Evaluate Fish Performance in the Estuary and Plume	Status of project implementation (including project milestones) through December of the previous year for all actions identified in implementation plans.
59	Monitor and Evaluate Migration Characteristics and Estuary/Ocean Conditions	• Status of project implementation (including project milestones) through December of the previous year for all actions identified in implementation plans. • Tabulate the amount of absolute acreage by habitat type that is restored or protected every year. (Initiate in FY 2007-2009 projects.) • Report annually on indices of productivity for the estuary and ocean (i.e., Pacific Decadal Oscillation, primary productivity indices).
60	Monitor and Evaluate Habitat Actions in the Estuary	Status of project implementation (including project milestones) through December of the previous year for all actions identified in implementation plans.
61	Investigate Estuary/Ocean Critical Uncertainties	Status of project implementation (including project milestones) through December of the previous year for all actions identified in implementation plans.
RME Strategy 5		
62	Fund Selected Harvest Investigations	Status of project implementation (including project milestones) through December of the previous year for all actions identified in implementation plans.
RME Strategy 6		

Table 17. RME Strategy Reporting

RPA Action No.	Action	Annual Progress Report
63	Monitor Hatchery Effectiveness	Status of project implementation (including project milestones) through December of the previous year for all actions identified in implementation plans.
64	Investigate Hatchery Critical Uncertainties	Status of project implementation (including project milestones) through December of previous year for all actions identified in implementation plans.
65	Investigate Hatchery Critical Uncertainties	Status of project implementation (including project milestones) and analysis of new information through December of the previous year.
RME Strategy 7		
66	Monitor and Evaluate the Caspian Tern Population in the Columbia River Estuary	Status of project implementation (including project milestones) through December of the previous year for all actions (habitat actions are population response) identified in implementation plans.
67	Monitor and Evaluate the Double-Crested Cormorant Population in the Columbia River Estuary	Status of project implementation (including project milestones) through December of the previous year for all actions (habitat actions are population response) identified in implementation plans.
68	Monitor and Evaluate Inland Avian Predators	Status of project implementation (including project milestones) through December of the previous year for all actions (habitat actions are population response) identified in implementation plans.
69	Monitoring Related to Marine Mammal Predation	Status of project implementation (including project milestones) through December of the previous year for all actions (habitat actions are population response) identified in implementation plans.
70	Monitoring Related to Piscivorous (Fish) Predation	Status of project implementation (including project milestones) through December of the previous year for all actions identified in implementation plans.
RME Strategy 8		
71	Coordination	Status of coordination of RME projects through December of the previous year will be provided.
72	Data Management	Status of data management projects through December of the previous year will be provided.
RME Strategy 9		
73	Implementation and Compliance Monitoring	The Action Agencies will use the project-level detail contained in the Action Agencies' BA 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.

RME Strategy 1 (RPA Actions 50–51)

A comprehensive list of all actions implemented by the Action Agencies for RPAs 50 and 51 is included in Section 3.

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)*

   In 2010, the Action Agencies RME workgroup evaluated and determined that only one BPA project supports the maintenance and management of the Columbia Basin PIT-Tag Information System (PTAGIS). BPA project number 1990-080-00 (Columbia Basin Pit-Tag Information) supported research that calls for the selection or diversion of specific PIT-tagged fish at any of the mainstem juvenile or adult fish facilities. PTAGIS provided additional coordination, set-up, operations, and maintenance over a dozen new PIT-tag array systems installed in 2010 for the NPCC FWP and AFEP projects throughout the fish migration season. The existing database will be revised to support PIT-tag forecasting management as well as management of additional information on operations of PIT-tag arrays across the region.

   New PIT-tag detection technology expanded the ways in which fish populations are monitored, but it also brought new challenges in how to manage and use the data collected. The emphasis on tributary instream PIT-tag arrays funded by the BPA and associated collaborating agencies led to PTAGIS and Pacific States Marine Fisheries Commission (PSMFC) recognizing the need to provide a formal process to identify the needs in the Columbia River basin and provide data management support systems to ensure consistent data collection and data access. Figure 9 shows a snapshot of the 2010 PIT-tag array network whose data are submitted to PTAGIS.

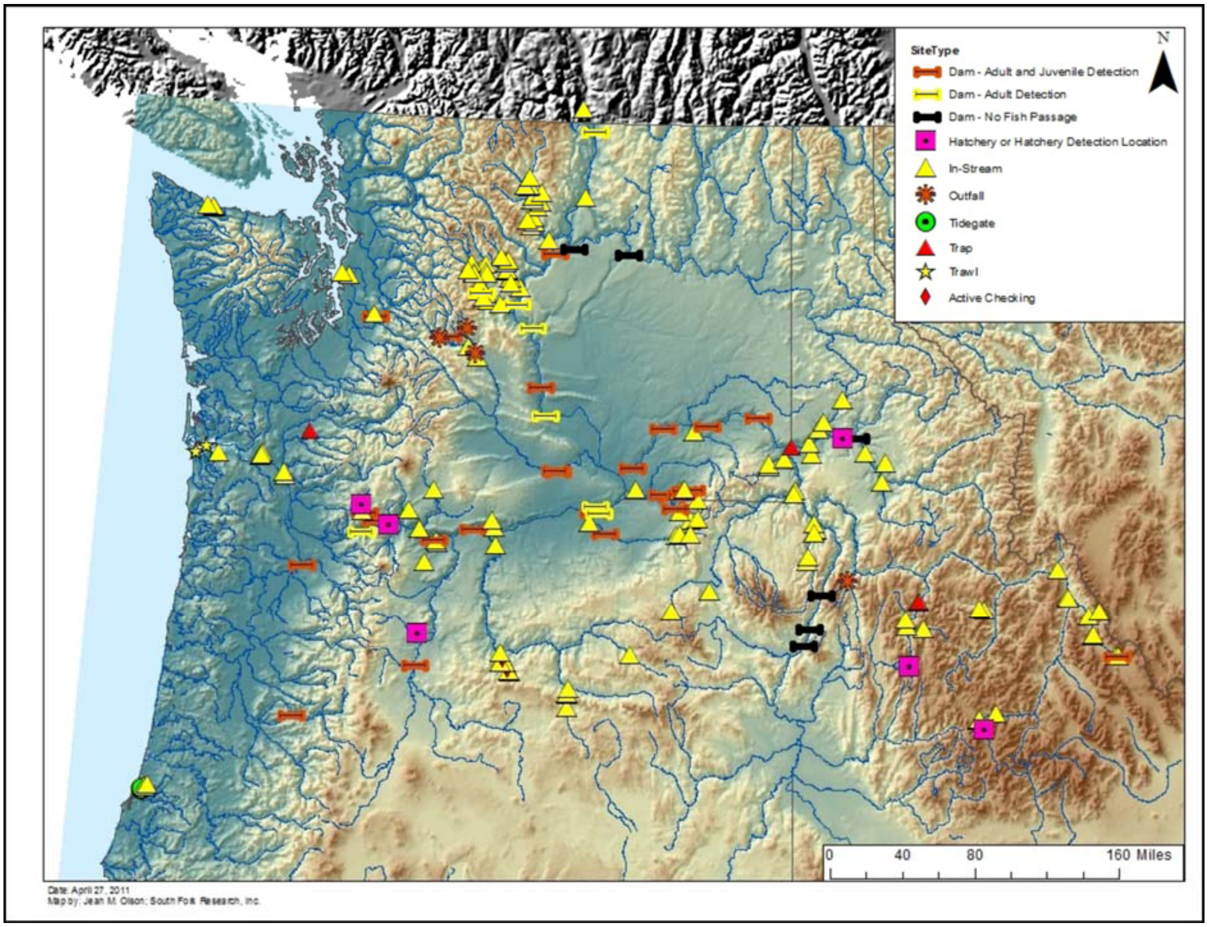


Figure 9. Pacific Northwest PIT-tag arrays managed by PTAGIS. (BPA 2011)

2. *Monitor adult returns at mainstem hydroelectric dams using both visual counts and the PIT-tag detection system (see Hydrosystem section). (Annually)*

In 2010, the Corps again implemented its adult fish count program as described in the FPP. Results are available in the 2010 Annual Fish Passage Report: Columbia and Snake Rivers (ACOE Annual Fish Passage Report) at *http://www.nwp.usace.army.mil/environment/FishData/docs/2010afpr.pdf*.

BPA continued implementation of three projects in 2010 to support of this RPA subaction. For example, BPA project number 2001-003-00 (Lower Granite Dam Adult Trap Operations) continued in 2010 for daily operation of the Lower Granite Dam adult trap to sample steelhead, spring/summer Chinook, and PIT-tagged fall Chinook (scales and length measurement) for run-reconstruction and transportation and life history studies. Fish with coded-wire-tags or PIT-tags (if targeted) were diverted into the adult trap holding area for collection of timed samples (a percentage of all passing adults) for run reconstructions. Operation information was included in the adult trap annual report provided to the BPA. This RPA is well covered through the Corps' adult fish count program and the BPA projects. Additional PIT-tagging by multiple BPA projects also improved sample size and population specific return data at the mainstem dams.

3. *Monitor juvenile fish migrations at mainstem hydroelectric dams using smolt monitoring and the PIT-tag detection system (see Hydrosystem section). (Annually)*

BPA continued implementation of seven smolt monitoring projects and supported expansion of two additional projects in 2010 to address the needs of this RPA subaction. For example, BPA project number 1994-033-00 (Smolt Monitoring by Non-Federal Entities) collected species, condition, and external mark detail from all sampled fish; condition and length data from a subsample of the smolts; and all incidental species caught in the samples. This RPA will be expanded and fully addressed in 2010 with additional PIT-tagging of juvenile fish guided by a tagging plan. Additional PIT-tagging of juveniles by multiple BPA projects also improved sample size and population specific return data at the mainstem dams.

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).*

In 2010, seven BPA projects continued to be implemented, and one BPA project was initiated to support ongoing pilot studies. Four BPA projects previously identified to support this RPA were determined not to support this RPA in 2010. Results for most BPA projects are reported in their Annual Progress Reports or technical reports in the BPA project tracking system, PISCES. For example, for BPA project number 1998-016-00 (Escapement and Productivity of Spring Chinook and Steelhead) ODFW sampled 50 random, spatially-balanced sites throughout the John Day River basin during the spring and early summer (March 2–July 7) of 2010 to determine summer steelhead redd abundance. ODFW estimated that of the 11,027 steelhead on the spawning grounds in 2010, 882 were of hatchery origin and 10,145 were wild. The 2010 estimate is the highest since ODFW implemented the Environmental Monitoring & Assessment Program (EMAP) sampling protocol in 2004. On the other hand, their coefficient of variation (CV) values challenge the "Guidance for Monitoring Recovery of Pacific Northwest Salmon & Steelhead listed under the Federal Endangered Species Act" that NOAA Fisheries issued (Crawford and Rumsey 2009). Since 2004, ODFW has provided escapement estimates for steelhead spawners that have had CVs in excess of 200 percent. NOAA Fisheries suggests that recovery monitoring should strive for a CV of 15 percent when describing adult spawner populations that are listed under the ESA in their Guidance for Monitoring Recovery of Salmon and Steelhead report (Crawford and Rumsey 2009). In 2010, ODFW sampled approximately 2 percent of the available habitat in the basin-wide sample and about 10 percent of the available habitat in the South Fork sub sample. Even with the increased sampling intensity, CVs for escapement estimates in the South Fork John Day River have averaged near 200 percent. Results indicate that a large amount of additional sampling would be needed to achieve recommended variance and that the 15 percent CV goal is not attainable using 26 spawning ground surveys.

For BPA project number 1997-030-00 (Chinook Salmon Adult Abundance Monitoring), natural origin adult salmon spawner abundance for the Secesh River system was 1,191 fish, exceeding the Technical Recovery Team (TRT) minimum viability threshold. Natural origin spawner abundance for 2010 was comparable to that observed in 2009 (1,126 fish). A resistance board weir was constructed to install for natural origin adult steelhead escapement monitoring in Joseph Creek in 2011. BPA project number 1998-010-04 (Monitoring & Evaluation [M&E] Performance of Juvenile Snake River Fall Chinook Salmon from Fall Chinook Acclimation Project) documented the highest return of adult fall Chinook salmon to the Snake River basin since construction of the lower Snake River dams. Preliminary escapement upstream of Lower Granite Dam was estimated at 11,176 natural origin and 44,659 hatchery origin fish. This project contributed to documenting the highest number of redds in the Snake River basin since the inception of surveys; 132 and 263 redds were observed in the Imnaha and Grande Ronde rivers, respectively.

BPA project number 2003-017-00 (Integrated Status and Effectiveness Program) documented tributary adult salmon and steelhead escapement estimates in the Snake River basin. Spring/summer Chinook salmon population levels were monitored using redd surveys to index population size and a subset of tributary streams that have weirs that estimate spawner escapement; however, the majority of populations have little quantitative data available.

Steelhead population estimations are historically extremely problematic and very little information is available on distribution and population sizes in the Snake River because of extreme stream conditions during the upstream migration rendering redd surveys impossible. Recent advances in instream PIT-tag arrays construction and analytical techniques have allowed scientists to place arrays in streams to estimate the number of upstream migrating fish. Utilizing existing trapping facilities at Lower Granite Dam, Integrated Status and Trend Monitoring program (ISEMP) tags adult spring/summer Chinook salmon and steelhead and collects biological information (age, sex, genetics, etc.) for the purpose of decomposing the run-at-large into population and/or tributary specific escapement estimates. Once tagged and released there is no need to handle the fish again and they can proceed uninterrupted upstream to the spawning tributaries. Data obtained from the first steelhead from 2009-2010 and spring/summer Chinook salmon from 2010 tagging operations has provided the first escapement estimates in many tributaries, including several Intensively Monitored Watersheds (IMW) and ISEMP watersheds and other BPA Fish and Wildlife Program funded projects. ISEMP scientists have developed several models to determine the best method to estimate the number of upstream migrating fish tagged at Lower Granite Dam passing tributary arrays while accounting for sampling biases and time varying migration behaviors exhibited by the different populations. Using PIT-tag arrays to de-compose the Snake River basin run into tributaries/populations was extremely successful and, in conjunction with independent estimates where available, the resulting escapement data were very accurate, as displayed in Figure 10 and Table 18.

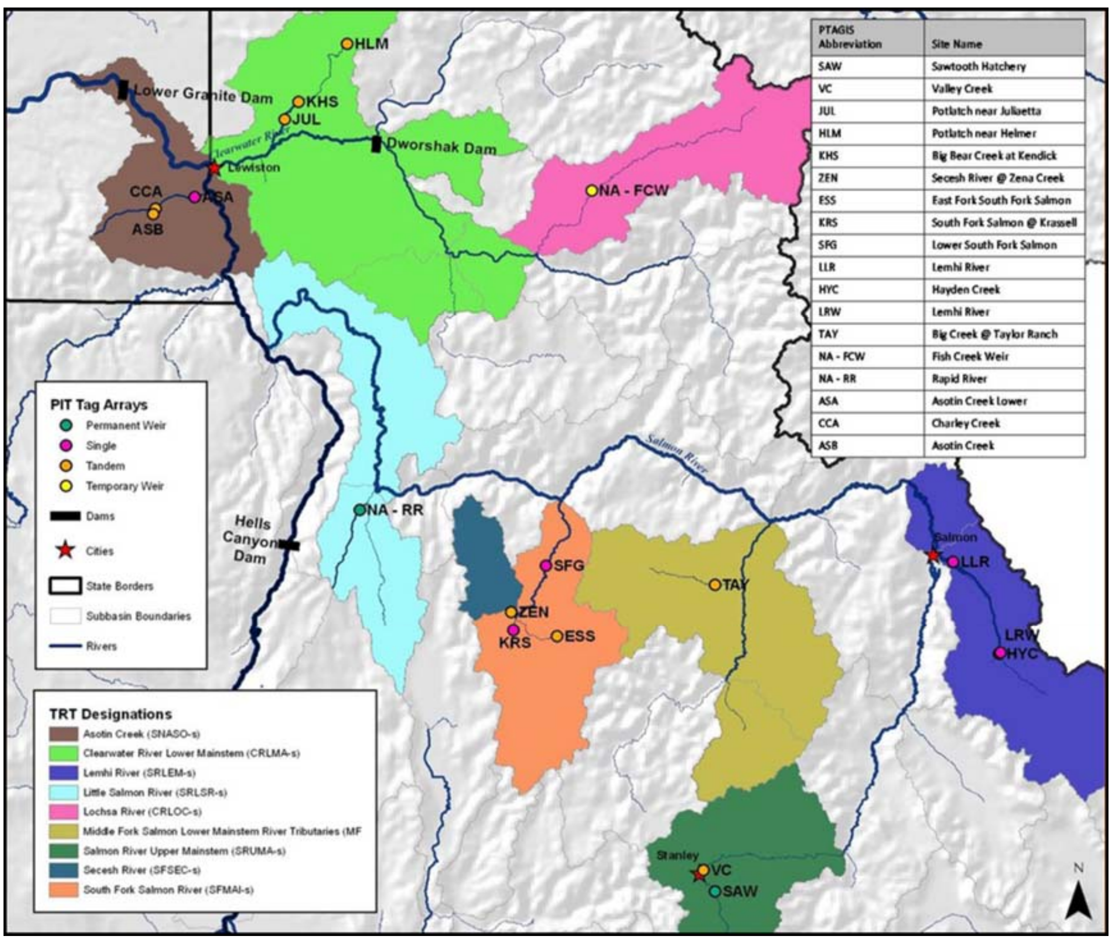


Figure 10. New PIT-tag arrays for the ISEMP steelhead populations in the South Fork Salmon, and Lemhi rivers. (BPA 2011)

Table 18. Snake River basin adult steelhead tributary escapement estimates for run-year 2009-2010 (95 percent confidence intervals in parenthesis). The three different models model different tagging conditions and population behaviors assumed to be important for decomposing the run upstream of Lower Granite Dam. (BPA 2011)

Tributary	Time-varying Model	Time-invariant Model	Basic Model	Independent Estimate
Asotin Creek	1687 (1407-1963)	1576 (1332-1842)	1415 (1296-1536)	~1400
Potlatch River	784 (621-992)	778 (602-993)		
Rapid River	136 (72-235)	132 (74-224)	134 (125-143)	~150
Fish Creek	246 (129-434)	246 (116-432)	235 (176-294)	~205
South Fork (SFK) Salmon	1795 (1527-2081)	1867 (1574-2140)	1870 (1778-1962)	
Secesh River	298 (169 – 558)		234 (198-270)	
E. Fk. SFK Salmon			545 (519-572)	
Big Creek	753 (431-1914)	996 (496-3466)	1174 (81-2267)	
Lemhi River	630 (455-928)	610(444-859)	574 (502-645)	
Valley Creek	237 (155-411)	249 (162-412)	239(194-285)	
Sawtooth (Upper Salmon)	138(76-226)	147 (84-234)	133 (122-144)	

Table 19. Snake River basin adult Chinook tributary escapement estimates for run-year 2009-2010 (95 percent confidence intervals in parenthesis). (BPA 2011)

Tributary	Basic Model	Independent Estimate
Lower South Fork Salmon	7,005 (6655-7355)	
Secesh River	1,308 (1165-1451)	~1,077
E. Fk. SFK Salmon	1,026 (1015-1038)	~1,032
Upper South Fork Salmon	3,450 (2731-4169)	
Lower Lemhi River	262 (243-281)	
Big Creek	285 (160-411)	
Valley Creek	235 (191-281)	

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)*

Ten projects were continued and three were initiated in 2010 to assess B-run steelhead abundance and productivity. For example, BPA project number 2005-002-00 (Lower Granite Dam Adult Trap Operations) PIT-tagged steelhead and acquired genetic samples that were used to assess population information. As a result of that project, ISEMP's PIT-tag analysis results posted in RPA 50.4 provided the first population return assessments for many B-run steelhead populations. In combination with the PIT-tag data BPA project number 2010-026-00 (Chinook and Steelhead Genotyping for Genetic Stock Identification [GSI] at Lower Granite Dam) and BPA project number 2010-031-00 (Snake River Chinook and Steelhead Parental Based Tagging) supported analysis of genetic samples of adult returners passing Lower Granite Dam to help support B-run steelhead pedigree analysis to support the 2010 population assessments as well as provide a baseline for the potential future assessments with genetics data.

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. (Initiate in FY 2008, develop proposed modification in FY 2009, and implement modifications in FY 2010)*

Forty-eight BPA projects were implemented that supported fish population status monitoring based on strategies developed through the Anadromous Salmonid Monitoring Strategy (ASMS) in 2010. As a revision of the ASMS strategy and identification of priority populations several project relationships ended because they did not directly support population assessments for the refined one-population-per-MPG strategy. Regional fish population status monitoring standards and protocol documentation tools were advanced through BPA project number 2004-002-00 (Pacific Northwest Aquatic Monitoring Partnership [PNAMP]) in 2010. This project facilitated further management of the Protocol Library resulting in the creation of the *www.monitoringmethods.org* web tool to track and support the documentation of protocols and designs and the standardization of methods and associated metrics and indicators, which was used in the RME Artificial Production Categorical Review. During this review over 120 unique methods to assess fish abundance for various life stages were identified. Throughout the review, standard approaches for data collection and analysis were adopted by many sponsors. Additional work will continue to refine standard methods for data collection and analysis for population abundance of juvenile out-migrants and adult spawners in the future through the Coordinated Assessments from the ASMS. Thirteen BPA project RPA associations were removed because, after further review, it was determined the projects did not support the RPA strategy as proposed in the Action Agencies RME RPA Recommendation Report; of which BPA project number 2007-377-00's scope of work was transferred to BPA project number 1992-026-04 (Grand Ronde Early Life History of Spring Chinook and Steelhead).

For the BPA status-trend project number 1991-028-00 (PIT-Tagging Wild Chinook) wild spring-summer Chinook parr have been tagged in 10-15 Idaho streams for over two decades. When the surviving smolts are detected at traps and dams, the resulting data have been used for both trend information on the stocks tagged, hydrosystem reach survival, and upstream survival from Bonneville Dam to Lower Granite. More recently, installation of flat plate detectors in Valley Creek and Big Creek have allowed researchers to estimate within subbasin survival rates, and have yielded information on temporal patterns in emigration from the subbasins of origin.

BPA project number 1997-030-00 (Chinook Salmon Adult Abundance Monitoring) involved collection of adult Chinook salmon escapement and productivity information for long-term monitoring of the natural origin (wild) salmon population in the Secesh River since 2004. This is the first project in the Columbia basin in which dual frequency identification sonar (DIDSON) was evaluated and then used to determine total adult escapement. DIDSON is a newer class of identification sonar that allows near video quality images for identification of objects underwater. Validation monitoring of DIDSON target counts with underwater optical cameras occurred for species identification. The 10-year geometric mean natural origin spawner abundance was 646 salmon (2000 through 2009). Escapement ranged from 223 to 1,139 adults from 2003-2009. Adults per redd estimates ranged from 1.7-3.7 9 (66 to 705 redds). Arrival timing of adults ranged from a minimum of July 2 (10 percent of adults) to maximum of August 28 (90 percent of adults) from 2004-2009.

BPA project number 1999-020-00 (Analyze Persistence and Dynamics in Chinook Redds) monitors wild Chinook salmon distribution, abundance, and trend by mapping the annual distribution of Chinook salmon redds across the entire Middle Fork Salmon River basin, and it assesses spatial and temporal patterns in extinction and colonization dynamics of wild Chinook salmon. Redds were counted by foot and helicopter surveys during the first week of September from 1995 through 2009. Basin-wide total redd counts from 1995-2009 have averaged 691 redds (range 20 to 2,271). In low escapement years, redds have occurred sporadically through much of the used spawning reaches, while in years with larger escapements, spawning has been more widespread. During this time, the population grew at a rate of 5.3 recruits per spawner, and redds increased from 20 to 2,271. Connectivity between spawning areas was the strongest predictor of redd distribution, but connectivity interacted with habitat size. The results demonstrate that the size and connectivity of existing habitat networks should be maintained whenever possible.

In the Okanogan Basin Monitoring and Evaluation Program (OBMEP) (BPA project number 2003-022-00) the CTCR continued for their sixth consecutive year to monitor habitat and Viable Salmonid Population (VSP) conditions of upper Columbia River summer steelhead in the Okanogan River basin. Highlights included annual summer steelhead adult population estimates using a combination of traps, underwater video counting stations, and redd surveys. Reports document the percentage of wild summer steelhead returning to Omak Creek has increased from an average of less than 10 percent wild steelhead adults to over 80 percent wild returning adults. These results coincide with favorable and stable juvenile rearing conditions during the previous several years and habitat improvement actions implemented by the Tribes. Also, BPA project number 1998-007-02 (Grande Ronde Supplementation Operations and Maintenance (O&M) and M&E on Lostine River) documented the highest redd count in recent history was recorded for the Lostine River (696 redds). The newly constructed weir will go into operation in spring of 2010 and enable steelhead escapement monitoring into the Lostine River and provide representative broodstock collections and escapement monitoring of spring Chinook salmon.

New results from BPA project number 1997-015-01 (Imnaha River Smolt Monitoring Study), which evaluated the survival, biological characteristics, and migration performance of natural and hatchery spring/summer Chinook and steelhead from the Imnaha subbasin showed:

- Survival of PIT-tagged natural Chinook salmon from the Imnaha trap to Lower Granite ranged from 53 to 88 percent, and natural steelhead from 79 to 92 percent for migration years 1994 through 2008.
- Survival from the trap to McNary ranged from 53 to 79 percent and 18 to 72 percent respectively.
- An SAR rate index from Lower Granite back to Lower Granite for natural Chinook salmon ranged from 0.2 to 6 percent for migration years 1998 to 2005.
- The median date of arrival of natural Chinook smolts at Lower Granite was from May 5 through May 13 (May 18 for natural steelhead) in 2008.

All of the actions identified in the 2010-2013 FCRPS BiOp Implementation Plan were implemented as planned, with the exception: “Fund ODFW 2007-09 proposal 2007-33-700.” The activities to monitor fish as proposed in BPA project number 2007-33-700 (Fund ODFW 2007-09) were actually funded under BPA project number 1992-026-04 (Grand Ronde Early Life History of Spring Chinook and Steelhead).

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)*

Sixteen BPA projects were continued, and two were initiated in 2010 that supported the workgroup recommendation that 100 percent of all hatchery fish should be marked to meet VSP, hatchery, and habitat action effectiveness evaluation needs identified under several RPAs and regional recovery plans. Eight BPA project associations to the RPA were removed because the tagging of fish was determined not to be used to support marking hatchery origin fish.

In addition, BPA implemented a policy to support the Implementation Plan action “Where 100 percent of the hatchery fish cannot be marked with an adipose fin clip, alternative external or internal marks and marking rates will be used to assess VSP and habitat and hatchery effectiveness called for under the BiOp and Columbia Basin Recovery Plans."

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 information on population viability metrics for NOAA Fisheries to facilitate population viability assessments for future reports. In 2010, the Coordinated Assessments Project coordinated with fishery management co-managers and NOAA Fisheries to develop data exchange templates (DET) to facilitate assessments for adult spawners abundance and juvenile out-migrant abundance indicators.

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)*

Ten projects were continued to fully support annual synthesis of fish population data for reports. For example, BPA project number 2008-505-00 (StreamNet Library Project) supported participation in planning, development, and/or coordination meetings with regional projects and programs under the NPCC's FWP to help develop a regional data management framework to establish data type and data service priorities, and to provide advice in the area of data management.

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)*

Two BPA projects were continued to support ongoing collaboration to develop regional strategies. In collaboration with NOAA Fisheries, the Action Agencies, and the NPCC, a draft recommendation report was created. As part of the regional review and collaboration on this report, BPA project number 2008-733-00 (Regional Strategy-Status/Trend project) was funded to support a process to engage state and tribal fish managers through regional workshops to review existing status and trend monitoring and gaps in monitoring programs. This led to the development of the ASMS strategy in Skamania, Washington. The Action Agencies also supported the ongoing PNAMP coordination process through funding of BPA project number 2004-002-00 (PNAMP Coordination) and contracted staff support in the PNAMP steering committee and fish population workgroup.

As identified in the 2010-2013 FCRPS BiOp Implementation Plan

- The Action Agencies continued coordination of a Hydro Action Plan for marking and tagging.
- Generated Random Tessellated Sample (GRTS)-based, master-sample management tools were be used in development of population status and trend programs from BPA project number 2004-002-00 (PNAMP Coordination).
- The Action Agencies continued to work collaboratively with the region to further develop and implement BiOp critical work identified in the Columbia Basin Anadromous Fish Monitoring Strategy, and to advance data management and data sharing capabilities to ensure that status and trend data are readily accessible for needed BiOp assessments. See RPA 72 results for BPA project number 2008-727-00 (Regional Data Management Support and Coordination)

3. *Provide cost-shared funding support and staff participation in regional coordination forums such as the Pacific Northwest Aquatic Monitoring Partnership (PNAMP) 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)*

Five BPA projects were continued in 2010 to fully provide cost sharing for staff support in regional monitoring and evaluation coordination. For example, BPA project number 2004-002-00 (PNAMP Coordination) facilitated coordination at the program, subbasin, and regional level by providing personnel to serve as the lead staff, liaison, and point of contact for the PNAMP. This project supports coordination of PNAMP efforts to integrate resource monitoring programs of state, federal, tribal, local, and private organizations in the Pacific Northwest. This project also facilitates the transfer of information within PNAMP and across relevant organizations to establish and maintain strong relationships between science and management, and to promote and facilitate communication among organizations and disciplines. In 2010, BPA also provided contract support for facilitation of the Northwest Environmental Data (NED) Network forum to advance coordinated data management strategies. In addition to internal Action Agency staff support, technical experts were funded for participation in the PNAMP workgroup products. Action Agency staff supported the formation of the Northwest Information Sharing Executive Forum, which involved executives from multiple entities across the Pacific Northwest to advance the common goal of more efficient and robust monitoring and information sharing. BPA project number 2007-216-00 (PNAMP RME Design and Protocols) ended in 2009 with final publications in 2010.

RME Strategy 2 – Hydrosystem RME (RPA Actions 52–55)

A comprehensive list of all actions implemented by the Action Agencies for RPAs 52 through 55 is included in Section 3. All but two RPA subactions are met by projects that either currently or soon will be in place. RPA subactions 52.6 and 55.3 are expected to involve additional action.

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.*

The effects of configuration and operation changes were evaluated at John Day and Bonneville dams in 2010. At John Day Dam, an evaluation of 30 percent and 40 percent spill treatments was conducted. Other changes in configuration included relocating spillway weirs from bays 15 and 16 to bays 18 and 19, construction of an extended-length flow deflector in Bay 20, and completion of the avian predation deterrent array over the tailrace. At Bonneville Dam, a dam passage survival evaluation was conducted for spring migrants, and an evaluation of two spill treatments was conducted for summer migrants (24-h 95 kcfs and 85 kcfs daytime/TDG nighttime spill). The first year of juvenile salmon dam passage performance standard testing was conducted at The Dalles Dam. The experimental design and virtual/paired release survival model developed and reviewed in 2009 was utilized to estimate survival for spring and summer migrants passing The Dalles Dam during 40 percent spill operations.

No dam survival or passage efficiency telemetry studies were performed in 2010 at Lower Granite, Little Goose, Lower Monumental, Ice Harbor, or McNary dams.

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.*

Eight projects were continued that addressed this RPA subaction. Tagged smolts entering and migrating through the FCRPS (Lower Granite through Bonneville dams) were used in 2010 to estimate survival and have been produced annually since 1994. NOAA Fisheries conducts the analysis under BPA project number 1993-029-00 (Survival Estimate for Passage through Snake and Columbia River Dams and Reservoirs) using PIT-tagged fish under BPA project number 1987-127-00 (Smolt Monitoring Program) and BPA project number 1996-020-00 (Comparative Survival Study [CSS]). CSS concluded that as in-river survival has increased in recent years, transport in-river ratios have declined for both Chinook and steelhead, although both NOAA and the CSS report a benefit to steelhead from transportation under most conditions even though the benefit may be reduced from some previous years. The benefit to Chinook salmon from transportation appears to be more variable in both the magnitude and duration.

3. *Monitor and evaluate adult salmonid system survival upstream through the FCRPS.*

Three projects were continued to fulfill this subaction. For example, BPA project number 1990-080-00 (PTAGIS system) provides data on returning adults of known origin. In addition, NOAA Fisheries biologists conducted analyses and reported upstream passage survival for 2010.

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. In 2010, system survival estimates for both upper Columbia River ESUs were among the highest measured since 2002 and well above recent year estimates.

Long term system survival performance is evaluated for five stocks using a 5-year rolling average of annual system survival estimates. Snake River stocks are used as surrogates for Snake River sockeye and mid-Columbia steelhead. In 2010, Snake River fall Chinook and upper Columbia River steelhead surpassed the performance standard while the Snake River spring/summer Chinook salmon ESU, the Snake River steelhead DPS, and the upper Columbia River spring Chinook ESU were below adult performance standards (Figure 11). Several factors are being addressed that likely affect the attainment of adult performance standards: modifications to operations and structures at dams designed to increase juvenile survival that may increase fallback and delay of adults; effects related to sea lion predation; and additional levels of straying and harvest related mortality not addressed using current methodology. Each of these factors is being addressed through BiOp RME actions. The Action Agencies are investigating adding PIT-tag detection capabilities to adult passage facilities at The Dalles and John Day dams and adding PIT-tag interrogation capability in fisheries above Bonneville Dam to better understand and quantify unexplained losses within those reaches.

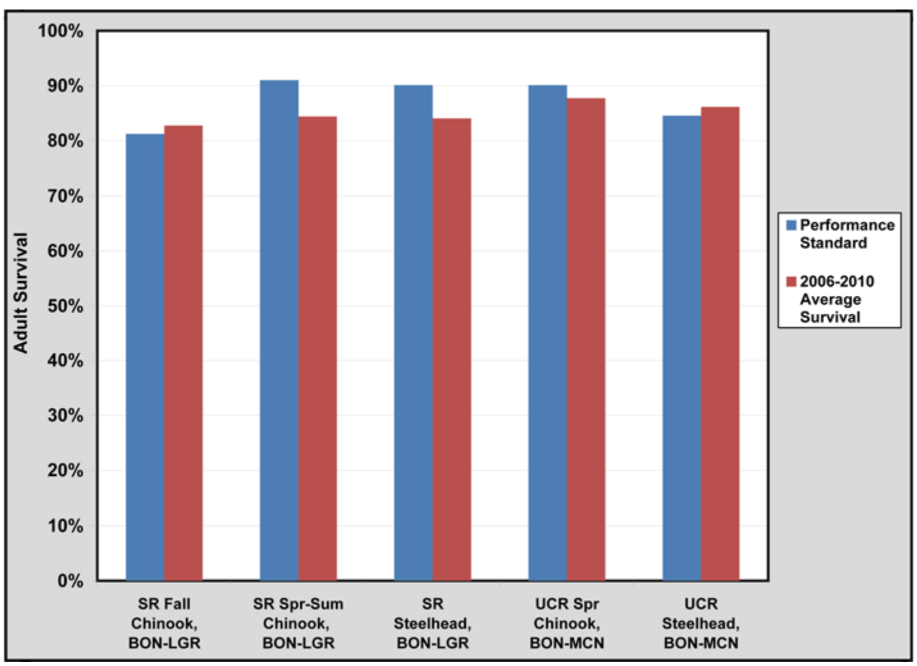


Figure 11. 2008 FCRPS BiOp Adult Survival Standard and Five-Year Rolling Average Survival of Adults that Migrated In-River as Juveniles, Based on PIT-Tag Conversion Rates of Snake River (SR) and Upper Columbia River (UCR) ESUs. (BON = Bonneville, MCN = McNary, LGR = Lower Granite)

Adult conversion rates from Bonneville to Lower Granite dams were sometimes lower for fish that had been transported compared to those that migrated in-river, although the effect on adult conversion rates is variable between species and across years.

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.*

Two projects were continued to fully address this effort in 2010: BPA project numbers 2008-724-00 (PIT-tag Sr Sockeye-Uc Sp.Chinook) and 1987-127-00 (Smolt Monitoring by Non-Federal Entities). Planning is ongoing for the extent of tagging and stock coverage required and will be specified in the tagging plan being developed under RPA Action 52.6. The extent of tagging and stock coverage has not yet been specified. These populations would be incorporated into the annual system smolt and adult survival monitoring. Efforts being undertaken by public utility districts may supplement the federal effort.

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.*

Two projects, BPA project numbers 2008-724-00 (PIT-tag Sr Sockeye-Uc Sp.Chinook) and 1987-127-00 (Smolt Monitoring by Non-Federal Entities), were continued to address this subaction. This work was initiated as a pilot study by the Corps in 2009 to assess long-term needs with respect to precision levels and sample sizes for future work.

Juvenile sockeye salmon from Idaho were PIT-tagged and used for an evaluation of the efficacy of a transportation study on sockeye salmon. A total of 63,845 sockeye were PIT-tagged and released in 2010; 51,876 were reared at Sawtooth hatchery and 11,969 were reared at Oxbow hatchery. Survival probability from release to Lower Granite Dam was 0.15 and 0.21 for the Sawtooth and Oxbow reared fish, respectively, which suggest that substantial mortality occurs upstream from the Snake and Clearwater River confluence prior to entering the FCRPS. Survival probability from Lower Granite to Bonneville was 0.51 and 0.67 for the Sawtooth and Oxbow reared fish, respectively. Overall, collection efficiency was 7.5 percent in 2010.

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)*

One BPA project was continued to support the baseline monitoring needs of this RPA. This RPA Action will be addressed in FY 2009 and FY 2010 through development of a regional PIT-tagging plan, including input from the Action Agencies, NOAA Fisheries, other federal agencies, state, and tribal agencies.

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 UCR steelhead and spring Chinook salmon compared to SR 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.*

Three BPA projects were continued to support this RPA. The feasibility of using a tributary PIT-tag antenna to detect adult salmon in the John Day River (see RPA Action 52) was evaluated. The PIT-tag antenna withstood spring freshet flows and has been detecting PIT-tagged adult fish. Effectiveness monitoring was initiated in 2010 to determine the detection efficiency of the system.

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, 2010. At Lower Granite, 24-hour counts were conducted from June 15 through September 30, 2010, rather than through August 31, 2010. All changes were fully coordinated during development of the FPP and through the FPOM workgroup process.

RPA Action 53 – Monitor and Evaluate Migration Characteristics and River Condition

1. *Monitor and estimate the abundance of smolts passing index dams.*

Three BPA projects were continued in 2010 to address this subaction. For example, BPA project number 1994-030-00 (FPC) calculated passage indices at all collector dams, as well as population estimates at Lower Granite Dam. One BPA feasibility project was unsuccessful in providing alternative methods for validating monitoring and was discontinued.

2. *Monitor and describe the migration timing of smolts at index dams, identify potential problems, and evaluate implemented solutions.*

Eleven BPA projects were continued in 2010 to fully address this subaction. For example, this was addressed through BPA project number 1987-127-00 (Smolt Monitoring by Non-Federal Entities). Data provided by this program were analyzed through BPA project number 1994-030-00 (FPC) and NOAA Fisheries, as well as a host of other regional fish management agencies. Additional evaluation of the Smolt Monitoring Program data is expected to determine the extent to which population-specific (PIT-tagged) data are needed to describe timing.

3. *Monitor and document the condition (e.g., descaling and injury) of smolts at all dams with juvenile bypass system (JBS) systems, identify potential problems, and evaluate implemented solutions.*

Eight projects were continued to fully address this subaction. As in RPA Action 53.2, the Smolt Monitoring Program monitored and documented fish condition in 2010. The FPC and other agencies provided analysis and implementation recommendations. The reduction in handling was the only potential problem identified that may be addressed in future operations.

4. *Monitor and enumerate adult salmonids passing through fishways in the FCRPS, identify potential problems, and evaluate implemented solutions.*

In 2010, the Corps again implemented its adult fish count program as detailed in the FPP. Results are available in the *2010 Annual Fish Passage Report: Columbia and Snake Rivers* (ACOE Annual Fish Passage Report) at *http://www.nwp.usace.army.mil/environment/FishData/docs/2010afpr.pdf.*

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*.

A post-construction evaluation of adult spring-summer Chinook salmon passage performance was conducted at the John Day North Fish Ladder following structural improvements to the count station and control section of the ladder in winter 2009-2010. Prior to these improvements, salmon and steelhead consistently demonstrated up-down, fallback, and jumping behaviors through the upper ladder sections. A radio-telemetry evaluation of tagged spring-summer Chinook salmon passage performance was supplemented through visual monitoring of passage behavior.

See also the discussion of adult passage improvements under RPA 28 above.

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.*

The Bonneville Corner Collector was opened for steelhead Kelt passage on March 14, 2010 (normal spill operations began on April 10, 2010), but was closed for four days in March 2010 due to maintenance issues. This provided 23 additional days of downstream passage for steelhead kelts. Discussions on future operation and evaluations are ongoing and will be addressed in the Kelt Management Plan (RPA 33).

RPA Action 54 – Monitor and Evaluate Effects of Configuration and Operation Actions

1. *Monitor and evaluate the effects of existing spillways, modifications, and operations on smolt survival.*

   Based on results of 2008 and 2009 studies, surface passage weirs at John Day Dam were relocated closer to the powerhouse, and an evaluation of this modification at both 30 percent and 40 percent spill was conducted. At The Dalles Dam an assessment of the new spill wall was conducted for both spring and summer migrants. At Bonneville Dam an assessment of 24-hour 95 kcfs spill vs. 85 kcfs daytime/121 nighttime spill was conducted for summer migrants. In addition, an evaluation of the BGS at the PH2 for both spring and summer migrants was conducted.

   Single-release survival estimates in 2010 from John Day Dam to The Dalles Dam indicated survival improvements compared to 2008 and 2009.

   No significant differences were found at John Day Dam during a preseason evaluation of direct injury rates or 48-hour survival rates between new extended-length deflectors and a standard deflector.

   Data processing and analysis for sockeye released at Mid-Columbia public utility district dams and detected passing McNary Dam was completed in 2010, complementing the Chinook and steelhead data previously reported.

   See the entries for RPA Actions 18 through 25 for specific studies and results.

2. *Monitor and evaluate the effectiveness of traditional juvenile bypass systems and modifications to such, on smolt survival and condition.*

   Orifice lighting evaluations were carried out at McNary Dam in 2010, as was a study to determine if gatewell descaling was increased by higher turbine discharges that are hypothesized to provide a safer passage environment for fish passing through the turbine. See the entries for RPA Actions 18 through 24 for specific studies and results.

   A study to evaluate the effects of bypass on adult return rates of Snake River basin hatchery fish was funded by the Corps in 2010 and an associated regional workshop was held in September 2010. While there was a general correlation between increased bypass events and reduced adult return rates, the mechanism of reduced adult return rates remains poorly understood. It is unclear whether the bypass systems themselves result in reduced SARs or if there is selectivity in the bypass systems.

3. *Monitor and evaluate the effectiveness of surface bypass structures and modifications on smolt survival and condition.*

   Surface passage weirs at John Day Dam, the ice and trash sluiceway at The Dalles Dam, and a BGS for the Corner Collector at Bonneville PH2 were evaluated.

   See the entries for RPA Actions 18 through 24 for specific studies and results.

4. *Monitor and evaluate the effectiveness of turbine operations and modifications on smolt survival and condition.*

   The Corps estimated route-specific passage and survival rates at John Day, The Dalles, and Bonneville dams.

   A Biological Index Test was planned to evaluate operating turbines at the higher end of the 1 percent band at McNary Dam. The evaluation was canceled due to concerns of potential gatewell descaling raised in the Studies Review Workgroup (SRWG) forum. As a result of fish health concerns a gatewell descaling evaluation was conducted in 2010 at McNary Dam. An additional gatewell descaling test is planned for 2012, after regional review of 2010 results.

See the entries for RPA Actions 18 through 24 for specific studies and results.

5. *Monitor and evaluate overall dam passage with respect to modifications at projects (including forebay delay and survival).*

Three Corps AFEP projects (at John Day, The Dalles, and Bonneville dams) conducted evaluations to address this subaction with passage and survival studies which estimated forebay and tailrace passage times and survival rates in the forebay.

See the entries for RPA Actions 18 through 24 for specific studies and results.

6. *Monitor and evaluate the effectiveness of the juvenile fish transportation program and modifications to operations.*

In 2010, the Action Agencies continued to make progress on monitoring and evaluating the effectiveness of the juvenile fish transportation program; this included six BPA projects. Information resulting from the 2010 RME will enable further progress in identifying the benefits of transportation and supporting adaptive management actions. Significant 2010 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 natural spring Chinook and steelhead transported from Lower Granite Dam continued in 2010. More precise transportation data in the April time frame should help clarify effects of transportation on early migrating fish. More precise data in the May time frame should allow for correlation of physical and environmental factors to guide Action Agencies on appropriate triggers of how to operate transportation on an annual basis to maximize adult returns.
- **Summer Migrants:** In 2010, 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 2010, intensive RME efforts were conducted on Snake River fall Chinook salmon. These efforts are expected to provide information to evaluate early life history and migration behavior, the performance of hatchery fish as surrogates for wild fish, and the benefits of late season transportation, as well as to compare production fish groups' performance to wild and surrogate fish.
- **Sockeye transport:** In an effort to better estimate in-river survivals and SARs, a pilot study was continued in 2010 to examine the relative survival of sockeye subject to transport, bypass, and spill. For this study, sockeye salmon smolts were PIT-tagged at Sawtooth Hatchery in Idaho (n=51,876) and Oxbow Hatchery in Oregon (n=11,969). PIT-tagged sockeye salmon were released into Redfish Lake Creek and into the upper Salmon River. Approximately 70 percent of the PIT-tag codes were to be diverted for transportation via barges, and 30 percent returned to the river; with the goal of achieving a 1:1 ratio of transported to in-river migration. However, the sort-by-code request was not implemented in time to achieve the desired split in transported fish and in-river migrants.
- **Steelhead Straying:** The Corps initiated a study in 2010 to evaluate straying by identifying imprinting associated markers in steelhead. This study is an initial step in addressing observations of elevated straying rates in transported steelhead. The overall goal of the study is to reduce or eliminate straying that may be the result of juvenile transportation while maintaining the consistent benefits of transportation observed for steelhead.

7. *Monitor and evaluate the effects of environmental conditions affecting juvenile fish survival.*

Seven projects were continued to fully address this subaction. TDG, temperature, turbidity, and flow are considered key factors, and they are regularly monitored throughout the FCRPS. Many

PIT-tagged fish migrating through the system from assorted projects provide response units for analyzing effects on smolt survival or migration characteristics. The FPC, NOAA Fisheries, and the CSS have conducted these types of probative analyses. The Corps funds the collection and recording of temperature and TDG data and index flow at dams. Data Access Real Time (DART) compiles and displays these and other environmental and fish data, as does the FPC.

8. *Monitor and evaluate the effectiveness of reducing predation toward improving juvenile fish survival.*

In 2010, ongoing research under CRFM and BPA FWP funding continued monitoring of avian predators and their colonies, dam angling, and estimates of annual exploitation of pikeminnow (modeling), in conjunction with juvenile dam survival studies.

9. *Investigate, evaluate and deploy alternative technologies and methodologies for fish passage and the RME Action.*

New passage technologies have been and will continue to be prototyped, tested, and ultimately deployed as part of the AFEP and CRFM. In 2010, a third year of testing was conducted on two prototype spillway weirs in conjunction with an extended-length flow deflector and completed avian deterrent array over the tailrace at John Day Dam (see RPA 20 for details).

A Juvenile Salmon Acoustic Transmitter (JSAT) downsizing project was initiated to allow new applications of study objectives and size ranges of fish that could be tagged, with decreased adverse tag effects.

Advanced video image processing by a Corps contractor, U.C. Davis, enabled the Corps and Fish Managers to observe salmon interaction with lamprey passage orifices within two days of real time. While the monitoring did not reveal any problems, this system would have allowed for quick corrective actions had they proved necessary. The addition of PIT-tag detectors to the adult passage system at Lower Monumental Dam was considered, but did not receive sufficient Regional support. Previous concerns for high adult fallback rates at Lower Monumental were likely related to the occasional passage delay seen at Little Goose Dam (The latter is discussed under RPA 29, above).

10. *Determine if actions directed at benefiting juveniles have an unintended effect on migrating adults (e.g., certain spill operations).*

An evaluation of passage behavior of radio-tagged adult spring-summer Chinook salmon was conducted at The Dalles Dam following completion of the extended spillwall between spillbays 8 and 9. This study was supplemented through monitoring of fish counts throughout the passage season. The purpose of these assessments was to assess the impacts of the new spill pattern, which increased discharge at north spillbays, on passage via the North Fish Ladder. Radio-tag study results and adult fish counts indicated that while adult salmon may have difficulty accessing the North Ladder during high flow conditions (spill >100 kcfs), the new spill configuration did not impede the ability of tagged salmon to find alternative passage routes via the East Fish Ladder. Passage times (first detection in the tailrace to ladder exit) were estimated at 12.1 hours in 2010 and were the fastest among all study years (1996-2010) (Caudill et al. 2010).

An evaluation of adult salmon day time count discrepancies between Ice Harbor and Lower Monumental was conducted as a result of regional concern over adult counts that were higher at Lower Monumental Dam than at Ice Harbor Dam downstream. In this evaluation the number and distributions of jack Chinook salmon, steelhead, and sockeye salmon were compared at Ice Harbor and Lower Monumental dams from April 4 to August 11 or 13, 2009. The spring–summer Chinook run dates for each dam were compared to see if discrepancies observed in adult Chinook salmon counts were similarly reflected in counts of jack Chinook, steelhead, and sockeye salmon. Results indicate that a high fallback rate at Lower Monumental Dam by adult Chinook salmon was not likely responsible for the difference in counts at the two dams. Potential problems with the assumptions used for this evaluation include: a) the count at Ice Harbor Dam likely included salmon that fell back and re-ascended the dam, b) the sample of radio-tagged salmon passing Lower Monumental Dam is relatively small, and c) some salmon may have fallen back multiple times at Lower Monumental Dam. Additionally, results suggest the counting bias, if present at either dam, was larger during periods when there was relatively high numbers of salmon present in the fishways. Other potential sources of counting errors between dams include species misidentification, counter variability, downstream movements of fish past counting windows, and potential paths for salmon to pass count windows unobserved (e.g., a hole in a picketed-lead weir).

11. *Install and maintain adult PIT-tag detectors in fish ladders at key dams in the FCRPS and evaluate adult survival (conversion rates).*

See RPA 52.3 for 2010 adult system survival results.

12. *Monitor and evaluate the effects of fish ladder operations and configurations on adult passage rates.*

Three projects were continued to fully address this subaction. This issue is addressed at each project as needed through the AFEP process. In 2010, lamprey orifices were installed in the stem walls of the telescoping weir walls of the Oregon shore ladder at McNary Dam. Lamprey orifices at 3 stem walls were monitored using video cameras. This monitoring revealed “migrating stocks of adult salmon, steelhead, and shad were not delayed or otherwise harmed by the presence of lamprey orifices. Of all monitored species, Sockeye were most likely to attempt lamprey orifice passage, but at a very low frequency (0.016%) of the entire run.”

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–December 15 as a potential means to provide a safer fallback passage route for overwintering steelhead and kelts, implement if warranted.*

A second year of evaluation was initiated in December 2009 and continued through March 2010, including monitoring of turbine passage during the closed-sluiceway operation of mid-December 2009 through the end of February 2010. Results from the two years of monitoring, which suggested that high numbers of overwintering steelhead and steelhead kelts used the opened sluiceway in early December and March 2010, were used to inform The Dalles Dam sluiceway operation decisions for the 2011 passage season.

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).*

See RPA Actions 53.5 and 54.13 above for information.

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.*

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)*

Multiple projects (including nine BPA projects) were continued to fully address this subaction. Species coverage expanded in 2009 to include sockeye in 2010. Other species will continue at some level, but the frequency of and sample size for acquiring estimates needs clarification for future years. This complements RPA 52.2, which calls for D-estimates to be incorporated into system survival evaluations, as needed. See discussion of RPA Action 31 for further details.

In addition, a literature review of differential delayed mortality was developed, critical certainties were identified, and a workshop scheduled. However, schedule conflicts caused the workshop to be delayed until 2011.

2. *Investigate the post-Bonneville mortality effect of changes in fish arrival timing and transportation to below Bonneville. (Initiate in FY 2007–2009)*

Multiple projects (including 10 BPA projects) were continued to fully address this subaction through review in the AFEP, with focus on Bonneville-Bonneville SARs (i.e. from Bonneville to the ocean and back to Bonneville). Recent NOAA Fisheries transport studies treat this issue with the expectation that the regional PIT-Tagging Plan will fully address the details of this RPA (see discussion of RPA Action 31 for further details).

BPA project number 1991-051-00 (Modeling and Evaluation Statistical Support for Life-Cycle Studies) results from a life-cycle analyses of the joint juvenile-adult PIT-tag data using program ROSTER found ocean survival (i.e. Bonneville to the ocean and back to Bonneville [BON-to-BON]) to vary tenfold between the years 1999 and 2006 (range of 0.002–0.024) and constituted an average of 86.2 percent of the total mortality during Lower Granite-ocean-Lower Granite migration for yearling Chinook salmon. In-river mortality of juveniles constituted, on average, only 9.4 percent of the total mortality pressure on yearling Chinook salmon. Life-cycle analyses found that hatchery releases were a good surrogate for the performance of wild yearling Chinook salmon smolts. PIT-tag analyses also found that SARs were negatively impacted by the number of times a smolt was bypassed during outmigration.

The Corps' seasonal transportation study continued through 2010; it combines weekly SAR estimated with physical and biological data from the estuary and plume to determine factors that affect post-Bonneville survival and can be used for triggers to initiate transport in a year.

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).*

No scheduled action in 2010.

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).*

Four BPA projects were continued to fully address this subaction. Studies have been funded by BPA for more than a decade, and complementary projects (such as radio tag investigations in Snake reservoirs) have been funded by the Corps under the AFEP. Additionally, ongoing transport studies have important life history implications. This has been a complex, multifaceted set of investigations that have taken place over a number of years.

In addition, a workshop was conducted in May 2010, specifically on the Corps' Fall Chinook Transportation study. Status, data summaries, and plans for out years were discussed. A coordination team consisting of the Corps, USFWS, NMFS, ODFW, the Nez Perce Tribe, and FPC continue to collaboratively develop a methods for analysis report.

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 and the final report is posted at *http://www.nwp.usace.army.mil/environment/docs/afep/system/SFS_Tech_Report_2009-4_Final.pdf.*

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.*

In 2009, the Corps submitted a draft final report of the effects of rapid decompression, one of the major injury mechanisms to juvenile fish passing through turbine units, on tagged and untagged fish. Due to the possibility of biased results in that study, the Corps initiated a new study to determine whether effects of rapid decompression on tagged fish differ in type or degree from those on untagged fish. Results of that study were finalized and reported in early 2010.

The Corps conducted physical studies at the ERDC observational turbine model to determine alternatives for runner, stay vane, wicket gate, and draft tube designs for a new turbine runner at Ice Harbor Dam. The Corps advertised a contract for design, manufacture, and delivery of a fixedblade runner for Unit 2, with an option for manufacture and delivery of an adjustable-blade runner for Unit 3.

The Corps also completed a study of alternative methods of capturing fish that have passed through turbines, with study results recommending a direct capture device. Plans and specifications for that direct capture device were then developed and underwent extensive regional review. A decision was made to table those plans and not begin construction of the device in the foreseeable future at Ice Harbor Dam.

7. *Investigate feasibility of developing PIT-tag detectors for spillways and turbines.*

Two projects continued to fully address this subaction. BPA project number 1983-319-00 (New Marking Monitoring Techniques) continued to address new detectors for spillways and turbines and, based on the tests conducted by this project, Destron Fearing (a PIT-tag company) recommends a vertical antenna configuration. NOAA Fisheries further recommends testing of a shield attached to the face of the spillway gate instead of the bottom of the gate. They believe this will be effective based on tests demonstrating that a partial ferrite shield was as effective as a full ferrite shield. This would greatly simplify the overall shielding design and allow water to flow freely down through the spillbay gate. NOAA Fisheries also recommends testing a larger, 5-foot by 25-foot vertical antenna to determine whether it would permit detection of fish when the gate was opened the maximum of 5 feet. After these tests, if the fisheries community chooses to implement this design, the mechanical attachment and design of the antenna assembly would be evaluated. NOAA Fisheries recommends the use of pipe-style housing for the antenna housing enclosures. This would permit water to mostly go through the antenna instead of striking a solid structure. An alternative option to attaching an antenna to the spillbay gate would be to install an antenna system in the ogee area. In this location, the water depth is shallower (1 to 3 feet, depending on gate opening), and water velocity is faster (65 to 90 feet/s) than at the gate location, though the antennas would be more protected. The ogee area is the location that has been accepted for the PIT-tag system and is scheduled to be installed for the top-spill weir spillbay at Ice Harbor Dam. The ogee area design would permit multiple antennas to be installed across the length of the ogee instead of attaching only two antennas to the gate, and multiple antennas would reduce the impact of tag collisions. If the area were large enough, multiple antenna arrays could be installed, which is important from an O&M perspective. Water depth is lower in the ogee area than near the gate opening, and the ogee system could potentially work for all styles of spillbays.

The Corps supported efforts by NOAA Fisheries to develop a prototype spillway PIT-antenna design. Plans to evaluate a prototype at Ice Harbor Dam were halted because of unacceptable high bids. Working with the region through the all-H PIT Plan, the Action Agencies will review the need and benefits of spillway detection and determine the best location to install a prototype detector.

8. *Evaluate new tagging technologies for use in improving the accuracy and assessing delayed or indirect hydro effects on juvenile or adult fish.*

Through the Corps Survival Methodologies Program, research was conducted on the effects of tagging juvenile Chinook salmon in an effort to improve surgical implantation techniques used for implanting acoustic transmitters. Utilizing this research as well as input from regional experts, substantial progress was made on the standardization of surgical tagging protocols. A final protocol document was finalized in 2010.

BPA funded three projects, including BPA project number 2003-114-00 (Pacific Ocean Survival Tracking Project [POST]). This project continued the development of tags and methods in 2009 to determine delayed or indirect effects of hydro passage by looking in the estuary below Bonneville Dam and the ocean environment off the Pacific coast. Data from these efforts are presented in a variety of government reports and peer-reviewed journal articles.

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.*

The feasibility of using a tributary PIT-tag antenna to detect adult salmon in the John Day River was evaluated. The PIT-tag antenna withstood spring freshet flows and has been detecting PIT-tagged adult fish. Effectiveness monitoring in New Marking Monitoring Techniques by BPA was initiated in 2009 and continued through 2010 to determine the detection efficiency of the system.

See RPA 55.7 above for results of spillway detection feasibility evaluations.

RME Strategy 3 (RPA Actions 56–57)

A comprehensive list of all actions implemented by the Action Agencies for RPAs 56 and 57 is included in Section 3. For RPA 56 and 57, the RME Workgroup identified additional monitoring to supplement this ongoing monitoring.

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.*

Eleven BPA projects and three Reclamation projects were continued with elements that support 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) and improve the development and parameterization of models used in the planning and implementation of habitat projects. These studies provide a means of evaluating the effectiveness of tributary mitigation actions. It was determined that 17 BPA projects identified in the 2010-2013 Implementation Plan that collected data that could contribute to this RPA assessment were not necessary to fulfill the RPA and, therefore, the RPA associations were removed.

Relationships of Fish Production to Habitat Condition

The BPA and Reclamation funded research to understand the relationships between stream complexity (channel morphology, channel connectivity, riparian function) and fish productivity. BPA funded the ISEMP program in pilot basins to understand how habitat rehabilitation projects may affect stream complexity and fish production. ISEMP has pioneered the use of new technologies that provide more precise and accurate means to characterize stream morphology. To monitor the effectiveness of this work ISEMP has not only employed a traditional cross-section approach, but also methods that capture three-dimensional habitat surveys. Tools such as total stations, GPS, and Light Detection and Ranging (LiDAR) have been used extensively to collect X, Y, and Z points that can be used to create detailed topographic maps of the streambed, or Digital Elevation Maps (DEMs). Subsequent DEMs can be overlaid on each other and the data from the old DEM subtracted from the new DEM. This creates a DEM of Difference (DoD), which highlights specific habitat change, as in the illustration below (Figure 12) where red in the DoD means erosion and blue indicates deposition.

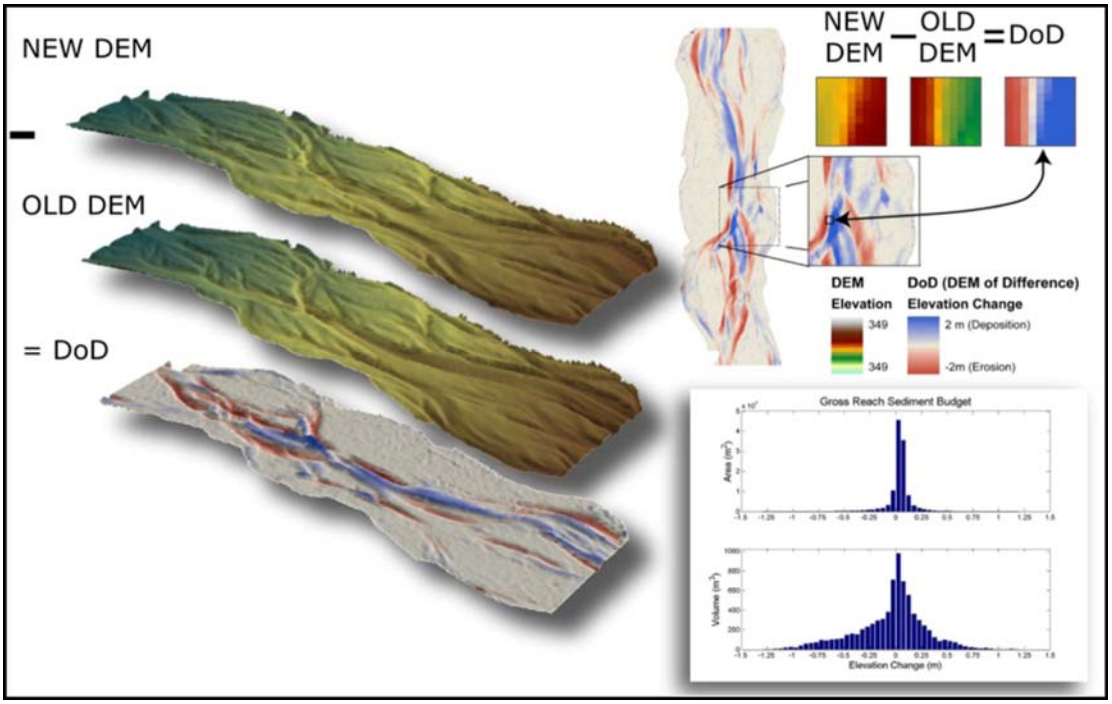


Figure 12. Creation of a DEM of Difference (DoD). (BPA 2011)

In the Bridge Creek IMW in the John Day subbasin, which has suffered dramatic incision, ISEMP restored fish habitat by assisting beavers to build stable dams which helped deposition of streambed materials and the reconnection of the stream to the floodplain (Figure 13). ISEMP has used DoD to describe changes one year after 89 structures were installed to support dams in 4 km of Bridge Creek.

Figure 13. These posts in the deeply incised channel of Bridge Creek provide beaver with a stable framework to construct their dams.

ISEMP Data Collection Summary

Habitat and Benthic Macroinvertebrates

Habitat and benthic macroinvertebrate samples were collected at 49 of 58 sites in the summer of 2010; samples were not collected at nine sites due to access issues which have been resolved for the FY2011 field season. The habitat data were entered into the ISEMP Databank used an automated template module (ATM) and the macroinvertebrate data was sorted and analyzed by Rhithron Associates in Missoula, MT.

Rotary Screw Trap

In 2010, a total of 24,499 fish were captured within the rotary screw traps. Total juvenile fish capture consisted of 9,683 spring Chinook salmon (39.52 percent), 5,283 summer Chinook salmon (21.59 percent), 3,582 steelhead trout (14.62 percent), 166 coho salmon (0.68 percent), 13 cutthroat trout (0.05 percent), 82 bull trout (0.33 percent), and 5,690 non-target species (including adult salmonids) (23.32 percent). A total of 15,146 wild salmonids were implanted with PIT-tags (Desgroseillier et al. 2010). Data have been uploaded to PTAGIS.

Reach-scale Mark-Recapture - Summer 2010

A total of 3,176 target species fish, Chinook and steelhead, were captured at 14 study sites throughout the Entiat and Mad rivers in August 2010. 1,442 Chinook salmon and 1,734 steelhead were caught. A total of 2,690 wild salmonids (83.57 percent) were implanted with PIT-tags (Desgroseillier et al. 2010). Spring Chinook had a recapture probability of 19.52 percent over a 24-hour period, and steelhead had a recapture probability of 17.76 percent over a 24-hour period.

Site Level Point Estimates

Point estimates of abundance and 95 percent confidence intervals were generated for wild Chinook and steelhead at each of the 14 sites sampled (Table 20). Estimates were generated using the Chapman modification of the Peterson equation.

Table 20. Point estimates of abundance for Chinook salmon and steelhead captured at IMW sites in 2010. Estimates that did not pass validity criteria are identified by INV (Invalid).

Site	Species	New Cptrs	Total Marked	Total Recaps	Recap prob.	Pop. Est.	Lower 95% C.I.	Upper 95% C.I.	Stdrd Error
1BC14	Wild Chinook	67	43	4	0.09	597	163	1,031	221.4
	Wild steelhead	134	101	9	0.09	1,376	623	2,120	379.4
1D7	Wild Chinook	60	53	5	0.09	548	184	912	185.8
	Wild steelhead	210	120	19	0.16	1,276	801	1,750	242.1
1E2	Wild Chinook	90	70	17	0.24	358	233	483	63.7
	Wild steelhead	87	76	6	0.08	967	353	1,581	313.1
1F18	Wild Chinook	126	61	15	0.25	491	303	680	96.1
	Wild steelhead	30	47	4	0.09	297	90	503	105.3
1G2	Wild Chinook	56	47	9	0.19	273	142	403	66.7
	Wild steelhead	51	36	4	0.11	384	112	656	138.9
2A5	Wild Chinook	19	23	0	0.00	INV	--	--	--
	Wild steelhead	4	1	0	0.00	INV	--	--	--
2C7	Wild Chinook	90	16	1	0.06	INV	--	--	--
	Wild steelhead	48	7	2	0.29	INV	--	--	--
3A5	Wild Chinook	176	41	9	0.22	742	370	1,115	190.0

Site	Species	New Cptrs	Total Marked	Total Recaps	Recap prob.	Pop. Est.	Lower 95% C.I.	Upper 95% C.I.	Stdrd Error
	Wild steelhead	9	1	0	0.00	INV	--	--	--
3C3	Wild Chinook	53	36	4	0.11	399	115	682	144.5
	Wild steelhead	13	3	1	0.33	INV	--	--	--
3D4	Wild Chinook	10	9	1	0.11	INV	--	--	--
	Wild steelhead	13	2	0	0.00	INV	--	--	--
3F2	Wild Chinook	121	57	13	0.23	504	295	714	106.9
	Wild steelhead	21	4	0	0.00	INV	--	--	--
M04	Wild Chinook	30	26	13	0.50	59	43	74	7.9
	Wild steelhead	117	105	23	0.22	520	360	681	81.8
M14	Wild Chinook	16	8	4	0.50	30	16	43	7.0
	Wild steelhead	110	74	18	0.24	437	286	588	77.1
M23	Wild Chinook	25	11	4	0.36	61	27	96	17.5
	Wild steelhead	123	93	33	0.35	342	265	419	39.4

In addition, monitoring needed to infer relationships based on correlation among limiting factors, habitat actions, and productivity in support of RPA 3 (comprehensive evaluations) will also be addressed under RPAs 50.6 and 56.3.

In 2010, the GRTS-based master-sample management tools were used to design a habitat monitoring program to monitor habitat status and trend in the Methow basin. This is based on the results from BPA project number 2003-017-00 (ISEMP) and is discussed in the proposed CHaMP monitoring program (BPA project number 2011-006-00), which will be initiated in 2011.

In the Methow River basin, Reclamation implemented an intensive effectiveness monitoring program that will address the effects of actions intended to address the primary limiting factors there (loss of channel connectivity and channel complexity). This program began in 2009.

Reclamation continued a series of planning meetings in 2009–2010 to finalize the Methow Study Plan. The study plan includes research on habitat limiting factors to fish production, a before-after-control-impact (BACI) design study of a large channel rehabilitation project, a nutrient supplementation project in the Twisp River, a steelhead relative reproductive success (RRS) study in the Twisp River, and an ongoing study of passage and recolonization of anadromous fish in Beaver Creek, a Methow River tributary. An extensive PIT-tag array system was constructed on all major tributaries and the main river of the Methow River basin.

Reclamation also completed field work through a sub-contract with Idaho State University to assess fish food webs in the middle Methow River. The work identified invertebrate and fish production and species assemblages by main channel and side-channel habitats that will be used in a modeling exercise to assess the relations between community structure and listed fish species population response to channel habitat improvements. The USGS, Yakama Nation, WDFW, USFWS, and the U.S. Forest Service (USFS) are monitoring partners for the Methow Monitoring Plan.

Parameterization of Models Using Limiting Factor Data

The 2010 contract period was the ISEMP's second year of implementing the Lemhi River monitoring strategy. The primary goal of the Lemhi River portion of ISEMP is to identify and quantify the effects of habitat modifications on the productivity and survival of anadromous and resident salmonids within the Lemhi watershed. Within the Salmon Subbasin, ISEMP has implemented a habitat and population status and trends monitoring project in the South Fork Salmon River (SFSR) watershed and habitat action effectiveness evaluation in the Lemhi River watershed. These initiatives are joined through the application of a watershed model that views fish vital rates (survival/productivity, abundance, and condition) as a function of the quantity and quality of available habitat. These functions are constructed using both coarse (e.g. GIS) and fine (e.g., site-scale, airborne LiDAR) scale habitat measures. Once validated via the collection of empirical data within habitat classes, the model provides a statistical framework to assess the effects of different classes of habitat actions on life-stage specific vital rates (productivity/survival and condition) of anadromous and resident salmonids. Additionally, the model includes survival functions enabling the user to alter survival rates (juvenile to emigrant and emigrant to adult) as necessary to compensate for hatchery production. The watershed model requires multiple years of adult escapement and juvenile abundance, survival, distribution, and growth data in order to generate capacity and freshwater productivity estimates. Tying these estimates to physical habitat at appropriate spatial scales (e.g., subwatersheds of the Lemhi River targeted for reconnection) similarly requires multiple years of ground-based surveys enhanced by remote sampling. Given that the ISEMP project initiated sampling in 2009, the first adult return data were produced in 2010 using PIT-tagged fish from Lower Granite Dam tagging operations. Thus, the watershed model will be sufficiently populated for preliminary runs in 2013 for Brood Year 2010 juvenile production. During 2010, ISEMP cooperators continued the implementation of the remote juvenile PIT-tagging, adult salmon and steelhead PIT-tagging at Lower Granite Dam, site-specific habitat surveys, PIT-array installations and operations, and continued the operation of rotary screw traps. Field crews tagged approximately 5,000 adult salmon and steelhead at Lower Granite Dam. Roving surveys within the Lemhi tagged approximately 6,600 juvenile salmon and steelhead and rotary screw traps operations tagged an additional approximately 6,000 juvenile salmonids. Associated with the PIT-tagging, ISEMP cooperators completed the installation of two additional PIT-tag arrays in the Canyon and Big Timber creeks for a total of six instream PIT-tag arrays in the Lemhi River watershed. ISEMP cooperators plan to install two more instream arrays in 2011 for a total of eight. Lastly, ISEMP habitat survey crews completed the second of a two-year annual panel for a total of 118 sites surveyed.

2010 marked the first year of monitoring in the Entiat IMW. The Entiat IMW experimental design enables a quantitative evaluation of the potential benefits of habitat actions at several scales:

- Reach scale – changes over 200-300 meters of stream associated with one or more actions.
- Sub-watershed scale – aggregate of project or reach scale (e.g., juvenile tagging along the mainstem and Mad River to evaluate survival prior to emigration).

- Watershed scale – aggregate of impacts over the entire watershed (e.g. total abundance of juvenile emigrants as assessed at a screw trap located near the mouth of the Entiat River).

The hybrid staircase hierarchical experimental design will allow us to determine how effective habitat actions were at increasing the abundance and overall quality of habitat, the expected value of the habitat changes as a function of fish vital rates, and the empirical response in fish vital rates. The habitat monitoring design is based on a single panel of sampling sites designed to assess changes in habitat complexity and the effect it may have on fish productivity. Salmonid responses relevant to changes in population performance, such as factors that are related to fitness or production, were monitored. This included parameters that are necessary for determining the long-term viability of salmonid populations, such as: freshwater production (smolts/spawner); survival (over summer and over winter); changes in life history patterns; and distribution (as measured by change in density, age-at-emigration, or observed movement of tagged individuals), and growth.

Fourteen geomorphic reaches are monitored within this IMW using a single annual panel. Sampling sites in the mainstem Entiat River are 300 m long (based on average bankfull width) with a 30-meter buffer at each end with a maximum of six sites per geomorphic reach (number of sites depends on geomorphic reach length). Sampling sites are 200 meters long on the Mad River. A total of 58 sites across the 14 reaches were selected for sampling in 2010.

Although 58 sites per year is logistically feasible for habitat monitoring, this would be too labor intensive for fish sampling, especially when conducting mark-recapture estimates which will require a resampling of the site 4 to 24 hours after release of the tagged fish. Therefore, one randomly selected habitat site within each of the 11 geomorphic habitat reaches on the Entiat River and all three sampling sites on the Mad River are surveyed for a total of 14 fish sampling sites each year. Fish sampling sites are randomly chosen annually from among the 58 habitat sampling sites.

By pairing habitat and juvenile monitoring at each site, the Action Agencies can collect information on the mechanisms by which structures influence habitat quality and how this influences fish performance. Juvenile abundance is estimated by a mark-recapture study using fish implanted with PIT-tags. Fish are sampled over two consecutive days to allow for equal capture probabilities per sample event. The Action Agencies use a variety of capture methods (e.g., snerding, e-herding, seining, angling, dipnetting). Captured fish are anesthetized, tagged with 12 mm or 9 mm PIT-tags, weighed and measured, and revived and released near the site of capture. Fish sampling occurred during two time periods in 2010: summer (July/August) and winter (February/March) to obtain seasonal estimates of the response variables. Sampling during higher flows and winter conditions posed some challenges. This information will provide the responses and potential covariates at the highest resolution of comparisons (treatment/temporary control areas) but can be rolled up to address larger area comparisons as well.

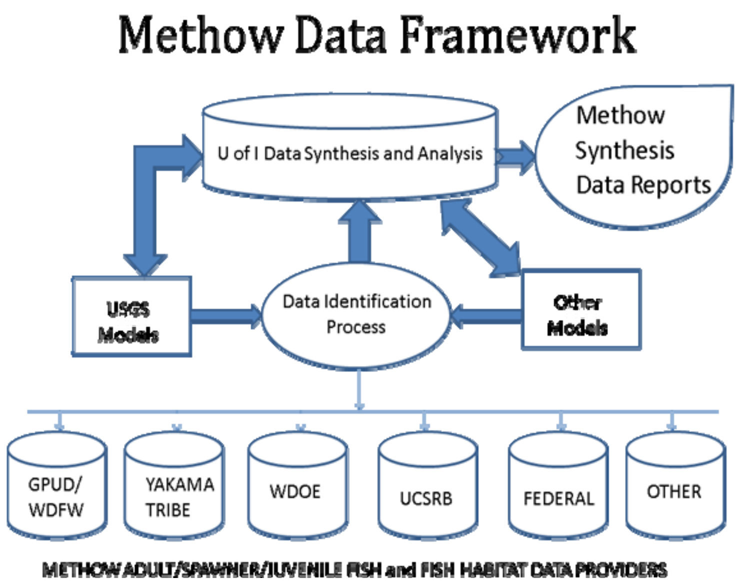
Instream PIT-tag detection antennas have been installed at six locations on the Entiat and Mad rivers. This will allow the Action Agencies to generate seasonal survival estimates and detect juvenile movement in or out of tributaries and along the mainstem as the fish travel around the watershed. Smolt abundance, size-at-emigration, and a growth rate for recaptures will be estimated from fish caught at the rotary screw trap at the mouth of the mainstem Entiat River as fish emigrate from the Entiat.

Additional evaluation by the RME RPA workgroup members from Paulson Environmental Research Ltd. continued work based on Paulsen, C. et al. (2005). Results of the analysis:

> "demonstrate how long-term (parr- and smolt-adult) survival was higher for juveniles from streams with more habitat actions versus those with fewer actions. Using logistic regression models with approximately tagged 700,000 parr and 90,000 smolts, the

number of habitat actions was associated with a significant increase in survival. Furthermore, these increases were sufficiently large to be of importance to the co-managers of these stocks. Past habitat actions likely substantially increased survival, and there may be real potential for implementing additional actions that might benefit many of these populations. While we could not demonstrate mechanistic relationships between habitat actions and survival, it was discovered that higher numbers of actions were associated with larger parr and earlier arrival at Snake River dams as out-migrating smolts, which in turn were associated with higher juvenile to adult survival."

Reclamation funded an interagency agreement with the University of Idaho through a cooperative ecosystem study unit to develop data capture, synthesis, and reporting software. The software will be developed and tested for the Methow Intensively Monitored Watershed data, and subsequently validated for other basins. The following schema shows the interrelationship between model



development and data capture and synthesis (Figure 14)

Figure 14. Data framework for the Methow Intensively Monitored Watershed

Reclamation has an ongoing project with USGS to develop bioenergetic and life-cycle models. For the Methow IMW, USGS began work to construct a mark-recapture model that will estimate subwatershed movement, survival, and detection probabilities of PIT-tagged juvenile Chinook and steelhead for use in the life-cycle model. The work will be constructed as a general framework for application to other basins.

Coordination with Hatchery Projects

Reclamation provided PIT-tags to the USFWS at the Winthrop NFH to tag and release large groups of hatchery fish to understand the potential effects of hatchery juveniles on stream-reared juvenile fish production, and to evaluate the success of a new steelhead rearing program at the hatchery. PIT-tag release groups were also used to help estimate trap and detection efficiencies in the Methow River.

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 project continue to provide a means of evaluating the effectiveness of tributary mitigation actions.)

Six projects were continued that have elements that supported the implementation of habitat status and trend monitoring as a component of the pilot basin studies. BPA project number 2010-051-00 (Upper Columbia Water Quality and Water Quantity Gauges), was delayed in implementation and will begin implementation in 2011. BPA project numbers 1984-02-500 (Blue Mountain Fish Habitat Improvement) and 2007-083-00 (Grande Ronde Supplementation Monitoring and Evaluation (M&E) on Catherine Creek/Upper Grand Ronde River) were implemented outside of the pilot basins and no longer are associated with this RPA. For example, BPA project number 2003-017-00 (ISEMP) finalized a revised protocol for monitoring tributary habitat status and trend for all pilot basins. This protocol *Scientific Protocol for Salmonid Habitat Surveys within the Columbia Habitat Monitoring Program (CHaMP)* is available at *http://www.monitoringmethods.org/Protocol/Details/416*. In 2010, BPA reviewed a proposed implementation plan consistent with the FCRPS BiOp 2010-13 Implementation Plan for the proposed CHaMP monitoring program (BPA project number 2011-006-00), which will be initiated as a pilot in 2011. As discussed with NOAA Fisheries, the strategy for habitat monitoring will not include monitoring in the Yankee Fork, Fifteen Mile because these are at levels greater than 1 per MPG, nor will it include habitat monitoring in Hood River for Chinook based on results from the PNAMP Integrated Status and Trend Monitoring (ISTM) project, which identified the Sandy River as a better population for monitoring fish and habitat relationships. For the Snake River Fall Chinook mainstem population, the Action Agencies/NOAA/NPCC RME RPA workgroup will discuss monitoring needs for this population.

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.*

Seven projects continued to be implemented in 2010 to support this RPA. The ASMS was finalized in early 2010. The Action Agencies and NOAA Fisheries BiOp RME workgroups for fish population and tributary habitat monitoring updated the RME Recommendations Report in June 2010 to support the implementation of the ASMS which included fish population and habitat monitoring for at least one population per major population group. This strategy guided the development of the CHaMP for implementation in 2011 and 2012. The ASMS was appended to the NPCC's Monitoring Evaluation and Research Report (MERR) for Fish and Habitat Monitoring. The ASMS strategy and Action Agencies RME RPA workgroup identified opportunities to expand habitat status and trend monitoring for one population per major population group. To further support this RPA's need for habitat status and trend monitoring, proposals were solicited for all John Day River populations, the Wenatchee River, Entiat River, Methow River, Lemhi River, South Fork Salmon River, Minam River, Catherine Creek, Tucannon River, upper Grande Ronde River, Wind River, Lolo Creek, Toppenish Creek, Klickitat River, Okanogan River, Umatilla River, Asotin Creek, Pahsimeroi River, Big Creek, and Imnaha River populations.

Revisions to this RPA interpretation to only include projects supporting the implementation for the CHaMP protocol resulted in a reduction of projects associated with this RPA, such as BPA projects: 1996-035-01 (Yakama Reservation Watershed Project), 2003-013-00 (Grays River Watershed Assessment), 2002-032-00 (Snake River Fall Chinook Salmon Life History Investigations), 2002-068-00 (Evaluate Stream Habitat-Nez Perce Tribe Watershed M&E Plan), 2007-402-00 (Snake River Sockeye Captive Propagation), 2010-037-00 (Toppenish Creek Steelhead Status & Trend Monitoring), 2010-055-00 (Upper Grande Ronde and Catherine Creek IMW). This is due to the fact that they were outside of the revised one-per-MPG strategy or the proposed work was consolidated into the future implementation of the CHaMP project.

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 numbers 2010-034-00 (Upper Columbia Spring Chinook and Steelhead Juvenile and Adult Abundance, Productivity and Spatial Structure Monitoring) and 2003-017-00 (ISEMP) were continued to support action effectiveness pilot studies in the Entiat River basin to study treatments to improve channel complexity and fish productivity. Results of this project are still pending the return of adults who may have been affected by treatments as juveniles. BPA project number 2010-034-00 (Upper Columbia Spring Chinook and Steelhead Juvenile and Adult Abundance, Productivity and Spatial Structure Monitoring) was initiated in 2010 to support increase intensity of monitoring of adult spawners and out-migrating juveniles.

   The RPA association for BPA project number 2002-059-00 (Yankee Fork Salmon River Restoration) was removed because this work did not support the study in the Entiat River basin.

2. *Pilot study in the Lemhi River Basin to study treatments to reduce entrainment and provide better fish passage flow conditions.*

   Two BPA projects were continued to fully address the pilot study in the Lemhi River basin to assess treatments to reduce entrainment and provide better fish passage flow conditions. BPA project number 2003-017-00 (ISEMP) successfully installed large Biomark PIT-tag arrays in the Lemhi and collected PIT-tag information for 2009. The project also continued to conduct habitat and fish population density monitoring to support the evaluation of treatments to reduce entrainment and provide better fish passage flow conditions.

   The RPA association for BPA project numbers 2002-059-00 (Yankee Fork Salmon River Restoration) and 2003-010-00 (Historic Habitat Food Web Link) were removed because the projects work did not support the study in the Lemhi.

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.*

   Three BPA project numbers 1984-021-00 (John Day Habitat Enhancement), 1998-016-00 (Escapement and Productivity of Spring Chinook and Steelhead), and 2003-017-00 (ISEMP) were continued to fully support 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 number 1984-021-00 (John Day Habitat Enhancement) is still implementing a habitat restoration action effectiveness monitoring program, and results are expected in the future. BPA project number 2003-017-00 (ISEMP) continued to evaluate changes in fish density relative to action implementation. Findings supported effectiveness of reintroduction of beavers on improving fish habitat condition as a treatment to channel incision. As presented under RPA 56.1 above, in the Bridge Creek IMW in the John Day subbasin, preliminary results have shown that the ISEMP project has restored fish habitat by assisting beavers to build stable dams, which help deposition of streambed materials and the reconnection of the stream to the floodplain to address channel incision and potential impacts on stream flows and summer water temperatures. Final results are pending further implementation of the study. The changes in incision were analyzed by use of the DoD to describe changes one year after 89 structures were installed to support beaver dams in 4 km of Bridge Creek.

   The RPA association for projects, 2002-059-00 (Yankee Fork Salmon River Restoration) and 2003-007-00 (Lower Columbia River Estuary Ecosystem Monitoring) were removed because the projects work did not support the study in the John Day River basin.

4. *Project and watershed level assessments of habitat, habitat restoration and fish productivity in the Wenatchee, Methow and John Day basins.*

BPA project numbers 1984-021-00 (John Day Habitat Enhancement), 1998-016-00 (Escapement and Productivity of Spring Chinook and Steelhead), 2010-034-00 (Upper Columbia Spring Chinook and Steelhead Juvenile and Adult Abundance, Productivity and Spatial Structure Monitoring), and 2003-017-00 (ISEMP) were continued to support project- and watershed-level assessments of habitat, habitat restoration, and fish productivity in the Wenatchee, Methow, and John Day river basins. For example, as mentioned previously, BPA project number 2003-017-00 (ISEMP) finalized a revised protocol for monitoring tributary habitat status and trend for all pilot basins for monitoring salmonid habitat conditions and fish juvenile density to support watershed assessments of habitat condition. This protocol *Scientific Protocol for Salmonid Habitat Surveys within the Columbia Habitat Monitoring Program (CHaMP)* is available at *http://www.*monitoringmethods.org/Protocol/Details/416.

The RPA association for projects 1984-025-00 (Blue Mountain Fish Habitat Improvement), 1994-042-00 Trout Creek O&M), 1996-040-00 (Mid-Columbia Reintroduction Feasibility Study), 2002-059-00 (Yankee Fork Salmon River Restoration), 2007-083-00 Grande Ronde Supplementation M&E on Catherine Creek/Upper Grande Ronde River), and 2009-003-00 (Upper Columbia Habitat Restoration) were removed because the projects work did not support the study in the John Day, Methow or Wenatchee river basins.

Reclamation continued its work through an interagency agreement with USGS to evaluate listed steelhead population changes in response to barrier removals in Beaver, Libby, and Gold creeks, which are tributaries in the lower Methow River. A doctoral thesis on landscape ecology and genetics is near completion.

Reclamation's habitat program provided technical assistance to a suite of partners to help implement habitat improvement projects as defined by RPA Actions 34 and 35. Reclamation, through an interagency agreement with USGS (see RPA 56 above), performed a pre-treatment effectiveness monitoring of proposed M2 Reach habitat improvement actions in the mainstem Methow River, including a doctoral thesis assessment of fish food webs in the riverine floodplain environment. The USGS agreement accomplished a number of task elements in 2010:

- Point-abundance surveys were conducted at three sites in the M2 reach and one location in the Chewuch River, upper Methow, and lower Methow.
- Multiple pass-removal population estimates were performed on 10 side channels: 4 in the M2 reach, 3 in the upper Methow, 2 in the Chewuch River, and 1 in the M3 (Silver) reach.
- A multiplexing PIT-tag interrogator was built and installed in the Chewuch River. Five single-antenna PIT-tag interrogation systems were maintained in side channels: three in two side channels in the M2 reach and one each in two side channels in the upper Methow.
- All six existing single-antenna, PIT-tag interrogation systems were maintained in lower Methow tributaries (lower Beaver Creek, lower Libby, two in lower Cold creeks) in 2010.
- The rotary screw trap was installed in the Chewuch River on March 4, 2010 at the same site used in 2009.
- Fin clips of naturally-produced steelhead and Chinook salmon were taken for genetic samples in 2010. Genetic samples have been organized and stored for analysis.
- Twenty-one thermographs in key locations were maintained in 2010, including at sites identified as gaps.

Reclamation continued its effort since 2009 to track fish production relative to fish habitat with mark-recapture methods using PIT-tags. The level of tagging effort is shown below in Table 21.

Table 21. Level of PIT-tagging efforts for Chinook salmon and steelhead in the Methow watershed during each year of the project, 2009-2014.

Site	Group	PIT-tags	USGS effort of total
Smolt traps (n=2, existing)	WDFW	2,000	0
Smolt traps (n=1, new)	USGS	1,000	1,000
Methow R. - upper	USGS and WDFW	1,500	1,000
Methow R. - treatment	USGS and WDFW	1,000	500
Methow R. - middle	USGS and WDFW	1,000	500
Chewuch River	USGS and WDFW	1,000	500
Twisp River	WDFW	500	0
Wolf Creek	USGS	500	500
Eightmile Creek	USGS	500	500
Beaver Creek	USGS	500	500
Gold and Libby Creeks	USGS	500	500
Hatchery(s)	WDFW	5,000	0
Totals		15,500	6,000

Further details can be found in *Mainstem Methow habitat effectiveness monitoring of stream restoration: Study Plan update for FY2011 and FY2012. Report to Michael Newsom, Bureau of Reclamation* (Connolly and Martens 2010).

Reclamation also led coordinated monitoring planning in the Methow River basin, including the development of a water quality monitoring program and an inventory of basin-wide passage projects that will lead to an assessment in 2010. Meanwhile, Reclamation and USGS developed models to predict the response to treatments.

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.*

Internal Action Agency technical service contracts supported the RME RPA Tributary Habitat and Fish Population Workgroup, which continued to meet in 2010 to evaluate survival models and participate in a model workshop to evaluate model components that would be useful to use in development of the Shiraz model for evaluation of improvements/degradation in the environment resulting from habitat actions. In addition, the model workgroup integrated with the Life Cycle Model Workgroup to support the AMIP needs to support development of a habitat module for the life-cycle model effort led by NOAA Fisheries. However, the technical group did not include other technical staff from the co-managers (federal and state agencies and the tribes).

RME Strategy 4 (RPA Actions 58–61)

A comprehensive list is included in Section 3 for all actions implemented by the Action Agencies during 2010 for RPAs 58 through 61. Most of the RPA specifications either were fully covered by ongoing projects or would be fully covered with some additional work elements. Included after the RPA 61 description, below, is a synopsis of 2010 estuary and ocean RME results.

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.*

Two projects continued to support this subaction. Corps AFEP Project EST-02-01 (A Study of Salmonid Survival and Behavior through the Columbia River Estuary Using Acoustic Tags) directly addressed this RPA. During 2010, approximately 12,000 juvenile salmonids were tagged with miniaturized acoustic transmitters, released at several sites upstream of Bonneville Dam, and detected at seven acoustic telemetry arrays deployed across the lower Columbia River and estuary at locations ranging from the Bonneville Dam tailrace to the jetties at the mouth of the Columbia River. Data from the study were used to estimate survival rates of yearling and subyearling Chinook salmon and steelhead in various reaches of the lower river and estuary.

BPA project number 2003-114-00 (Coastal Ocean Acoustic Salmon Tracking [COAST] [formerly POST]) also assessed early marine survival and ocean movements of Columbia River salmon stocks by measuring their movements and survival along the west coast of North America using an ocean tracking array. Estimating survival over the COAST array enabled comparison of relative survival from Bonneville Dam to Astoria, Astoria to Sand Island, Sand Island to Willapa Bay (north) and Cascade Head (south), and north to Vancouver Island. These data represent segment survival for the lower river, estuary, and plume. The magnitude of these survival estimates can also be contrasted with coastal ocean survival data for the same tagging cohorts as they migrate north to BC waters. BPA project number 2003-007-00 (LCRE Ecosystem Monitoring) collects some data that may be used to support this RPA, as data collected in this study can be used by the Corps in future analyses.

2. *Develop an index and monitor and evaluate life history diversity of salmonid populations at representative locations in the estuary.*

During 2010, this subaction was addressed directly by Corps AFEP project EST-09-P-01 (Evaluation of Life History Diversity [LHD], Habitat Connectivity, and Survival Benefits Associated with Habitat Restoration Actions in the Lower Columbia River and Estuary). This study is developing standardized methods and models to approximate relative improvement in habitat connectivity, juvenile salmon early life history diversity, and survival benefit (fitness) as a result of habitat restoration in the LCRE. For this study:

- “Habitat connectivity” represents a change in structural, functional and hydrologic condition; and is measured as a change in fish passage barriers at a site (width, area of restored passage and area made available) and landscape scale (nearest neighbor distance). The habitat connectivity index, in combination with the life history diversity index are correlates for habitat access, defined by the ERTG (RPA 37).

- "Life history" represents a change in juvenile salmon estuarine rearing in the LCRE; and is measured as a change in spatial and temporal habitat use by juvenile salmon (species - body size – month). The life history diversity, in combination with the habitat connectivity are correlates for habitat access, defined by the ERTG (RPA 37).
- "Survival benefit" (SB) represents a change in juvenile salmon condition in different habitats (wetland channels, off-channel, and main channel) at different times of the year. SB is measured as a change in factors that promote fish production and indicate fish condition. The salmon benefit index is a correlate to increased habitat capacity by the ERTG (RPA 37).

The study began in 2009 with a literature review of existing methods to approximate habitat connectivity, early life history diversity of juvenile salmon, and survival benefit in the LCRE. A method for a LHD index was developed and applied to existing data from the LCRE. In 2010, methods and research development continued, along with an experimental, integrated field study.

BPA project numbers 2003-010-00 (Historic Habitat Food Web Link) and 2005-001-00 (Tidal Freshwater Monitoring) also contributed to fulfilling the requirements of this subaction and were transferred to the Corps for future implementation. Project 2003-010-00 (Historic Habitat Food Web Link) found a greater variety of salmonid species in Grays River wetlands than in the Columbia River main-stem wetlands and seasonal transitions in salmonid species composition. All life histories utilized a variety of habitats within the estuary complex, but most juvenile salmon preferred off-channel habitat to the tidal main-stem. Scale patterns suggest that subyearling coho that migrate downstream do not return upstream to their natal river to overwinter, in contrast to other studies (Miller and Sadro 2003; Murphy et al. 1984) and suggest an important role for tidal habitats of tributary systems for coho rearing. In particular, this study provided evidence that multiple subyearling coho salmon life history strategies exist within the Grays River. Project 2005-001-00 (Tidal Freshwater Monitoring) was designed to investigate the ecology and early life history of juvenile salmonids within shallow tidal freshwater habitats of the LCRE. The data on salmon density collected monthly at the Sandy River Delta study area were used to compute the life-history diversity index for subaction 58.2. For example, some fall Chinook salmon stock from east and west of the Cascade Mountains delayed migration and over-wintered in off-channel, tidal freshwater habitats instead of exhibiting the typical life-history pattern to migrate downstream as subyearlings during late spring and summer months. In addition, juvenile salmon were present in all types of habitat sampled, from off-channel wetlands to main-channel areas. The most common species in LCRE tidal freshwater habitat were (in order of prevalence): 1) unmarked Chinook (genetic stock varied depending on longitudinal position in the LCRE and time of year); 2) chum; and 3) coho salmon. In general, juvenile salmon use shallow tidal freshwater habitats to feed and grow year-round, although such habitat use varies by season, stock of origin, life-history stage, and other factors. Habitat use, as evidenced by salmon density and diet, was highly variable depending on salmon origin and life-history stage from the west coast of Vancouver Island to southeast Alaska. Multiple life history strategies were evident based on fish length frequency distributions through time (see description of growth rates described in this study in RPA subaction 58.3).

3. *Monitor and evaluate juvenile salmonid growth rates and prey resources at representative locations in the estuary and plume.*

Four BPA projects continued to fully address the RPA subaction. BPA project number 1998-014-00 (Ocean Survival of Salmonids) updated annual predictions of the relative productivity (prey abundance) in the CR plume based on ocean conditions (Figure 15). BPA project number 2003-007-00 (LCRE Ecosystem Monitoring) collected datasets (e.g., vegetation, habitat, prey, and salmonids) to characterize habitat, fish, and prey at all sites and assess year-to-year trends at previously sampled sites. BPA project number 2003-010-00 (Historic Habitat Opportunities and Food-Web Linkages; transferred to Corps) used scale pattern analysis to track differences in growth trajectories between subyearlings that reared in different locations. Subyearlings that reared in the estuary had the highest growth rates, although a group of subyearlings also experienced similarly high growth in the upper watershed prior to downstream migration. Scale patterns and FL distributions also indicate that subyearlings that achieve a threshold size migrate out of the Grays River estuary and may move into the greater lower Columbia River estuary or to the ocean. The results from BPA project number 2005-001-00 (Tidal Freshwater Monitoring; transferred to Corps) suggest seasonal differences in length frequency distribution for unmarked Chinook salmon in the Sandy River Delta. This study also used bioenergetics modeling, the results of which suggest that maintaining adequate temperatures in tidally influenced shallow-water habitats is key for adequately supporting production of juvenile salmon prey resources. Juvenile salmonid diet have been characterized and growth rates have been modeled for various tidal freshwater habitat types in the Sandy River Delta (river kilometer [rkm]188–202) and lower Columbia River (rkm 110–141). Data from these studies and others were used to assess how environmental effects in the estuary and ocean affect juvenile salmon survival and adult return rates.

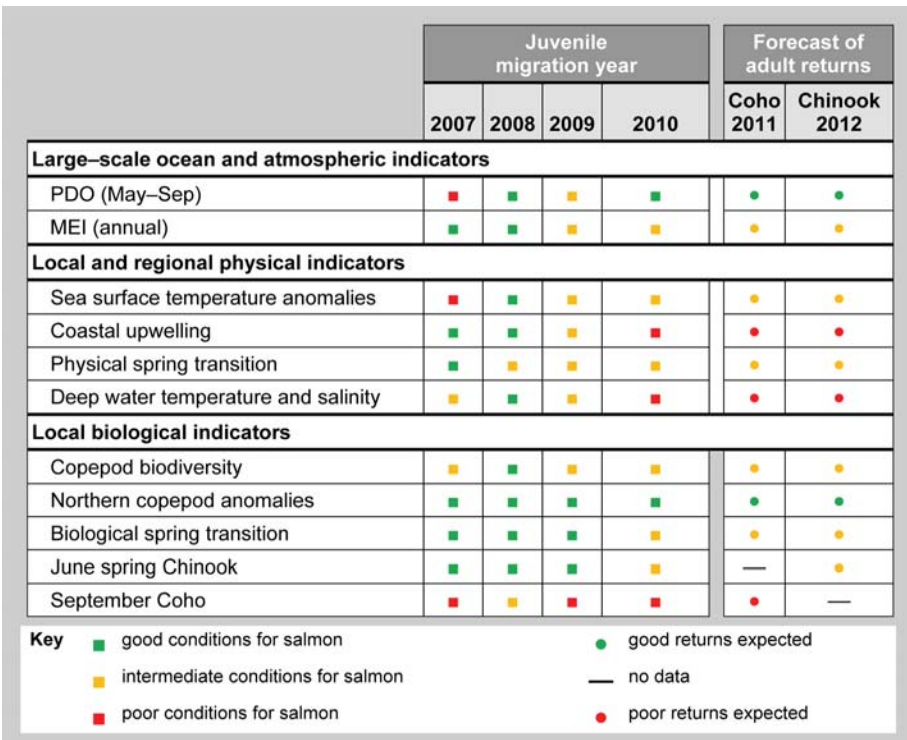


Figure 15: Ocean ecosystem indicators of the Northern California Current. Colored squares indicate positive (green), neutral (yellow), or negative (red) conditions for salmon entering the ocean each year. In the two columns to the far right, colored dots indicate the forecast of adult returns based on ocean conditions in 2009 (Peterson *et al.* 2011).

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.*

Two BPA projects continued to fully support this subaction. BPA project number 1998-014-00 (Ocean Survival of Salmonids) addressed avian predator densities and forage fish abundance in the CR plume, finding that the arrival and movements of forage fishes probably has a large influence on predation rates by marine fishes on juvenile salmonids emigrating from the CR estuary. BPA project number 2003-007-00 (LCRE Ecosystem Monitoring) monitored habitat metrics and juvenile salmon at habitat and fish monitoring locations. The estuary component was addressed through several projects that focused on avian and other piscivorous predators. Additional relevant information is presented below as part of the predation RPAs 68-70. Annual surveys of predation on juvenile salmon are conducted, revealing the most common predators and in some cases, lead to estimates of predation rates.

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.*

Two BPA projects fully addressed this subaction. Under BPA project number 2003-007-00 (LCRE Ecosystem Monitoring), researchers collected 12,640 acres of shallow water bathymetry in the LCRE in 2009, based on bathymetric data gaps identified and prioritized at a workshop in October 2007. In 2010, the remaining 3,200 acres of bathymetry classified as medium or high priority were acquired (6,990 acres total bathymetry in the LCRE). To date, all new bathymetric data have been converted to NAVD88 and delivered to the Estuary Partnership to process the final raster grids. BPA project number 2003-011-00 (Columbia River Estuary Habitat Restoration) provided ancillary information for this RPA subaction (e.g., updated inventory of dredge material deposits, research on tidal datums) to support development of the Columbia River Estuary Ecosystem Classification developed under the previous BPA project number (2003-007-00) and further detailed in RPA subsection 59.2. Numerous other projects, such as BPA project number 2003-011-00 (Columbia River Estuary Habitat Restoration Reference Site) collected site-scale elevation data using real-time kinematic GPS. In addition, LiDAR data for topography were processed for selected sites under AFEP Project EST-02-P-04 (Cumulative Effects of Habitat Restoration).

2. *Establish a hierarchical habitat classification system based on hydrogeomorphology, ground-truth it with vegetation cover monitoring data, and map existing habitats.*

One BPA project was designed to fully address this subaction. BPA project number 2003-007-00 (LCRE Ecosystem Monitoring) further developed the Columbia River Estuary Ecosystem Classification. In 2010, the project delineated draft Classification Levels 4-6 for Reach F and developing ancillary datasets (dikes/levees, floodplain, and dredge material) (Figure 16). The classification system was strengthened by on-the-ground monitoring of vegetation, habitat, juvenile salmon, and water quality (e.g., dissolved oxygen, temperature, conductivity) data at habitat and fish monitoring locations.

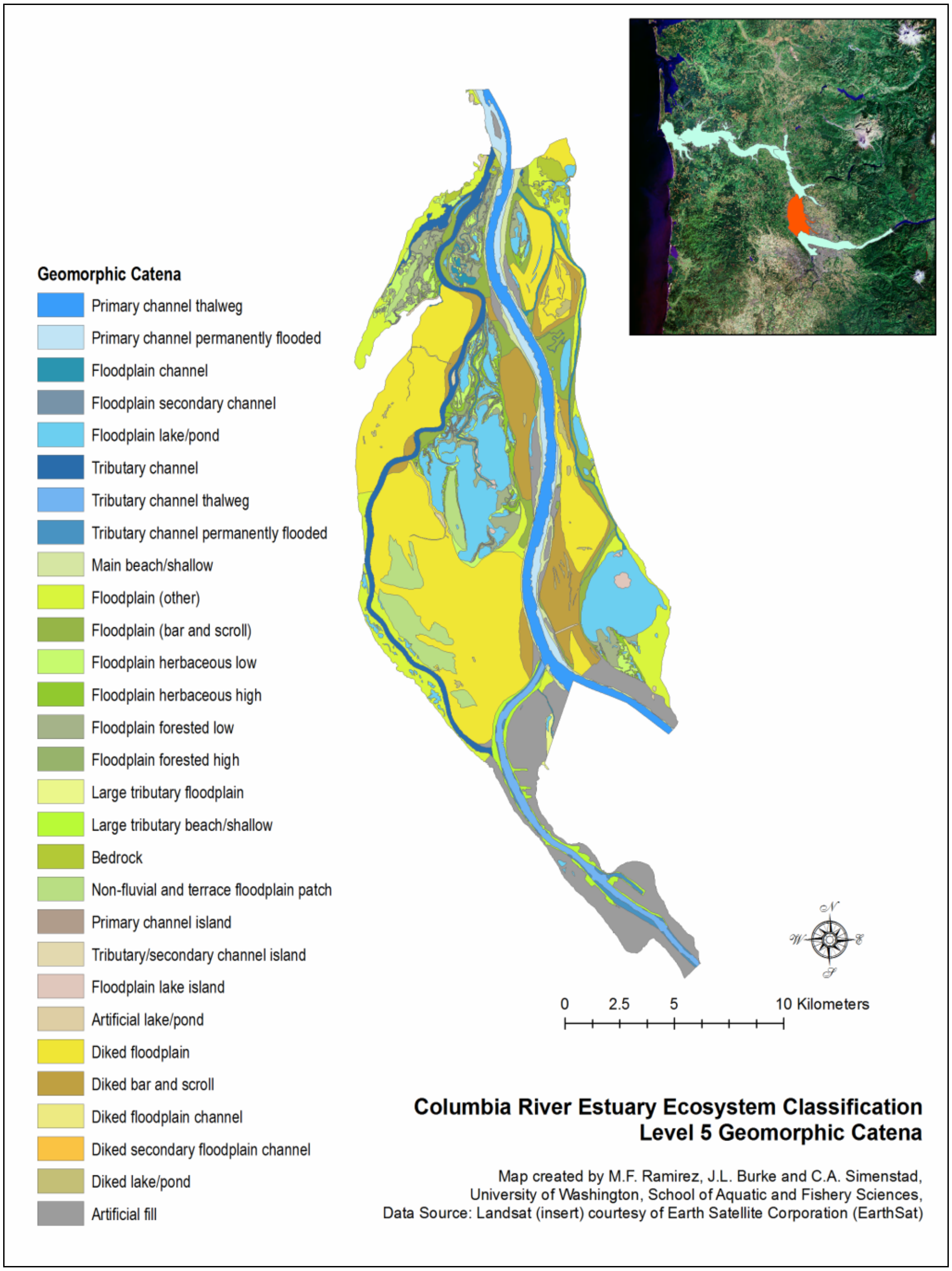


Figure 16: Illustrates the 29 classes of geomorphic catena identified within Reach F. This includes ten tidal flood plain classes and an additional two relict classes (bedrock, terrace) that occur both within and outside flood plains, and seven artificial classes which are extensively modified by anthropogenic modifications but which are still embedded within the ecosystem complexes. While many of the geomorphic catena are somewhat discrete (e.g., floodplain terrace features), although often composing ‘clusters’ that may serve unique functions in their own right, some catena are extensively interconnected. For instance, floodplain channels typically connect to floodplain lake/pond and floodplain herbaceous low marsh and floodplain forests. Similarly, floodplain bar and scroll features are often associated with floodplain lake/ponds and herbaceous low marshes within the scroll features.

3. *Develop an index of habitat connectivity and apply it to each of the eight reaches of the study area.*

During 2010, this subaction was addressed directly by Corps AFEP project EST-09-P-01 (Evaluation of Life History Diversity, Habitat Connectivity, and Survival Benefits Associated with Habitat Restoration Actions in the Lower Columbia River and Estuary). This project was initiated in part to address RPA Action 59.3. Research showed habitat connectivity, site-scale passage barriers, dike breaches, and wetted area can be extracted using remote-sensing and modeling techniques for passage barrier change assessment. In addition, standard nearest-neighbor distance methods can be modified for salmon using hydrologic routing and directional thresholds. Other projects collect habitat data that are relevant to this subaction include BPA project number 2003-007-00 (LCRE Ecosystem Monitoring) and AFEP EST-02-P-04 (Cumulative Effects study).

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.*

One Corps and four BPA projects continued to fully address this RPA subaction (two of the four BPA projects were transferred to the Corps in 2010 for implementation). BPA project number 2003-007-00 (LCRE Ecosystem Monitoring) assessed habitat, fish, and prey year-to-year trends at previously sampled sites. BPA project number 2003-010-00 (Historic Habitat Opportunities and Food-Web Linkages; the first of two BPA projects transferred to the Corps) conducted multi-year simulations and scenario comparisons between the modern and predevelopment conditions, finding that only strategies aimed at re-establishing some connectivity between the river and its floodplain through modifications of both flow and bathymetry can restore physical habitat opportunity in the Columbia River estuary. BPA project number 2004-002-00 (PNAMP) developed a tool to incorporate spatially explicit information on both the priority of the monitoring data and the feasibility/relative expense of obtaining it that was used for integrated status and trend monitoring of salmon and steelhead populations in the lower Columbia River, as well as results from monitoring adult and juvenile life stages at various spatial scales. BPA project number 2005-001-00 (Tidal Freshwater Monitoring; the second BPA project transferred to the Corps) sampled juvenile salmon in different types of estuarine habitat from the west coast of Vancouver Island to southeast Alaska during spring/summer, fall, and winter. Habitat use, as evidenced by salmon density and diet, was highly variable from off-channel wetlands to main-channel areas. The data increased understanding of specific habitat use and the relative importance of these habitats to juvenile salmon.

The majority of acoustic-tagged yearling and subyearling Chinook salmon and steelhead travelled in the main navigation channel from rkm 86 to rkm 37, at which point most fish left the river-influenced navigation channel, crossed a broad, shallow tidal flat, and migrated the final 37 rkm in a secondary channel on the Washington side of the estuary. Although no significant differences in survival probability were observed between navigation channel and off-channel migrants, several areas of high mortality were identified. This study revealed life history characteristics supporting population resiliency that can be used to focus future research and management activities aimed at recovering salmon populations listed by the ESA in areas identified as having high mortality.

5. *Monitor habitat conditions periodically, including water surface elevation, vegetation cover, plan community structure, primary and secondary productivity, substrate characteristics, dissolved oxygen, temperature, and conductivity, at representative locations in the estuary as established through RME.*

Nine AFEP and four BPA projects continued to address this RPA subaction. BPA project number 1998-014-00 (Ocean Survival Of Salmonids) substantially extended and revised the Climatological Atlas for the Columbia River plume and estuary, and circulation simulations were conducted to study the sensitivity to sea level rise of the plume/estuary metrics with fisheries relevance. BPA project number 2003-007-00 (LCRE Ecosystem Monitoring) monitored vegetation, habitat, prey, and salmonids to characterize habitat, fish, and prey at all sites and assess year-to-year trends at previously sampled sites. BPA project number 2004-002-00 (PNAMP) developed a prioritization tool that includes factors such as population recovery priority, current natural origin abundance, the potential for fish in/out monitoring, and special cases identified in the recovery plans along with the prioritization of VSP population monitoring indicators. To this end, this project also constitutes a programmatic implementation to integrate monitoring data collected in other projects. BPA project number 2005-001-00 (Tidal Freshwater Monitoring; the second BPA project transferred to the Corps) has monitored water-surface elevation and water temperature continuously at most Sandy River Delta (SRD) sites since 2007 and one-time habitat characterizations have been performed at the nine SRD sites.

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).*

Three BPA projects continued to fully address this RPA subaction. BPA project number 2003-007-00 (LCRE Ecosystem Monitoring) assesses year-to-year trends at previously established reference sites. BPA project number 2003-011-00 (LCRE Habitat Restoration) included a component to continue monitoring four reference sites as part of action effectiveness monitoring in the lower Columbia River and estuary. Data were collected from four sites during 2010 to assess the structure, function, and condition of a suite of tidal freshwater wetland habitats. Combined with data from previous years, there are over 40 sites in the reference database. Reference site data will be compared with restoration site data to determine the effectiveness of habitat restoration (see RPAs 60.2 and 60.3). BPA project number 2005-001-00 (Tidal Freshwater Monitoring) includes Site B (Chatham Island) and Site H (McGuire Island), which are part of the LCREP's reference site network of over 45 sites in the LCRE that are monitored for fish and habitat metrics.

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.*

Three BPA projects and two AFEP projects continue to address this RPA subaction. BPA project number 2003-011-00 (LCRE Habitat Restoration) generally showed positive ecological responses to restoration at four pilot sites: Mirror Lake (culvert enhancement, riparian improvement), Sandy River Delta (invasive removal and re-vegetation), Scappoose Bottomlands (cattle exclusion and re-vegetation), and Fort Clatsop (culvert removal for tidal reconnection). Data collected at these sites demonstrate the potential effectiveness of the restoration actions and allow managers to determine if further interventions (e.g., invasive species treatment, re-plantings) are needed. In addition, this project continued to develop the Columbia River Estuary Salmonid Restoration: Conservation Strategies and Restoration Goals strategy document, which serves as the documentation of this estuary restoration identification process, as well as a template for engaging the expert panel. BPA project number 2005-001-00 (Tidal Freshwater Monitoring) found juvenile salmon seemed to use habitats in all three of the sampled reaches, and data does not indicate a higher priority for one reach over another for restoration. Based on limited data, researchers suspect lateral distance between off-channel habitats and the main channel influences conditions such as structural hydrologic connectivity, temperature, and growth potential. In addition, juvenile salmon likely benefit from restoration actions focused on maintaining adequate flow and temperature regimes in these habitats. These and other projects showed that juvenile salmon typically access the newly restored areas once the opportunity is provided. Site-scale action effectiveness was also conducted under AFEP EST-02-P-04 (Cumulative Effects study). This study involved intensive, comparative studies paired by habitat type (tidal swamp versus marsh), trajectory (restoration versus reference site), and restoration action (tide gate replacement vs. culvert replacement vs. dike breach).

In project AFEP EST-05-P-07 at Julia Butler Hansen National Wildlife Refuge, the effectiveness of newly installed self-restrained tide gates was assessed at two sloughs during spring 2010. Water temperature profiles within these two sloughs approached those of reference sloughs. Numerically, more salmon were captured in treatment sloughs after installation of the new tide gates than before. However, more salmon than previously were also captured in a control slough that continues to be disconnected from its historical mouth.

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.*

One AFEP project directly addresses this subaction. EST-02-P-04 (Cumulative Effects study) during 2010 focused on: 1) standard monitoring protocols and methods to prioritize monitoring activities; 2) a theoretical and empirical basis for a CE methodology using a levels-of-evidence approach; 3) evaluations of cumulative effects using ecological relationships, geo-referenced data, hydrodynamic modeling, and meta-analyses; and 4) an adaptive management process to coordinate and coalesce restoration efforts in the LCRE. A solid foundation is being developed for future comprehensive evaluations of restoration program progress to understand, conserve, and restore LCRE ecosystems.

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 nearshore ocean environments to the viability and recovery of listed salmonid populations in the Columbia River Basin.*

Five BPA projects continued to address this RPA subaction. BPA project number 1998-014-00 (Ocean Survival of Salmonids) updated annual predictions of the relative survival of juvenile coho and Chinook salmon in the CR plume based on ocean conditions. BPA project number 2003-007-00 (LCRE Ecosystem Monitoring) had findings that will help fill data gaps regarding juvenile salmon use of wetland habitats in the LCRE and have implications for refining restoration actions in the future. BPA project number 2003-009-00 (Canada-USA Shelf Salmon Survival Study) investigated habitat use in the lower Columbia River. Among their significant findings, marine survival and production of Columbia River Chinook, coho, and sockeye salmon seem to be strongly influenced by the growth conditions and food web quality off the west coast of Vancouver Island. In addition, Redfish Lake and Columbia River sockeye smolts have migration speeds among the fastest of any known sockeye salmon populations. BPA project number 2003-114-00 (COAST) provided direct estimates of segmented residency and survival data (hydrosystem, estuary, plume, and coastal ocean) within months of tagging occurring that was used to analyze the relative ecological importance of these environments. BPA project number 2005-001-00 (Tidal Freshwater Monitoring) collected seasonal juvenile salmon and oceanographic data from the west coast of Vancouver Island to southeast Alaska, finding that juvenile salmon use shallow tidal freshwater habitats to feed and grow year-round. However, habitat use varies by season, stock of origin, life-history stage, and other factors and it is still unclear if certain habitat types are used more than others. Collectively, these multi-year projects and others investigated the relationships among juvenile salmon condition, growth, distribution, migration, and survival indicators. Data showed the importance of understanding factors affecting salmon populations over the entire salmon life cycle.

2. *Continue work to define the causal mechanisms and migration/behavior characteristics affecting survival of juvenile salmon during their first weeks in the ocean.*

Three BPA projects continued to fully address this RPA subaction. BPA project number 1998-014-00 (Ocean Survival of Salmonids) updated annual predictions of the relative survival of juvenile coho and Chinook salmon based on ocean conditions. Among other findings, the movement of forage fish to the mouth of the Columbia River (influencing juvenile salmon predation rates) appears to happen suddenly and be strongly controlled with ocean conditions. BPA project number 2003-009-00 (Canada-USA Shelf Salmon Survival Study) continued to assess the effects of ocean conditions from southern British Columbia to southeast Alaska on the production of Columbia River basin salmon by monitoring growth and change in physical features in this region. Among other findings, ocean conditions and circulation appear to affect salmon growth and survival indirectly by changing prey community composition and quality, rather than by a direct effect of temperature on salmon growth or prey quantity. Fat content and growth differences in Chinook and coho salmon varied along different parts of the coast and among years. These differences appear to be associated with differences in prey quality rather than by a direct effect of temperature on salmon growth or prey quantity. BPA project number 2003-114-00 (COAST) assessed early marine survival and ocean movements for Columbia River salmon stocks. By tagging over the smolt migration period, COAST can be used to determine optimal timing of ocean entry and allow these direct estimates of survival to be correlated with large-scale ocean and atmospheric indicators, local and regional physical indicators, and local biological indicators that might aid in the prediction of juvenile salmon survival in the ocean. Because these estimates do not include the two to three years of subsequent life in the ocean until the adults return, they are direct and immediate.

The Corps funded seasonal effects of transportation study continues to collect marine environmental data to identify specific conditions when transporting juveniles will result in the greatest adult return rates. This marine data will be analyzed with the weekly SAR data being collected by the Action Agencies in order to evaluate what ocean conditions might trigger an increase in adult returns.

3. *Investigate the importance of early life history of salmon populations in tidal fresh water of the lower Columbia River.*

Six BPA projects continued to fully address this RPA subaction. BPA project number 1989-107-00 (Statistical Support for Salmon) helped to refocus the sample design for salmonids monitoring in the Ocean for BPA project number 2003-114-00 (COAST). BPA project numbers 2003-007-00 (LCRE Ecosystem Monitoring) and 2003-011-00 (Columbia River Estuary Habitat Restoration) surveyed sites to refine the fish habitat catena detailed in RPA subaction 59.2. BPA project number 2003-010-00 (Historic Habitat Opportunities and Food-Web Linkages; transferred to the Corps for implementation) found that a mixed community of juvenile salmonids use a diverse array of habitat types in the Grays River tributary estuary. Juvenile salmon use the wetlands in Grays River extensively, just as in the Columbia River mainstem. BPA project number 2005-001-00 (Tidal Freshwater Monitoring; transferred to the Corps for implementation) found that feeding ecology and bioenergetics data showed that shallow tidal freshwater habitats in the SRD are making positive contributions to juvenile salmon growth and development. BPA project number 2009-020-00 (UW-CBR Internal Statistical/Technical Support to BPA (Skalski et al. 2010)) provided technical assistance on an “as needed” basis, particularly with regard to BPA project number 2003-114-00 (COAST).

4. *Continue development of a hydrodynamic numerical model for the estuary and plume to support critical uncertainties investigations.*

Two BPA projects continued to address this RPA subaction, although BPA project number 2003-010-00 (Historic Habitat Food Web Link) was transferred to the Corps. BPA project number 1998-014-00 (Ocean Survival of Salmonids) updated annual predictions of the relative survival of juvenile coho and Chinook salmon in the CR plume based on ocean conditions. The Science and Technology University Research Network (SATURN) is an integrated system of networked sensors, platforms, models, data, analyses and social processes whose outputs can function as a Virtual Columbia River (Figure 17). This project employed the Virtual Columbia River space-time simulation environment (*http://www.stccmop.org/datamart/virtualcolumbiariver*) to characterize contemporary plume variability and understand the role of the plume in salmonid survival through multiple representations of circulation processes, variability, and change in the estuary and shelf environments. This simulation environment replaces and substantially expands a pioneering coastal margin observatory through the collaborative pilot environmental observation and forecasting system CORIE. In the future, it may be possible to provide guidance on the optimal timing of steelhead smolt release that would maximize SAR ratios using extensions of the Virtual Columbia River daily forecasts with historically observed SAR ratios paired with in-simulation metrics of plume size and location. Other areas of interest include the role of plume fronts potentially linked to avian predation and the impact of coastal hypoxia on salmon behavior inside the estuary. To address critical uncertainty with respect to historical changes and contemporary status of salmon habitat availability, BPA project number 2003-010-00 (Historic Habitat Opportunities and Food-Web Linkages) used hydrodynamic modeling to hindcast how salmon habitat availability has changed in response to human and climate alterations in river flow, temperature, tidal regime, and sediment budget over the last century.

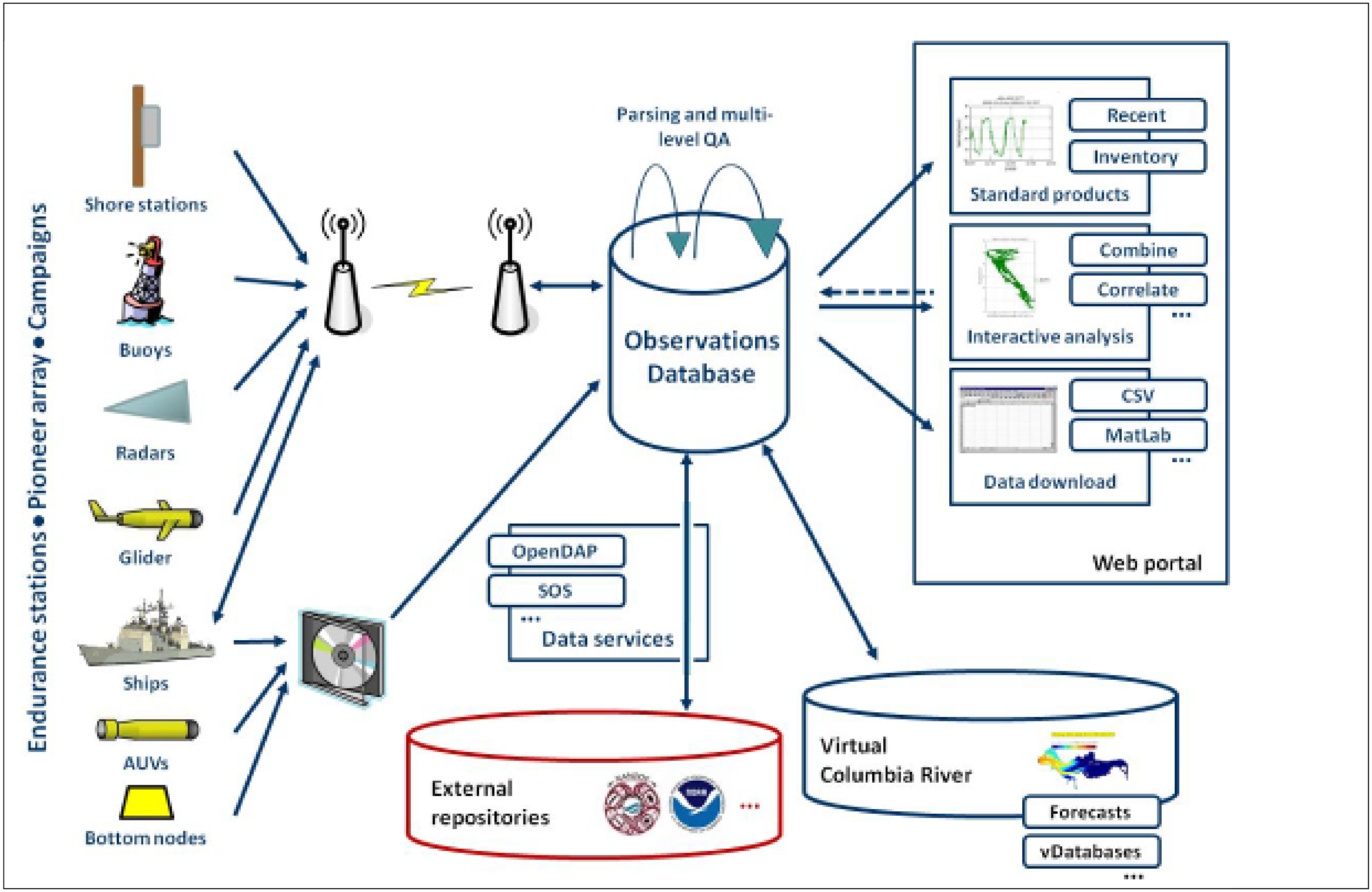


Figure 17: A high-level view of the SATURN cyber-infrastructure, with focus on the handling of observational data.

RME Strategy 5 (RPA Action 62)

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.*

   Nine BPA projects were continued and two were initiated to fully address this RPA subaction. For example, BPA project number 2008-508-00 (Power Analysis Catch Sampling Rates) evaluated run timing and upstream migration mortality of adult Chinook and sockeye salmon and steelhead through PIT-tagging at Bonneville Dam. A companion project, BPA project number 2008-502-00 (Increase Zone 6 Tribal Fishery Monitoring), improved the monitoring and catch sampling of the Zone 6 tribal fisheries by increasing the sample rates and employing additional data collection methods, including PIT-tag technology. In August 2010, WDFW and the PSMFC, with funding from the BPA, implemented PIT-tag sampling concurrent with the ongoing fisheries sampling for biological data and coded wire tags. The purposes of this monitoring program are to: 1) report PIT-tag fish sampled to PTAGIS, 2) develop estimates of PIT-tags sampled in fisheries, and 3) where possible develop estimates of harvest by PIT-tag group.

2. *Evaluate methods to develop or expand use of selective fishing methods and gear.*

   Four projects were continued to fully address this RPA subaction. The Action Agencies continued to support investigations of alternative gear and modifications to existing gear strategies for fisheries in the Columbia River basin. They support development of selective gear methods to reduce hatchery surpluses consistent with HSRG recommendations. BPA project number 2007-249-00 (Evaluate Live-Capture Fishing Gear for Salmon) focuses on evaluating the feasibility and efficacy of various live-capture selective fishing gears to harvest hatchery-origin Chinook while protecting natural-origin Chinook in the upper Columbia and Okanagon rivers. In addition to gear testing, selective fishing can involve modifications to time and area management. BPA project number 1993-060-00 (Select Area Fisheries Enhancement) has investigated the use of off-channel terminal fishing locations in concert with hatchery rearing and acclimation protocols to offer commercial and sport fishers harvest opportunities even when conventional mainstem fisheries are severely constrained or eliminated because of ESA limitations.

3. *Evaluate post-release mortality rates for selected fisheries.*

   Three BPA projects were continued to support this RPA. BPA project number 2007-249-00 (Evaluate Live-Capture Fishing Gear for Salmon) incorporated monitoring protocols to assess fish condition after capture, holding, and release. Results of these evaluations are presented in the project's 2009 annual report. This is identified as a high-priority area by the RME Workgroup.

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.*

   Fourteen BPA projects were continued to address this RPA subaction. BPA has funded the recovery and stock identification of coded-wire tags since the early 1980s. In 2008, four BPA-funded projects implemented recovery efforts in ocean and in-river fisheries as well as some limited spawning ground surveys. In addition, many hatchery O&M projects contain resources directed toward the recovery and stock identification of coded wire tags. The RME Workgroup encouraged additional sampling effort on the spawning grounds. This may require shifting some effort from the ocean fisheries to in-river monitoring. The RME Workgroup also recommends that contracts include language to improve QA/QC, analysis, and data management.

5. *Investigate the feasibility of genetic stock identification monitoring techniques.*

Twenty-eight projects were continued and six were initiated to fully address this RPA subaction. Projects falling under this RPA subaction are primarily large-scale and comprehensive projects which are vital to gaining a better understanding of genetic identification techniques. For example, BPA project number 2009-005-00 (Influence of Environment and Landscape on Salmonid Genetics), a BPA-funded CRITFC project focusing on environmental influences on salmon genetics, has two high level project objectives; the first objective is an evaluation of genetic structure of natural populations of salmonids relative to their environment and identification of candidate markers associated with traits that are related to adaptation of steelhead and Chinook salmon populations. The second objective is to incorporate laboratory/hatchery experiments with controlled environmental variables in order to validate phenotypic response of fish with given genotypes. The project has just completed year one of the study, which focused on the first objective of identifying candidate single nucleotide polymorphism (SNP) markers under selection. The project has successfully identified candidate markers associated with thermal adaptation and anadromy in natural populations of steelhead. Markers identified high genetic differentiation among desert populations relative to montane sites, likely due to intermittent flows in desert streams. Additionally, the project found that populations exhibited a highly significant pattern of isolation-by-temperature and those individuals adapted to the same environment had similar allele frequencies across candidate markers, indicating selection for differing climates. These results indicate that several genes are involved in adaptation of redband trout to differing environments. Additionally, the project has identified three SNP markers associated with anadromy within the Klickitat River, but further testing is needed to evaluate this association across a broader distribution of this species' range. Further experiments may also help clarify the association of genotype of these candidate markers with smoltification phenotypes of individual fish.

Another project, BPA project number 2008-907-00 (the Genetic Assessment of Columbia River Stocks) combines four interrelated studies that contribute to addressing this RPA through the discovery and evaluation of SNP markers in salmon and steelhead; the expansion and creation of genetic baselines for multiple species (Chinook, steelhead, sockeye, and coho); implementation of the GSI programs for mainstem Chinook fisheries; and lastly, GSI of fish passing Bonneville Dam (steelhead and Chinook). Significant progress has been achieved in this project in the last two years. SNP discovery goals were achieved with successful development of 22 new assays for Chinook salmon and 24 new assays for steelhead. These newly discovered SNP markers will be combined with existing SNP markers to generate genetic baselines and for two applications of GSI. For genetic baseline expansion, 96 SNP markers were successfully genotyped in 32 new Chinook salmon collections and 192 SNP markers in 61 steelhead collections from the Columbia River Basin. Results from population genetics analyses suggest SNPs are a class of markers that perform well for distinguishing populations, and these baselines will be useful for estimating stock composition in GSI applications. Results also indicated that some loci may be candidate markers and valuable for analyses based on selective divergence. Future work will include the newly developed SNP baseline of steelhead populations to analyze recent years 2009-2010 of steelhead.

RME Strategy 6 (RPA Actions 63–65)

A comprehensive list of all actions implemented by the Action Agencies for RPA Actions 63 through 65 is included in Section 3. For RPAs 63 through 65, the RME Workgroup concluded that some subactions were fully addressed; however, additional monitoring was recommended to supplement ongoing monitoring.

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)*

Fifteen projects were continued, one project was consolidated, and two projects were initiated in 2010 in order to address critical hatchery effectiveness monitoring. All ongoing BPA-funded safety-net and conservation program projects to implement RPAs 41 and 42 have monitoring and evaluation elements to evaluate effectiveness. Additionally, in some cases there is a separate project identified to monitor effects on the viability and recovery of targeted populations. For example, BPA project numbers 1998-007-02 Grande Ronde Supplementation O&M and M&E on Lostine River), 1998-007-03 (Grande Ronde Supplementation O&M on Catherine Creek/Upper Grande Ronde River), and 1998-007-04 (Grande Ronde Spring Chinook on Lostine/Catherine Creek/ Upper Grande Ronde Rivers) all operate as well as monitor supplementation activities on the Grande Ronde River. Additionally, BPA project number 2007-083-00 (Grande Ronde Supplementation M&E on Catherine Creek/Upper Grande Ronde River) has been implemented to comprehensively monitor and evaluate the effectiveness of supplementation in recovering spring Chinook salmon populations in the upper Grande Ronde River. Results have shown that survival probability of the entire group of upper Grande Ronde River hatchery-origin juveniles (0.4121) was similar to that of the entire group of natural-origin (0.4066) (Boe 2010).

BPA project number 2007-402-00 (Snake River Sockeye Salmon Captive Broodstock) continues to address the Snake River sockeye program and is being expanded to include rearing facilities for juvenile fish. This project is specifically addressing requirements of this RPA subaction.

BPA project number 1989-096-00 (Genetic M&E Program for Salmon and Steelhead) monitored and evaluated the genetic characteristics of supplemented salmon and steelhead in the Snake River basin. This project demonstrated that there is geographic population genetic structure and temporal stability, despite some loss of diversity in both hatchery and natural populations. BPA project number 2010-057-00 (B-run Steelhead Supplementation Effectiveness Research), which focuses on B-run steelhead supplementation effectiveness research in order to better address the abundance, productivity, spatial structure, and diversity of B-run steelhead in the Clearwater Basin, was delayed in implementation until 2011.

BPA project numbers 2010-060-00 (Tucannon Spring Chinook PIT-tagging) and 2010-047-00 (Tuccanon GRTS Monitoring) scopes of work were transferred to BPA project number 2010-042-00 (Tucannon Expanded PIT-Tagging). BPA project number 2010-054-00 (Tucannon Spring Chinook Pedigree Study) was not implemented as proposed in the ASMS because the *U.S. v. Oregon* parties determined that a pedigree study was unnecessary for the hatchery program.

Efforts are ongoing with the Council and NOAA to facilitate the formation of a regional workgroup (BPA project number 2010-082-00 [Columbia River Hatchery Effects Evaluation Team [CRHEET]) in order to coordinate monitoring of regional hatchery effectiveness, individual HGMPs, as well as implementation of the recommendations made by the Ad Hoc Supplementation Workgroup (AHSWG).

2. *Determine the effect that implemented hatchery reform actions have on the recovery of targeted salmon and steelhead populations.*

Three projects addressed this RPA subaction in 2010. BPA project number 1993-056-00 (Advance Hatchery Reform Research) is a comprehensive RME project focused on investigating advanced hatchery reform across relevant Chinook, sockeye, and steelhead populations. Recent findings from this project revealed that, as the number of adult male Chinooks decreased, their access to females, participation in spawning events, and adult-to-fry reproductive success all increased. The same negative correlation between frequency and success was also observed in jacks. These findings demonstrate a genetic basis for the two distinct life history types and have implications for the management of both hatchery and natural populations. Additional research on hatchery emergence techniques for Chinook salmon suggests that the practice of altering emergence timing can dramatically affect later life history events. In particular, fish raised in high growth conditions had the greatest variation in seasonal timing and had the highest rates of early maturation, with most males maturing at age 1. These findings have strong implications for broodstock management of Chinook salmon.

Research on sockeye salmon suggests that there are multiple critical periods for imprinting and that these developmental periods correspond to several types of current release strategies employed by the captive broodstock program; strategies such as planting eyed eggs, as well as fall and smolt releases. The results of this research have contributed to the development and prioritization of future rearing and release plans in order to minimize straying in sockeye salmon at Redfish Lake.

Two projects were initiated in 2010 to address this RPA subaction on steelhead and Chinook populations in the Tucannon River: BPA project numbers 2010-042-00 (Tucannon Expanded PIT-Tagging) and 2010-050-00 (Evaluation of the Tucannon Endemic Program). BPA project number 2010-049-00 (Evaluation of the Touchet Endemic Program) was not implemented in 2010 because ongoing *U.S. v. Oregon* issues have not resolved the need for this project to begin.

There are plans in place for a stakeholders workshop to be held in the spring of 2011 to determine best methods to control the proportion of fish spawning in the wild that are hatchery-origin spawners (pHOS) for steelhead in the Methow Basin.

Project number 1993-056-00 (Advanced Hatchery Reform Research) has expanded and is currently investigating the development of local broodstocks in Winthrop NFH, Touchet, and Tucannon steelhead programs.

Efforts are ongoing with the Council and NOAA to facilitate the formation of a regional workgroup (BPA project number 2010-082-00 [CRHEET]) in order to coordinate monitoring of regional hatchery effectiveness, individual HGMPs, as well as monitoring of the recommendations made by the AHSWG.

RPA Action 64 – Investigate Hatchery 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 RRS feasibility study for Snake River fall Chinook to completion in 2009.*

Nine BPA projects were continued to support this RPA subaction. BPA project number 2010-033-00 (Study Reproductive Success of Hatchery and Natural Origin Steelhead in the Methow) was initiated in 2010 to investigate the reproductive success of hatchery and natural origin steelhead in the Methow River basin. BPA continued to fund RRS studies for listed spring Chinook salmon in the upper Grande Ronde River, Lostine River, and Catherine Creek; for listed steelhead in the Hood River; and for listed fall Chinook in the Snake River.

BPA project number 2003-039-00 (M&E Reproductive Success and Survival in Wenatchee River) completed data collection in 2010 and is currently in its final stages. Preliminary findings reveal that both male and female hatchery-origin fish produced far fewer juvenile progeny per parent when spawning naturally than did natural origin fish and that spawning location seemed to have the most significant effect on fitness for both males and females. For females, it also explained most of the reduced fitness observed for hatchery fish in this population.

BPA project number 2003-054-00 (Evaluate the Relative Reproductive Success of Hatchery-Origin and Wild-Origin Steelhead Spawning Naturally in the Hood River), which focuses on evaluating reproductive success of steelhead in the Hood River, investigated the genetic contribution of resident fish, both natural and residualized hatchery, on the anadromous steelhead population. Results found that although natural resident fish contribute heavily to anadromous steelhead population, residualized hatchery fish likely contribute less than 1 percent. This minimal impact of residualized hatchery fish on steelhead is likely correlated to the high proportion (99 percent, estimated from screw trap data) of hatchery fish which leave the river within one month of release.

BPA project number 1989-096-00 (Genetic M&E Program for Salmon and Steelhead) is now in its 11th sampling year. This genetic monitoring program evaluates the effects of hatchery-reared fish on natural and wild populations of spring/summer Chinook salmon and steelhead in the Snake River basin. Results from 2010 support previous findings that artificially produced Catherine Creek Chinook had RRS quite similar to natural-origin fish, which differs significantly from findings in Little Sheep Creek steelhead where RRS of hatchery steelhead is a half to a third that of natural origin fish. Monitoring techniques and efforts are constantly being reviewed and improved, and the implementation of standardized data collection techniques across multiple agencies has improved the reliability of the data. The information obtained from this study directly addresses a critical knowledge gap identified by co-managers: under what conditions does hatchery supplementation provide a sustained contribution to natural production? Results show a broad distribution of effects and incorporating genetic monitoring work will also be an essential part of hatchery reform. It also will be critical when using widespread hatchery propagation for the recovery of natural populations.

BPA project number 2003-060-00 (Evaluate the Relative Reproductive Success of Wild and Hatchery Origin Snake River Fall Chinook Spawners Upstream of Lower Granite Dam) was completed. The lack of adequate genetic distinctions between groups of hatchery- and natural-origin fish made using mixture analysis for RRS studies infeasible in this population. However, the study did yield valuable information on effective size and possible subpopulation structure.

2. *Determine if properly designed intervention programs using artificial production make a net positive contribution to recovery of listed populations.*

Thirty-one projects were continued and three were initiated to address this RPA subaction. In addition, project number 1993-056-00 (Advanced Hatchery Reform Research) was added as an associated project; this project has also been expanded in order to better address the net contribution of artificial production on the recovery of listed populations.

BPA project number 2003-060-00 (Evaluate the Relative Reproductive Success of Wild and Hatchery Origin Snake River Fall Chinook Spawners Upstream of Lower Granite Dam) conducted comparative genetic data analyses between and among all project samples by brood year. Genetic comparisons showed that wild juvenile samples from 1999 to 2007 brood years were more often similar to Lyons Ferry Hatchery broodstocks rather than divergent. It is proposed that this high genetic representation of Lyons Ferry Hatchery broodstock is a result of high proportions of Lyons Ferry Hatchery stock fish passing upstream of Lower Granite Dam. The upper Snake River spawning ground adult samples from 2005 to 2008 contained high percentages of hatchery-origin fish and these samples were generally very similar genetically to Lyons Ferry Hatchery samples. These results suggest that Lyons Ferry Hatchery-origin fish were the major contributors to natural production.

BPA project number 2010-043-00 (Deschutes Hatchery Stray Study) was implemented in 2010 in order to address reproductive success and stray impact relevant to this RPA subaction. Results from the first year of the study will be included in the 2011 Annual Progress Report.

BPA project number 2010-085-00 (Columbia River Hatchery Effects Evaluation Team [CHREET]) is currently under development for implementation in early 2012. NOAA Fisheries will be providing technical assistance to BPA in 2011 to promote project effectiveness.

BPA project number 2009-001-00 (Expand Multispecies Acclimation Wenatchee/Methow) continued an evaluation of longer-term (two-year) rearing of juvenile steelhead as part of a program to transition to a locally-adapted steelhead broodstock in the Methow River. The program will continue for several more years and was expanded from 25,000 juvenile steelhead in 2008, to 40,000 in 2009, and to 50,000 in 2010. The release goal of 100,000 fish annually is still being met during the transition to locally adapted stock. Study plans were established with NOAA Fisheries to evaluate the survival benefits of the locally adapted broodstock. Fourteen BPA project RPA associations were removed in 2010 pending the future funding and assessment of the BPA project number 2010-082-00 (Columbia River Hatchery Effects Evaluation Team), while one BPA project number, 2008-310-00 (White River Supplementation), was closed in 2010.

3. *In collaboration with the other entities responsible for steelhead mitigation in the Methow River, BPA will fund a new RRS study for ESA-listed steelhead in the Methow River. BPA will also fund a new RRS 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.*

BPA project number 2010-033-00 (Study Reproductive Success of Hatchery and Natural Origin Steelhead in the Methow) is currently in implementation to support this subaction. The RRS study for ESA-listed steelhead in the Methow River that was under a “fast track” in 2009 was implemented in 2010. The project is currently in data collection stage and does not yet have findings to report. Other projects were previously proposed as associated with this RPA subaction, however based on the workgroup review, these projects were deemed unnecessary for consideration under the specifications of this subaction.

NOAA Fisheries and other regional technical experts provided technical assistance to the BPA in 2010 to support the development of a targeted solicitation in 2011 for a study or studies to determine fall Chinook hatchery/wild RRS and/or effects of hatchery programs on productivity of the Snake River fall Chinook salmon ESU. The project proposal is currently expedited and is anticipated to commence in late 2011.

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.*

Three BPA projects continue to support this RPA subaction and one project was completed. BPA project number 2003-060-00 (Evaluate the Relative Reproductive Success of Wild and Hatchery Origin Snake River Fall Chinook Spawners Upstream of Lower Granite Dam) was completed, which determined that the lack of adequate genetic distinctions between groups of hatchery- and natural-origin fish made using mixture analysis for RSS studies infeasible. Continued studies on the efficacy of hatchery fish released into the Snake River include BPA project number 1983-350-03 (Nez Perce Tribal Hatchery O&M). This project recently implemented specific small-scale studies to better examine different rearing strategies on post-release survival of hatchery-origin juvenile spring Chinook. In implementing these studies, the Nez Perce Tribal Hatchery (NPTH) determined that NPTH smolt releases are successfully meeting broodstock needs for the NPTH program and is supported by the recent documentation of record high redd counts in the Clearwater and Snake rivers. Additional studies under BPA project number 1983-350-03 (Nez Perce Tribal Hatchery O&M) have documented natural-origin Chinook salmon migrating from three treatment streams. The greatest numbers of natural-origin migrants were documented in Meadow Creek, followed by Lolo and Newsome creeks.

BPA project number 1998-010-03 (Spawning Distribution of Snake River Fall Chinook Salmon) conducts spawning ground surveys on fall Chinook in the Snake River basin upriver of Lower Granite Dam. In 2009, the survey reported a total of 2,095 redds counted in the Snake River and 1,198 redds in the Clearwater River. Redd surveys were conducted by helicopter surveys, ground truthing, and underwater surveys of deep-water sites.

BPA project number 1991-029-00 (Research, monitoring, and evaluation of emerging issues and measures to recover the Snake River fall Chinook salmon ESU) found relationships between biological variables that influence subyearling growth, migration rate, and mortality in rearing areas and the increase in fish densities following hatchery supplementation in the Snake River. In addition, distinct morphological differences were found between hatchery and natural subyearlings, and this distinction can be used to identify hatchery and natural subyearlings with an accuracy rating of over 99 percent. Identifying key morphological distinctions are critical to ensuring that future inferences from PIT-tag data are also applicable to the natural population of Snake River fall Chinook salmon.

2. *Estimate fall Chinook hatchery program effects on the productivity of the fall Chinook salmon ESU.*

Five BPA projects are ongoing to contribute to this RPA subaction. For example, BPA project number 1991-029-00 (Research, monitoring, and evaluation of emerging issues and measures to recover the Snake River fall Chinook salmon ESU) focuses on the RME of emerging issues and measures to recover the Snake River fall Chinook salmon. The project has evaluated the post-release performance of acclimated hatchery, directly-released hatchery, and natural subyearlings in the Snake River and found that acclimated subyearlings: 1) usually passed downstream faster on average than directly released subyearlings, 2) always passed downstream earlier than directly released subyearlings, and 3) always survived during early seaward migration at higher rates than directly released subyearlings. Based on comparisons of growth rate, passage rate, and survival made between the two groups of hatchery subyearlings and natural subyearlings, less potential was found for interaction between acclimated and natural subyearlings than between directly released and natural subyearlings.

BPA project number 1991-029-00 (Research, monitoring, and evaluation of emerging issues and measures to recover the Snake River fall Chinook salmon ESU) also examined the post-release performance of hatchery subyearlings that are used as surrogates for natural fish. Results reveal that: 1) juvenile life history varies markedly between the natural and production populations and 2) post-release performance was more similar between natural and surrogate subyearlings than between natural and production subyearlings. These empirical findings will provide the fisheries community with information needed to evaluate the efficacy of the surrogate release strategy to better interpret patterns in future SARs from PIT-tagged surrogate and production subyearlings with different passage experiences.

Efforts are ongoing with the Council and NOAA to facilitate the formation of a regional workgroup (BPA project number 2010-082-00 [CRHEET]) in order to coordinate monitoring of regional hatchery effectiveness, individual HGMPs, as well as monitoring of the recommendations made by the AHSWG.

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 RRS study and any additional study or studies needed to estimate the effects of the fall Chinook hatchery programs on productivity of the ESU. There is agreement among the Action Agencies and NOAA that there are necessary prerequisite studies which need to be conducted prior to the implementation of a RRS study or other studies of hatchery effects in Snake River fall Chinook.

RME Strategy 7 (RPA Actions 66–70)

A comprehensive list of all actions implemented by the Action Agencies for RPA Actions 66 through 69 is included in Section 3. For these RPAs, the RME Workgroup concluded that most subactions were fully addressed. However, additional monitoring was recommended to supplement ongoing monitoring.

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 number 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. Results are further reported at *http://www.birdresearchnw.org*. The Action Agencies also funded Caspian tern monitoring at the alternate habitat sites identified in the Caspian Tern Management Plan.

The Caspian tern colony on East Sand Island in the Columbia River estuary, the largest of its kind in the world, consisted of about 8,283 breeding pairs in 2010, significantly smaller than in 2009 and the smallest the colony has been since it became fully established in 2001. Although the recent decline in size of the East Sand Island tern colony was commensurate with a reduction in the amount of nesting habitat made available to terns on East Sand Island, nesting habitat did not appear to limit the size of the East Sand Island tern colony in 2010. Based on nesting densities observed at the East Sand Island tern colony over the past several years, the reduction in available nesting habitat from five acres in previous years to 3.1 acres in 2010 was not the primary cause for the decline in colony size observed in 2010. Further reductions in the amount of tern nesting habitat provided on East Sand Island in future years will be necessary to realize the goal of relocating a majority of the East Sand Island tern colony to alternative sites as part of the Caspian Tern Management Plan.

Juvenile salmonids continued to be a large part of the diet of Caspian terns nesting on East Sand Island, comprising 33 percent of the overall diet in 2010, slightly higher than the 10-year average during 2000-2009 (30 percent). As in previous years, marine forage fishes dominated the diet of Caspian terns nesting on East Sand Island, comprising 62 percent of all identified bill loads in 2010. Caspian terns nesting at the East Sand Island colony consumed about 5.3 million juvenile salmonids (95 percent c.i. = 4.5 to 6.1 million) in 2010, lower but not significantly different than the smolt consumption estimates from the previous two years. Since 2000, the average number of smolts consumed by Caspian terns nesting on East Sand Island was 5.3 million smolts per year, less than half the annual consumption of juvenile salmonids by Caspian terns in the Columbia River estuary prior to 2000, when the breeding colony was located on Rice Island. Further reductions in smolt consumption by Caspian terns nesting on East Sand Island will require a significant reduction in the size of the tern colony; future management plans are designed to reduce the size of the East Sand tern colony to about one-third its pre-management size.

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.

Avian monitoring was conducted by BPA, Reclamation, and the Corps. One BPA project was continued to fully address this RPA subaction. BPA project number 1997-024-00 (Avian Predation on Juvenile Salmonids) provided for the monitoring of the double-crested cormorant colony on East Sand Island. Colony size, reproduction rates, diet composition, and predation rates are monitored to determine the effect of the colony on juvenile salmon. Results are discussed below and further reported at *http://www.birdresearchnw.org*.

East Sand Island is home to the largest double-crested cormorant colony in western North America, consisting of about 13,596 breeding pairs in 2010, the second consecutive year when the colony grew by more than 10 percent. Juvenile salmonids represented about 16.4 percent of the diet of double-crested cormorants nesting on East Sand Island in 2010, compared with 9.2 percent in 2009. Double-crested cormorants nesting at this colony consumed approximately 19.2 million juvenile salmonids (95 percent c.i. = 14.6 to 23.8 million) in 2010, the highest smolt consumption estimate ever recorded at the East Sand Island cormorant colony. For the past two years, smolt consumption by double-crested cormorants nesting on East Sand Island was significantly greater than smolt consumption by Caspian terns nesting on East Sand Island.

Management options to reduce or limit smolt losses to the double-crested cormorant colony on East Sand Island are under consideration. To reduce predation on juvenile salmonids by double-crested cormorants in the Columbia River estuary, it will be necessary to reduce the size of the cormorant colony on East Sand Island. Non-lethal management approaches, such as limiting nesting acreage and relocating a portion of the colony to alternative colony sites along the Pacific coast, seem appropriate in the context of the cormorant colony on East Sand Island. As was the case with Caspian tern management in the Columbia River estuary, any management of double-crested cormorants to reduce smolt losses in the estuary will likely require analysis under the National Environmental Policy Act (NEPA), a process that is currently underway.

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.

Monitoring and evaluation of avian predation on the Columbia Plateau was conducted by BPA, Reclamation, and the Corps in 2010. BPA project number 1997-024-00 (Avian Predation on Juvenile Salmonids) provided aerial surveys to identify significant avian colonies located in the mid-Columbia River. The efforts in 2010 to monitor the impacts to juvenile salmonids at the primary avian colonies on the Columbia Plateau included the Caspian tern colonies on Goose and Crescent Island and the double-crested cormorant colony on Foundation Island. Research at the Goose Island colony emphasized impacts to the Upper Columbia River Steelhead ESU.

In 2010, the largest breeding colonies of Caspian terns in the Columbia Plateau region were on Crescent Island (in McNary Pool) and Goose Island (Potholes Reservoir, WA), where 375 and 416 pairs nested, respectively. Caspian tern nesting success at Crescent Island averaged 0.52 young raised per nesting pair, higher than it has been in recent years, while the Goose Island tern colony experienced almost complete nesting failure in 2010. Three other smaller Caspian tern colonies in the Columbia Plateau region also failed or nearly failed to produce any young. In 2010, salmonid smolts represented 71 percent of tern prey items at the Crescent Island colony and 21 percent of tern prey items at the Goose Island colony; estimated smolt consumption was 420,000 and 122,000 smolts, respectively. The largest colony of double-crested cormorants on the mid-Columbia River was on Foundation Island (in McNary Pool), where 308 pairs nested in 2010. Sampling during 2005-2010 indicated that ca. 50 percent (by mass) of the diet of Foundation Island cormorants was juvenile salmonids during May 2010 (the peak of smolt out-migration), while less than 10 percent of the diet was salmonids in early April, June, and July 2010.

In total, 36,764 PIT-tags from 2010 migration year smolts were deposited on bird colonies in the Columbia Plateau region. PIT-tag recoveries indicated that smolt losses in 2010 were similar for Foundation Island cormorants (8,481 tags) and Crescent Island terns (8,255 tags). Substantial numbers of smolt PIT-tags were also detected on the Caspian tern colony on Goose Island in Potholes Reservoir (8,512 tags) and on a mixed California gull (*Larus californicus*) and ring-billed gull (*L. Delawarensis*) colony on Miller Rocks in The Dalles Pool (5,045 tags). PIT-tags recovered from the Caspian tern colony in Potholes Reservoir were almost exclusively from upper Columbia River salmonid

ESUs, while PIT-tags recovered on other bird colonies in the Plateau region consisted of smolts from upper Columbia, Snake, and middle Columbia ESUs. Preliminary results indicate that Caspian terns from the Goose Island colony in Potholes Reservoir consumed an estimated 9.6 percent of the juvenile steelhead PIT-tagged and released at Rock Island Dam in 2010. Predation rates by Crescent Island Caspian terns on Snake River steelhead (ca. 2.8 percent) and by Foundation Island cormorants on Snake River steelhead (ca. 1.3 percent) and Snake River sockeye (ca. 1.7 percent) were also notable in 2010, although lower compared to previous years (2004-2009).

California and ring-billed gulls have nested in large numbers on islands on or near the mid-Columbia River, but these gulls have generally consumed few fish and even fewer juvenile salmonids, with the exception of the gull colony in The Dalles Pool on Miller Rocks (see above). In 2010, the number of gulls counted on the Miller Rocks colony was 5,533, down from 6,016 gulls counted on-colony during the 2009 breeding season. Despite this decline in the number of gulls counted on the Miller Rocks gull colony, the number of gulls utilizing Miller Rocks during the breeding season has increased by 54 percent compared to 1998. Similarly, the American white pelican (*Pelecanus erythrorhynchos*) colony in McNary Pool on Badger Island has experienced significant growth since the late 1990s, from 100 to 1,643 adults counted on-colony in 1999 and 2010, respectively. But unlike the Miller Rocks gull colony, pelicans nesting at Badger Island are not consuming large numbers of juvenile salmonids, based on the relatively small numbers of smolt PIT-tags detected on the colony.

Stomach contents of 35 double-crested cormorants collected along the lower Snake River during the winter of 2009-10 indicated that salmonids comprised about 12.4 percent of the diet; most salmonids found in cormorant stomachs were from the ESA-listed run of Snake River fall Chinook. Surveys during winter 2009-10 indicated that less than 250 cormorants over-wintered along the lower Snake River; on average, only 20 percent were observed at one of the four lower Snake River dams. The highest concentrations of cormorants over-wintering along the lower Snake River during 2009-10 were observed between Ice Harbor Dam and the confluence with the Columbia River.

The increase in consumption of PIT-tagged smolts by Miller Rocks gulls likely reflects both an increase in size of the gull colony (numerical response) as well as an increase in foraging intensity shifting from the newer wire array at nearby John Day Dam to the downstream reach including the Deschutes River and The Dalles Dam (functional response). The magnitude of predation on salmonid smolts by Miller Rocks gulls appears to be unique among gull colonies along the mid-Columbia River.

RPA Action 69 – Monitoring Related to Marine Mammal Predation

As part of RPA 69, the Corps continued to monitor sea lion predation at Bonneville Dam in 2010. For a more comprehensive summary of 2010 monitoring efforts, refer to the field report by Stansell et al. (2010).

1. *Estimate overall sea lion abundance immediately below Bonneville Dam. (Initiate in FY 2007-2010 Projects)*

   Two projects were continued to fully address this RPA subaction. From January 1 to May 31, 2010, the Corps continued to visually monitor the abundance of California and Steller sea lions below Bonneville Dam (Figure 18). In addition, BPA project number 2008-004-00 (Sea Lion Non-Lethal Hazing and Monitoring) estimated general sea lion abundance while conducting in-river hazing on sea lions.

2. *Monitor the spatial and temporal distribution of sea lion predation attempts and estimate predation rates. (Initiate in FY 2007- 2010 Projects)*

   Two projects were continued to fully address this RPA subaction. In 2010, the Corps continued land-based visual observations to monitor sea lion predation on adult salmonids, white sturgeon, and lamprey in Bonneville Dam tailrace observation area. The Corps also monitored the date and location of individual sea lion predation events. BPA project number 2008-004-00 (Sea Lion Non-

Lethal Hazing and Monitoring) observed the total number of sea lion predation events and recorded their location and time.

The expanded adult salmonid catch estimate for the Bonneville Dam tailrace observation area was 2.2 percent (n=6,081) of the adult salmonid run at Bonneville Dam from January 1 through May 31, 2010. The adjusted estimated catch was 2.4 percent of the run (n=6,321). California sea lions were the primary salmonid predator, accounting for 84 percent (n=3,276) of the 3,910 observed salmonid catches. This percentage was lower than seen in previous years, as observed salmonid catch by Steller sea lions increased from 0.3 percent (n=12) in 2007 to 16 percent (n=634) of total salmonid take in 2010 (Table 22).

Chinook salmon were the most commonly identified prey species, comprising approximately 94 percent (n=3,675) of observed adult salmonid catch in 2010. The expanded Chinook catch estimate for the Bonneville Dam tailrace observation area was 2 percent (n=5,757) of the Chinook run through June 15, 2010. Note that this time period differs from the passage season used for total salmonid estimates and includes the Columbia River spring Chinook passage season at Bonneville Dam, which extends beyond the period during which sea lions are present. Steelhead comprised approximately 6 percent (n=235) of observed adult salmonid catch during the same period. Steelhead, which are present in the Bonneville Dam tailrace throughout the winter and spring, comprised the majority of salmonid catches until the spring Chinook salmon run began. Of the total pinniped catch for 2010, California sea lions consumed 83.6 percent of the Chinook and 86.8 percent of the steelhead (Table 23).

Physical barriers, including SLEDs and FOG barriers, apparently prevented sea lions from entering the fishways, but acoustic deterrents installed near fishway entrances continued to have no visible effect on sea lions. During daylight hours, dam-based USDA Wildlife Services agents contracted by the Corps, and boat-based crews from ODFW, WDFW, and CRITFC used non-lethal pyrotechnics and rubber bullets to harass sea lions in the dam tailrace. Harassment appeared to temporarily alter the behavior of some sea lions but did not reverse the upward trend in predation estimates.

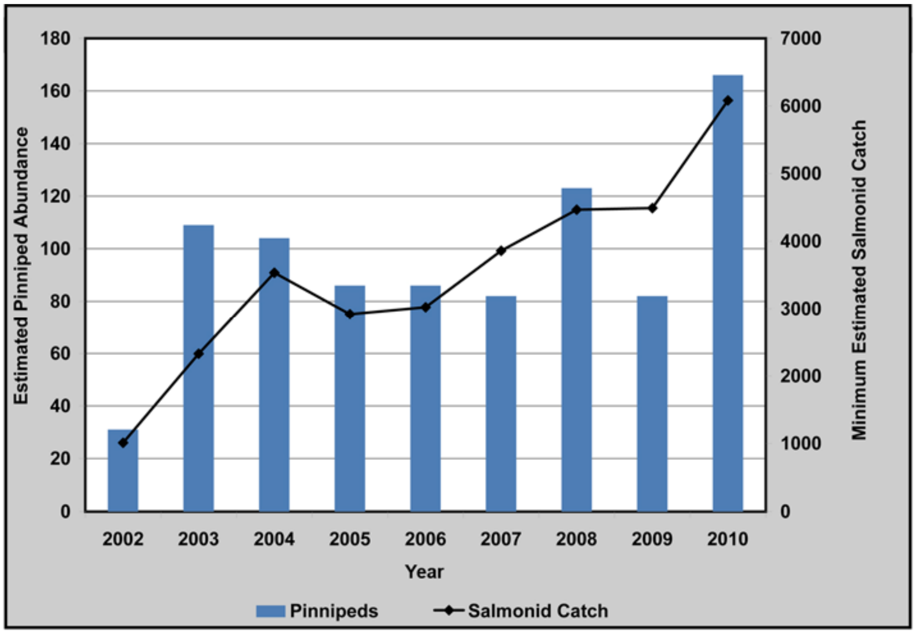


Figure 18. Estimated Minimum Number of Adult Salmonids Consumed by Pinnipeds and Estimated Total Number of Pinnipeds Observed at Bonneville Dam, January 1–May 31, from 2002 to 2010. *Note: In 2005, regular observations did not start until March 18. Pinnipeds observed included California sea lions, Steller sea lions, and harbor seals.*

Table 22. Bonneville Dam Salmonid Passage Catch Summary (2002–2010).

Year	Bonneville Dam Salmonid Passage (Jan. 1–May 31)	Observed Catch	% of Run (1/1 to 5/31)	Expanded Salmonid Catch Estimate: Estimated Catch	Expanded Salmonid Catch Estimate: % of Run (1/1 to 5/31)	Adjusted Salmonid Catch Estimate: Estimated Catch	Adjusted Salmonid Catch Estimate: % of Run (1/1 to 5/31)
2002	281,785	448	0.2%	1,010	0.4%	—	—
2003	217,943	1,538	0.7%	2,329	1.1%	—	—
2004	186,770	1,324	0.7%	3,533	1.9%	—	—
2005	81,252	2,659	3.1%	2,920	3.5%	—	—
2006	105,063	2,718	2.5%	3,023	2.8%	3,401	3.1%
2007	88,476	3,569	3.9%	3,859	4.2%	4,355	4.7%
2008	147,534	4,243	2.8%	4,466	2.9%	4,927	3.2%
2009	186,060	2,960	1.6%	4,489	2.4%	4,960	2.7%
2010	267,194	3,910	1.4%	6,081	2.2%	6,321	2.4%

Note: Total salmonid passage counts include all adult salmonids that passed Bonneville Dam January 1–May 31. "Expanded" estimates correct for the fact that observers are not present at all locations at all times. "Adjusted" estimates further correct to account for catch events where the prey species could not be identified.

Table 23. California Sea Lion 2010 Catch Estimates: Chinook vs. Steelhead.

	Percent of Total Pinniped Catch Taken by California Sea Lions (raw observed catch)	Expanded Catch Estimate (California sea lions)
Chinook	83.6%	4,773
Steelhead	86.8%	324

With funding from the BPA, ODFW and WDFW used four floating sea lion traps deployed along the PH2 corner collector to capture California sea lions. The sea lions not on the list for removal were then weighed, branded, and some were tagged and then released. Of the 22 California sea lions trapped in 2010, four were given brands and acoustic and/or satellite tags (C00-C03), five were branded only (C04-C08), and one was already branded but given an acoustic tag. All of these were then released. Fourteen were on the list for removal (including two of the above mentioned) and were euthanized as no zoo/aquarium facilities offered to take the animals. In addition, two California sea lions on the list for removal were trapped in Astoria, Oregon, in September 2010 and euthanized.

2. *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 2010 through BPA- and Corps-funded efforts. Physical barriers were effective at preventing sea lions from entering the fishways, but acoustic deterrents installed near fishway entrances had no visible effect. Harassment with non-lethal pyrotechnics and rubber bullets appeared to temporarily alter the behavior of some sea lions, but did not reverse the upward trend in predation estimates.

RPA Action 70 – Monitoring Related to Piscivorous (Fish) Predation

A comprehensive list of all actions implemented by the Action Agencies for RPA Action 70 is included in Section 34. For RPA 70, the RME Workgroup concluded that the subactions were fully addressed.

1. *Continue to update and estimate the cumulative benefits of sustained removals of northern pikeminnow since 1990.*

One BPA project was continued to fully address this RPA subaction. BPA project number 1990-07-700 (Development of Systemwide Predator Control) contains an extensive biological evaluation component implemented primarily by ODFW. This program component annually collects and validates biological field data and updates the benefit model with the previous year’s data. The 2010 estimated reduction in potential predation was 38 percent, based on the 2009 exploitation rate of 15.2 percent for pikeminnow 250 millimeters in fork length or larger and the cumulative effect of previous years removals.

2. *Continue to evaluate if inter and intra compensation is occurring.*

One BPA project was continued to fully address this RPA subaction. The evaluation of the NPMP annually assesses whether compensation is occurring as a result of cumulative removals to date. The program evaluation showed no indication of compensation by smallmouth bass, walleye, or channel catfish.

3. *Evaluate the benefit of additional removals and resultant increase in exploitation rate’s affect on reduction in predator mortality since the 2004 program incentive increase.*

One BPA project was continued to fully address this RPA subaction. Exploitation rates since the implementation of the monetary incentive increase in 2004 have significantly exceeded the average exploitation rate of the previous 14 years. System-wide exploitation in 2010 of northern pikeminnow was 15.2 percent based on a numerical catch of 178,981 from a sport reward and dam angling fishery. A significant increase and resultant benefit have been observed since the monetary incentive program was increased in 2004. Some of this may be a result of additional tagging research and the validation of annual tag loss estimates.

4. *Develop a study plan to review, evaluate, and develop strategies to reduce non-indigenous piscivorous predation.*

In December 2009, the project sponsors submitted for review of the ISRP for the NPCC, the proposal titled "Understanding the influence of predation by introduced fishes on juvenile salmonids in the Columbia River Basin: closing some knowledge gaps." As a result of a set of regional workshops held in 2009, the Action Agencies implemented a project to evaluate the influence of juvenile American shad on growth and condition of piscivorous predators in John Day Reservoir in the fall and early winter. 2010 represents the first year in a 3-year study to address this issue.

RME Strategy 8 (RPA Actions 71–72)

RPA Action 71 – Coordination

The Action Agencies will coordinate RME activities with other Federal, State and Tribal agencies on an ongoing annual basis.

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 AFEP.

In 2010, the Corps again implemented the AFEP program. One of the major activities was the selection and development of experimental design and methodology of research projects to be carried out in 2011. This process was extensively coordinated with other federal agencies, states, and tribal interests through their involvement in the SRWG, which met several times through the year. In December 2010, an annual review, open to all interested parties, was held to present the results of AFEP research conducted during the year.

The AFEP program also includes the FFDRWG, SRWG, and the FPOM workgroup. The FFDRWG provides ongoing review of fish facility design activities. The FPOM workgroup provides ongoing review of operational activities related to fish passage. All federal, state, and tribal fishery agencies are invited to participate in FFDRWG, SRWG, and FPOM meetings, both of which generally occur monthly.

Further information on the AFEP program, and on the research carried out in 2010 and planned for 2011, is available at *http://www.nww.usace.army.mil/planning/ep/fishres/afep-default.htm* and *http://www.nwp.usace.army.mil/environment/home.asp*

2. *Supporting and participating in the Council's Columbia River Basin Fish and Wildlife Program project planning and review efforts.*

In 2010, BPA continued to work with NPCC staff in coordinating its FWP's project planning and review efforts. In 2010, BPA and the NPCC conducted the RME and Artificial Production Categorical Review to support a comprehensive evaluation of the FWP's research and monitoring projects and hatchery program. Through this process, the ISRP reviewed the scientific merits of each project, requesting response to scientific deficiencies. The Action Agencies RME RPA workgroup also reviewed the projects' ability to support RME RPAs. This programmatic review by the ISRP provided a foundation for FY 12 funding recommendations. All proposal in this review may be viewed at *http://www.cbfish.org/Review.mvc/Display/310*.

3. *Supporting the standardization and coordination of tagging and monitoring efforts through participation and leadership in regional coordination forums such as PNAMP.*

Four BPA projects and one Reclamation project were continued to fully support this subaction. For example, BPA project numbers 1994-033-00 (FPC), 1996-020-00 (CSS), 1996-043-00 (Johnson Creek Artificial Propagation Enhancement), 2004-002-00 (PNAMP), and 2007-216-00 (PNAMP RME Design and Protocols) were continued to support RPA Action 71.3. BPA project number 2007-216-00 published recommendations on field protocols and methods for fish tagging and telemetry field data collection techniques. This compendium may be found at *http://www.pnamp.org/project/3141*. In addition, BPA project number 2004-002-00 (PNAMP), in coordination with funding from Reclamation, supported revisions to the protocol library tool by contracting with Sitka Technologies to create monitoring methods tool at *www.monitoringmethods.org* to support documentation of protocols to capture monitoring designs for data collection and analysis methods for various indicators and metrics. This tool supports use of a community forum to support standardization and review of protocols and various methods used to assess fish, wildlife, and the environment that they inhabit.

Reclamation directly participated in PNAMP by providing full-time equivalents (FTE) for the PNAMP steering committee, and by continuing to provide funding for its two coordinators and a database expert. Reclamation provided technical expertise for two major PNAMP tasks issued by the Northwest Environmental Information Sharing (NWEIS) executive forum, including development of a white paper on high-level indicators and planning for a region-wide data dictionary.

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.*

Ten BPA projects were continued support this subaction. For example, in 2010, BPA project number 2004-002-00 (PNAMP) published a report and completed objective one of the PNAMP ISTM demonstration project to support management of a regional master sample based on a GRTS design to support efficient and statistically based monitoring designs for fish and habitat programs across the Northwest. The primary purpose of the ISTM project is to improve integration of existing and new efforts that are intended to address status and trend monitoring needs. As a demonstration effort, it focused on processes and tools for the development and management of integrated regional strategic action plans or roadmaps for monitoring the status and trends of aquatic habitat, watershed health, and salmon populations (including steelhead). The lower Columbia River area has been chosen for this demonstration project because it is representative of the challenges faced when integrating monitoring across multiple ESUs and DPSs, between the states of Oregon and Washington, including the operation of the FCRPS and Bonneville Dam, and federal and tribal management through *U.S. v. Oregon* and the Pacific Salmon Treaty. Five objectives were identified to meet ISTM project goals including: 1) Identify and prioritize management decisions, questions, and objectives; 2) Evaluate the extent to which existing programs align with these management decisions, questions, and objectives; 3) Identify the most appropriate monitoring design to inform priority management decisions, questions, and objectives; 4) Use trade-off analysis to develop specific recommendations for monitoring based on outcomes of objectives 1-3; and 5) Recommend implementation and reporting mechanisms. The identified monitoring needs from recovery plans and monitoring guidance provided a framework to make informed decisions on where to allocate limited monitoring resources. To this end, the project developed a prioritization tool that includes factors such as population recovery priority, current natural origin abundance, the potential for fish in/out monitoring, and special cases identified in the recovery plans along with the prioritization of VSP population monitoring indicators. The tool incorporated spatially explicit information on *both* the priority of the monitoring data and the feasibility/relative expense of obtaining it. The report described the results of completing Objective 1. It identifies and prioritizes management decisions, questions, and objectives for ISTM of salmon and steelhead populations in the lower Columbia River planning domain and the results from the application of the prioritization tool across monitoring filters, VSP indicators, and adult and juvenile life stages at various spatial scales. This design and process was subsequently used by BPA project sponsors during the RME Categorical Review throughout the Columbia basin to redesign monitoring programs.

As mentioned previously, PNAMP, with support from the State of the Salmon, also supported further development of the Protocol Library tool and Monitoring Glossary at *www.monitoringmethods.org* and through the incorporation of the hosting the salmon monitoring advisor to help users to design and implement salmon monitoring programs at *https://salmonmonitoringadvisor.org*.

Two BPA project RPA associations were removed because the projects did not support the Action Agencies RME RPA Recommendation Report guidelines.

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.*

Two BPA projects were continued to participate and support the current Action Agencies, NOAA Fisheries, and NPCC workgroup collaboration on implementation planning, annual/comprehensive progress reporting, and adaptive management of RME strategies. These workgroups participated in the BPA RME A/P Categorical review and provided comments on how to improve project support for RPA implementation. For example, BPA project number 2003-017-00 (ISEMP) with technical service contracts with Bionalysts Inc. and Battelle Pacific Northwest National Laboratory, continued facilitation and coordination of the RME Tributary Habitat RME workgroup and provided staff time, developed monitoring inventories for the RME gap assessment, and supported improvements to PIT-tag data management through providing tributary monitoring guidance to the draft Federal PIT-tag plan and completed the Action Agencies, NOAA Fisheries, NPCC RME RPA workgroup 2010 RPA Recommendation Report at *http://www.salmonrecovery.gov/Files/RM&E%20Recommendations%20Report%20w%20revised%20Appendix.pdf*.

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.*

As stated in the 2010 implementation plan and Action Agencies, NOAA Fisheries, and NPCC RME RPA recommendation report, "Action agencies are actively participating in regional forums and accomplishing this sub-action through sub actions 71.1-71.5 above. No subsequent needed actions have been identified at this time."

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)*

One Reclamation and nine BPA projects were continued to fully support this sub-action. For example, BPA project number 1998-031-00 (Implement Wy-Kan-Ush-Mi Wa–Kis) continued to coordinate management of the Coded Wire Tag management program. BPA project number 2008-727-00 (Regional Data Management Support and Coordination) supported the implementation of the 2010 coordinated assessments projects through, PNAMP, CBFWA, and StreamNet to develop standard DETs across the Northwest for the indicators of adult spawner abundance and juvenile salmonid out-migrant production. The project document complex nature of data sets used to derive indicators are presented in Figure 19.

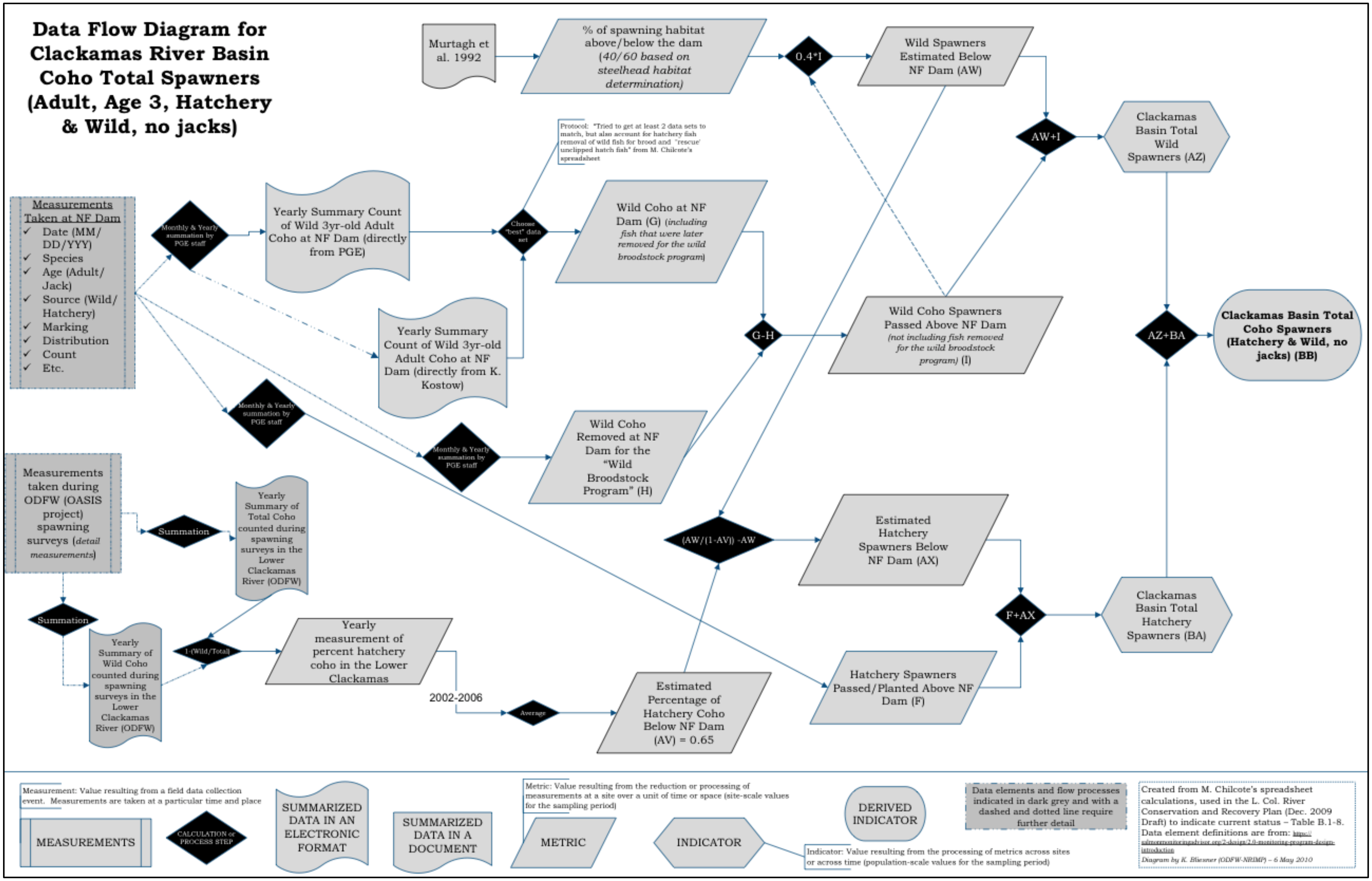


Figure 19. Example data needs for Data Exchange Template for Salmonid Spawner Abundance

BPA project number 2004-002-00 (PNAMP) continued the mission of NED in PNAMP through regional coordination of the Data Management Leadership Team (DMLT). Reclamation supported ongoing regional RME coordination through the PNAMP (see *http://www.pnamp.org* for information on PNAMP's 2010 accomplishments), completion of a major database to catalog monitoring protocols (Monitoring Methods), and the transfer of that technology to a NOAA Fisheries contractor to integrate protocols into a region-wide data dictionary that is being coordinated through PNAMP.

Two BPA project RPA associations were removed because the projects did not support the Action Agencies RME RPA Recommendation Report guidelines.

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)*

Three BPA projects were continued to address this subaction. BPA project number 1996-019-00 (DART) managed a second-tier database and Internet service and provides direct and timely public access to integrated Columbia River Basin environmental, operational, fishery, riverine, ocean, and climactic data resources for sound management of the Columbia River basin resources and hydrosystem by federal, state, public, and private entities. This project also provides web support to PNAMP. In addition, BPA project number 2008-727-00 (Regional Data Management Support and Coordination) was supported by use of a PNAMP data steward to help coordinate the DMLT and data management efforts in the region, which included coordination of the Coordinated Assessments Project to create DETs for the abundance of salmonids. Additional recommendations for data stewards and technical support were identified by the RME Workgroup and are being processed through the coordinated assessment and other forums as well. These actions continued to support implementations of actions consistent with processes identified in the FCRPS BiOp 2010-2013 Implementation Plan.

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).*

Seven ongoing BPA projects were continued to support this subaction. For example, BPA project number 1997-015-01 (Imnaha River Smolt Monitoring) supported the NPT in participation in regional processes including infrastructure improvements of their database to connect to the ISEMP's Status Trend and Monitoring data systems.

BPA project numbers 1988-108-04 (StreamNet - Coordinated Information System [CIS]/ Northwest Environmental Database [NED]), and 2008-505-00 (StreamNet Library) were implemented to support participation in coordination efforts to implement a regional data management strategy through the Coordinated Assessment project and through the PNAMP DMLT. The PNAMP funding for BPA project number 2004-002-00 (PNAMP) continued to provide staff for coordination or work sessions and regional collaboration discussion by the DMLT to continue implementation of NED recommendations.

RME Strategy 9 (RPA Action 73)

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 Action Agencies successfully implemented programs following government contracting requirements with quarterly and/or annual project implementation reporting. BPA continued to implement the PISCES program to track project implementation to support accordance and evaluations of project effectiveness.

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.*

BPA updated the Pisces program to track project implementation for all projects and produced the BPA Dashboard and Taurus program at *http://www.cbfish.org* to track action implementation for the FCRPS RPAs. Reclamation continued to assess and plan for the inclusion of its implementation data into a coordinated Action Agency database.

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 Section 3. These data currently are stored in the Pisces database for actions for which BPA provides funding and in a separate database for actions for which Reclamation provides technical assistance. Because these databases were developed in the early 2000s, they currently include only a subset of the metrics contained in Katz et al. (2006). Since 2008, most of these projects have already been integrated into the NOAA Fisheries Pacific Northwest Salmon Habitat Restoration Project Tracking (PNSHP) database that is based on Katz et al. (2006).

In 2010, the incorporation of Katz et al. (2006)/Pacific Costal Salmon Recovery Fund (PCSRF) program metrics was finalized for all agreed 2010 metrics for Pisces to ensure consistency with other NOAA Fisheries regional database tracking systems, which were in the process of validating Katz et al. (2006) This list of metrics and guidance is available at *http://www.cbfish.org/WorkElement.mvc/Landing*. Expectations for species list documentation were deferred until a solution to capturing metrics in a standard method could be approved by NOAA Fisheries in 2011. The resulting solution is to provide species lists as deliverables attachments for projects for planting and plant removal projects, while capturing species names as metrics for the removal of non-plant species. In addition to implementing the Pisces program on all BPA-funded projects to track Katz-compliant project performance metrics, BPA developed a crosswalk between the NOAA Fisheries, NWFSC, and PNSHP/PCSRF programs to support management of a comprehensive data system for restoration activities for salmonids. To further support action effectiveness assessments and validation of accurate reporting, BPA solicited a proposal to implement a pilot for compliance monitoring to help validate that Pisces-compliant Katz metrics are reported accurately, and provide recommendations to improve restoration project metric guidance to project sponsors.

Adaptive Management Implementation Plan (AMIP) Actions

In September 2009, the FCRPS 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 NOAA Fisheries' 2010 Supplemental BiOp. The following section provides information on AMIP actions implemented by NOAA and the Action Agencies in 2010. Although many of these actions were under way or completed in 2010, some will be implemented later in the BiOp period.

AMIP Reference	Action Description
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
II B	Reintroduction
II C	Predator & Invasive Species Controls
II D	Spill
AMIP Category: III Enhanced Research Monitoring & Evaluation	
III A	Enhanced Life-Cycle Monitoring for Evaluation of Contingencies
III B	Adult Status & Trend Monitoring
III C	Juvenile Status & Trend Monitoring
III D	Habitat Condition Status & Trend Monitoring
III E	Intensively Monitored Watersheds
III F	Climate Change Monitoring & Evaluation
AMIP Category: IV Contingency Plans in Case of Early Warning or Significant Fish Declines	
IV A	Expanded Contingency Process
IV A.1.	Early Warning Indicator for Chinook Salmon & Steelhead
IV A.2.	Significant Decline Trigger for Chinook Salmon & Steelhead
IV A.3.	Contingency Plan Implementation for Snake River Sockeye Salmon
IV B	Rapid Response Actions – Hydro, Predator Control, Harvest, Safety Net Hatchery Programs
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
AMIP Category: Amendments	
Amendment 1	Identify the use and location of adult salmon thermal refugia in Lower Columbia and Lower Snake Rivers
Amendment 2	Assess feasibility of adding adult PIT-tag detection systems at The Dalles Dam and John Day Dam
Amendment 3	Action Agencies to provide temperature data for NOAA's regional temperature database.
Amendment 4	Action Agencies to provide tributary habitat effectiveness study data for NOAA's regional climate change database.
Amendment 5	Action Agencies will provide available invasive species and site-specific toxicology information for consideration by the expert panels.

AMIP Reference	Action Description
Amendment 6	Action Agencies will assist NOAA to develop or modify existing studies that address the Ad Hoc Supplementation Workgroup Recommendations Report.

AMIP Category II – 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 Estuary MOA 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 Estuary MOA, 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.*

See RPA Actions 36 & 37 for discussion of estuary habitat actions and implementation status.

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 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 RIOG.

Schedule Change: As NOAA discussed with the RIOG in November 2010, the completion date for this project has changed from December 2010 to fall 2011 and will be available for consideration in long-term contingency plan development.

NOAA's NWFSC is developing a manuscript on principles of reintroduction for anadromous salmonids in collaboration with the Federal, state, and tribal members of the Recovery Science Implementation Team (RIST). Information on barriers was compiled for Interior Columbia ESUs and DPSs from state and Federal sources. Habitat metrics, proportion of spawning and population area blocked, and other GIS-based estimates were calculated for all complete barriers. Barrier status was determined from database searches (where available) and from regional biologists and by comparing current salmon and steelhead distributions to barrier locations. Engineering and logistical concerns were included and a rule set was established for selecting a list of candidate barriers based upon contribution to population and ESU/DPS. The multiagency group worked on an outline for the paper during summer and fall 2010.

II C. Predator and 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:*

- ***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*
- ***Catfish:*** *document the distribution and predation rates of channel catfish*
- ***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.

Completed on schedule. The Action Agencies contracted a new project "Understanding the influence of predation by introduced fishes on juvenile salmonids in the Columbia Basin." Implementation began in late 2010. The study addresses the role of juvenile shad in sustaining pikeminnow, smallmouth bass, and walleye over winter in FCRPS reservoirs.

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 the RPA action 29.*

Completed for 2010. On February 25, 2010, NOAA Fisheries requested ISAB assistance with a question related to a low flow transportation proposal for the spring 2010 juvenile salmon outmigration. River forecasters were predicting a low flow year for 2010, prompting NOAA Fisheries to propose maximizing the transport of Snake River juvenile steelhead and spring/summer Chinook in the month of May. NOAA's specific charge to ISAB was:

> Taking into account the ISAB's 2008 recommendation "*whenever river conditions allow during the late April-May period, a strategy allowing for concurrent transportation and spill is prudent*," NOAA (in looking at the data from the 2007 low-flow year), determined that if flow conditions in 2010 were similar to those in 2007 (i.e., < 65 kcfs), it would not be "*prudent*" to continue spilling water in May at the three collector projects as in 2007. The question for the ISAB was whether NOAA Fisheries had correctly interpreted the ISAB's recommendation. If not, NOAA requested further explanation of ISAB's reasoning in the 2008 recommendation.

This ISAB panel found that the NOAA Science Center's data was sound and that their conclusions were correct, but this panel also considered a number of different factors such as sockeye, straying, and lamprey (a non-ESA listed species) with information from a number of different sources. The ISAB found that NOAA's analysis and new data "buttress and extend the earlier data, but that uncertainties remain." The ISAB also found that "survival may be better between these dams with more spill, but overall SARs for the entire life cycle may be higher for transported fish." But relying on "ecological and evolutionary considerations", and taking into account sockeye, straying, and lamprey, the ISAB recommended maintaining a "mixed strategy for spill and transport" for this particular water year. Ultimately, it recommended that in the interest of collecting additional data on which future decisions could be based, the Federal agencies should maintain the existing spill operation.

The agencies conducted extensive outreach within many forums including RIOG and TMT to discuss this issue. After a thorough and well-reasoned process the Action Agencies ultimately determined not to implement a maximum-transport operation in 2010 and to maintain spill levels throughout the spring season.

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. The Action Agencies coordinated with the RIOG in developing a new adult based safeguard to be used to trigger spill continuation through August 31. The Action Agencies adopted a trigger level of 400 returning adult fish in any one year. This number was selected because it is the same as the level used for the Early Warning Indicator. However, since the Early Warning Indicator is a 4 year running average return of 400 fish, a one year return at that level would be more likely and therefore represents a very precautionary approach to this issue. A letter describing this choice was sent from Witt Anderson to Barry Thom on June 11, 2010 to inform NOAA of the new trigger.

AMIP Category III – Enhanced Research Monitoring & Evaluation (Actions A-F)

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 (VSP) 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.

Completed on schedule. Beginning in May 2008, NOAA and the Action Agencies conducted a review of the existing programs with the NPCC, the Columbia Basin Fish and Wildlife Authority, and its member state and tribal natural resource agencies to develop a monitoring strategy. The goal was to support fish status and trend monitoring, habitat improvement, and hatchery practices effectiveness monitoring needs for the 2008 BiOp and RPA, recovery plans, regional fisheries management objectives, and other programs. Collaborative regional workshops were held in November 2009. This collaborative process resulted in the Anadromous Salmonid Monitoring Strategy at *http://www.cbfwa.org/ams/FinalDocs.cfm*. NOAA and the Action Agencies submitted the ASMS narrative and accompanying tables of projects (prioritized in a 2009 workshop) to the ISRP and ISAB in July 2010.

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. Subsequently, NWFSC staff reviewed several modeling platforms and decided to implement life-cycle models using the Species Lifecycle Analysis Modules (SLAM). Existing models developed by the Interior Columbia Technical Recovery Team (ICTRT) were ported to SLAM and tested. NWFSC staff also began designing a database to store data that support the models. A workshop with the steering committee was held near Portland in November 2010. The modeling has made progress in the following areas: more realistic harvest module that includes abundance-based rules; modeling of hatchery-wild interactions based on ongoing analyses; incorporating habitat relationships into life cycle models; and developing new hydro scenarios, including dam breaching.

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 completed on schedule.

NOAA's NWFSC created the SPS database, which is available online at *https://www.webapps.nwfsc.noaa.gov/apex/f?p=238:home:0* to disseminate data to enable early detection of regional population specific changes in status.

III C. Juvenile Status & Trend Monitoring: *By December, 2011, the Action Agencies will enhance the existing monitoring of juvenile production and survival. This will ensure that at least one population per MPG is being monitored to better inform decisions regarding what Rapid Response and Long-term Contingency Actions will be taken if an adult trigger is tripped, as well as informing viability assessments. In addition to allowing the detection of downturns in natural freshwater production and juvenile survival, this monitoring will help to assess climate change impacts. The Action Agencies will develop a strategy to improve the management and timely reporting of juvenile salmon and steelhead monitoring data by December, 2010.*

Strategy completed on schedule. The Action Agencies and NOAA have developed a strategy for fish population monitoring in collaboration with the states and tribes as part of the Anadromous Salmonid Monitoring Strategy (see *http://www.cbfwa.org/ams/FinalDocs.cfm*). Associated project proposals were reviewed through the F&W Program Categorical Review through December 2010. Consistent with comments by the Independent Science Review Panel, BPA will proceed with a limited "pilot" project in 2011 for a Columbia Habitat Monitoring Program with associated paired fish population monitoring before full implementation occurs in 2012. This monitoring includes the status and trend in abundance, distribution, productivity and capacity of listed salmon and steelhead populations through and continued contracting of BiOp RPA critical monitoring projects identified within the Anadromous Salmonid Monitoring Strategy and that are specified in the 3 year BiOp Implementation Plans. This includes expansions to include monitoring of at least one population per MPG. BPA continues to work with NOAA and the PNAMP to advance regional monitoring approaches with common data collection and data management protocols. A data management strategy and advancements in access to the fish population data are being addressed through a regional collaboration process that started in October 2010, but will not be completed until December 2011, depending on the rate of progress.

III D. Habitat Condition Status & Trend Monitoring: *By December, 2011, the Action Agencies will expand habitat status and trend monitoring (for at least one population or watershed per MPG) and support updated modeling of the expected benefits of habitat actions. By December, 2011, the Action Agencies will also ensure monitoring of appropriate metrics across a diversity of ecological regions and habitat types to assess responses to climate change.*

The Action Agencies and NOAA have developed a Columbia Habitat Monitoring Program and associated project proposals were reviewed through the F&W Program Categorical Review through December 2010. CHaMP is a new fish-centric habitat quality monitoring program that aims to characterize responses to management action and provide information to improve the management community's understanding of fish-habitat relationships. CHaMP will be implemented in 11 watersheds in 2011, expanding to 18 in 2012. The stream habitat quality and quantity data generated by CHaMP are spatially explicit and will be evaluated in a GIS framework that also considers watershed, valley, and reach level information, with a focus on covering one population per MPG.

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 Potlach 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:

- *Timely funding and implementation of intensive habitat actions to ensure, where practical, an adequate treatment effect*
- *Sufficiently diverse representation of IMWs (geographically and with respect to limiting factors) and appropriate monitoring (e.g., temperature, flow) to detect climate change impacts*
- *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 coordinated with the RIOG and reported annually to the region.

Completed on schedule. NOAA and the Action Agencies held workshops in April, May, and August 2010 to evaluate the effectiveness of currently funded IMWs implemented through the PNAMP. Experts conducted inventory and gap assessments of IMWs and discussed ways to better coordinate and improve on the existing IMW network. They completed the draft "Inventory and Gap Assessment report" in May 2010 and the "Strategy for Coordinated Habitat Action Effectiveness Monitoring" in July 2010. Recommendations and next steps came from interagency workshops in September 2010, including: 1) improve alignment of protocols and methods among IMWs; 2) align data management among IMWs (for information exchange and analysis); and 3) develop coordinated approaches/measures for evaluating action effectiveness.

III F. Climate Change Monitoring & Evaluation - This AMIP Action enhances or clarifies other RPA actions as follows:

- *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.*

- *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.*
- *Under RPA Actions 35 and 37, 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.*
- *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.*
- *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.*

NOAA included an extensive review of the literature on climate science and oceanographic conditions relevant to Columbia basin salmonids in its 2010 Supplemental FCRPS Biological Opinion. It concluded that the new information indicated the potential for the physical and biological features of salmonid habitat to change over time due to increased temperatures and shifts in the timing of seasonal precipitation. These effects are likely to be within the range considered in the 2008 BiOp.

Habitat conditions and action effectiveness information will be collected and managed in the following databases to allow changes to be tracked over time:

1. Ocean Conditions / Indicators - NOAA will use its existing database *http://www.nwfsc.noaa.gov/research/divisions/fed/oeip/a-ecinhome.cfm*).
2. Stream habitat conditions will be monitored across the Columbia River basin beginning in 2011. All data from this program will be managed and distributed through a web-based data system (*http://www.champmonitoring.org*).

Stream habitat restoration and conservation actions are compiled region-wide by NWFSC staff and managed and distributed on a web-based data system (*http://webapps.nwfsc.noaa.gov/portal/page?_pageid=33,1&_dad=portal&_schema=PORTAL*)

AMIP Category IV – Contingency Plans in Case of Early Warning or Significant Fish Declines

(Actions A-C)

IV A. Expanded Contingency Process

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.*

Schedule Change: As NOAA discussed with the RIOG in November 2010, the completion date for this project has changed from December 2010 to fall 2011. This did not increase the risk to the listed species because the information available to NOAA as of December 2010 (including the previous season's dam counts) indicated that the early warning indicator had not been tripped.

NOAA developed a concept for the additional early warning indicator in August through October 2010. The approach proposed by NOAA would use a model to forecast adult returns two years into the future. The model would be used when two years of adult returns fall below the Significant Decline threshold. The model would use a variety of indicators to forecast the likelihood that returns for the subsequent two year period would also fall below the Significant Decline threshold. Further coordination and development work is underway.

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.***

Completed on schedule. Working with NOAA, the Action Agencies developed an approach combining 5-year rolling trend estimates with rolling 4-year averages of abundance for use as an additional trigger which was provided for discussion and comment by the RIOG. A letter from L. Bodi to B. Thom, dated December 23, 2010, conveyed the Action Agencies' choice of metric to indicate trend and their rationale with comments from OR and Spokane Tribe (as RIOG participants).

IV B. Rapid Response Actions: *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.*

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:

- *Hydro Actions: The Corps will implement, in coordination with NOAA Fisheries and the other Action Agencies, hydrosystem actions that will increase the survival of the species in question beyond the current juvenile dam passage performance standards. Specific actions will be based on the most recent data available and might include targeted spill and changes in fish transportation operations based on recent survival data. The federal agencies, in collaboration with the RIOG and appropriate technical groups, will review the current status of biological research and discuss where additional project survival benefits could be gained for the species in question.*
- *Predator Control: BPA and the Corps, in conjunction with the USFWS and the States, will implement more aggressive, targeted efforts to control predatory fish, birds, and invasive species to increase survival of listed fish. This will include a temporary increase in the pikeminnow sport fishery reward program and increased hazing of birds in close proximity to the dams.*
- *Harvest: All fisheries that affect the species of concern, including ocean, mainstem, and terminal will be reviewed by NOAA Fisheries to assess whether existing harvest management agreements provide adequate protection. Under the United States v. Oregon agreement, if the performance measure of any indicator stock declines for three consecutive years when compared to the base period, any party may request that an analysis of the decline is conducted. The analysis must be completed within one year. After review of the analysis, the parties may make recommendations to modify the agreement. If it is determined that additional protection is necessary, NOAA Fisheries will use existing procedural provisions of the agreements to seek consensus among the parties to modify the agreements.*
- *Safety-Net Hatchery Programs: BPA and NOAA Fisheries use safety-net hatchery programs to address short-term extinction risk. By December 2011, the federal agencies will consult with the RIOG and identify opportunities and further processes to implement safety-net programs that could be used for each interior species. BPA is the primary agency for safety-net hatchery program implementation. Such actions may require additional approvals and NEPA reviews. The goal is to establish safety-net programs within one year at existing hatchery facilities where only minor facility modifications are needed.*

No scheduled action in 2010.

IV C. Long-term Contingency Actions*: 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 1-12 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:

- *Phase II Hydro Actions*
- *Reintroduction*
- *Predator Control*
- *Harvest*
- *Conservation Hatcheries*
- *Hatchery Reform*
- *John Day Reservoir at Minimum Operating Pool from April – June*
- *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 only action scheduled for completion in 2010 was completed on schedule. On March 31, 2010, the Corps completed the *Lower Snake River Fish Passage Improvement Study: Dam Breaching Update Plan of Study* (Plan of Study). The Plan of Study was coordinated with NOAA Fisheries and the other Action Agencies, and details the scope, schedule, and budget to complete technical studies and a decision-making process. The draft Plan of Study was provided to the regional sovereigns through the RIOG for review and comment, and was subsequently modified to incorporate comments into the final plan. The Corps published the Plan of Study at: *http://www.nww.usace.army.mil/amip/lsrfip/report/plan_of_study_final_03_30_10.pdf*

AMIP Category: Amendments

Amendment 1: *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 of this report.*

In 2010, a letter report summarizing the data from past multi-year, large-scale radiotelemetry studies related to the use of thermal refugia was written to help guide development of the final report (Keefer et al. 2010).

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 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.*

No scheduled action in 2010.

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 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 within 6 months following the establishment of a regional database and annually thereafter. NOAA anticipates having a regional database established no later than 2012.*

NWFSC staff are working with the Action Agencies on the development of a regional stream monitoring program (CHaMP) that includes year-round temperature monitoring at over 200 locations across the Columbia River basin. In addition, NWFSC is collaborating with the USFS's Rocky Mountain Research Station on the development and implementation of regional stream temperature monitoring protocols, a data management system, and modeling that will predict stream temperature for all reaches of the Columbia River basin.

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 in its efforts to use existing tributary habitat effectiveness studies, IMWs, and the NOAA enhanced lifecycle modeling to track climate change impacts. Starting in September 2011, the Action Agencies will annually provide*

NOAA 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.

No scheduled action in 2010.

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.*

No scheduled action in 2010.

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 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 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.*

NOAA Fisheries began working with hatchery operators to incorporate important new RME into their operations plans. Standard protocols for monitoring hatchery performance and for determining hatchery effects are a requirement in all operating plans. As a result, scientific uncertainties over hatchery effects, positive and negative, on ESA-listed fish are now being investigated at selected locations and annual reviews are being scheduled to compile and report the results of ongoing and new studies.

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Acronyms, Abbreviations, and Glossary

The "Action Agencies" refers to Bonneville Power Administration, the U.S. Army Corps of Engineers, and the U.S. Bureau of Reclamation.

AFEP	Anadromous Fish Evaluation Program
AHSWG	Ad Hoc Supplementation Workgroup
AMIP	Adaptive Management Implementation Plan
ASMS	Anadromous Salmonid Monitoring Strategy
AWS	auxiliary water system
BA	Biological Assessment
BACI	Before, After, Control, Impact
BGS	behavioral guidance screen
BiOp	Biological Opinion
BIT	Biological Index Test
BPA	Bonneville Power Administration
BRZ	Boat Restricted Zone
cfs	cubic feet per second
CIG	Climate Impacts Group, University of Washington; is developing climate change streamflows for the Columbia River Basin
CLT	Columbia Land Trust
COMPASS	Comprehensive Fish Passage Model
COP	Configuration and Operational Plan
CORIE	Columbia River Ecosystem pilot environmental observation and forecasting system
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
CRITFC	Columbia River Inter-tribal Fish Commission
CSS	Comparative Survival Study
CTCR	Confederated Tribes of the Colville Reservation
CTUIR	Confederated Tribes of the Umatilla Indian Reservation
CV	coefficient of variation
CWA	Clean Water Act
DART	Data Access Real Time
DET	data exchange templates
DMLT	Data Management Leadership Team
DPS	Distinct Population Segment
EDR	Engineering Design Report
EMAP	Environmental Monitoring & Assessment Program
EPA	U.S. Environmental Protection Agency
ERDC	Engineering Research and Development Center
ESA	Endangered Species Act
ESU	Evolutionary Significant Unit
FCAP	Fall Chinook Acclimation Program
FCRPS	Federal Columbia River Power System
FFDRWG	Fish Facility Design Review Workgroup
FGE	fish guidance efficiency
FOG	floating orifice gate
FOP	Fish Operations Plan
FPC	Fish Passage Center

FPOM	Fish Passage Operations and Maintenance
FPP	Fish Passage Plan
FTE	full-time equivalent
FWP	Fish and Wildlife Program
GBT	gas bubble trauma
GIS	geographic information system
GRTS	Generated Random Tessellated Sample
GSI	genetic stock identification
HGMP	Hatchery and Genetic Management Plan
HSRG	Hatchery Scientific Review Group
IDFG	Idaho Department of Fish and Game
IMW	intensively monitored watershed
ISAB	Independent Scientific Advisory Board
ISEMP	Integrated Status and Trend Monitoring Program
ISRP	Indpendent Scientic Review Panel
JBS	juvenile bypass system
JFF	juvenile fish facility
JSAT	Juvenile Salmon Acoustic Transmitter
kaf	thousand acre-feet
kcfs	thousand cubic feet per second
KMP	Kelt Management Plan
ksfd	thousand second foot per day; k = kilo = thousand; ksfd = 1,000 cfs (cubic feet per second) per day. kfsd * 1.98347 = thousand acre-feet
LCR	Lower Columbia River
LCRE	Lower Columbia River Estuary
LCREP	Lower Columbia River Estuary Partnership
LHD	Life History Diversity
LIDAR	light detection and ranging
LSRCP	Lower Snake River Compensation Plan
LWD	Large Woody Debris
M&E	monitoring and evaluation
maf	million acre-feet
MERR	Monitoring Evaluation and Research Report
MGR	minimum gap runner
MOP	minimum operating pool
MPG	major population group
NED	Northwest Environmental Data
NEPA	National Environmental Policy Act
NFH	National Fish Hatchery
NPCC	Northwest Power and Conservation Council
NPMP	Northern Pikeminnow Management Plan
NPT	Nez Perce Tribe
NTS	non-treaty storage
NWEIS	Northwest Environmental Information Sharing
NWFSC	Northwest Fisheries Science Center
NWRFC	Northwest River Forecast Center
O&M	operations and maintenance
OBMEP	Okanogan Basin Monitoring and Evaluation Program
ODFW	Oregon Department of Fish and Wildlife

PCSRF	Pacific Coastal Salmon Recovery Fund
PDT	Product Delivery Team
pHOS	hatchery-origin spawners
PH2	second powerhouse
PIT	Passive Integrated Transponder
PNAMP	Pacific Northwest Aquatic Monitoring Partnership
PNSHP	Pacific Northwest Salmon Habitat Restoration Project Tracking
POST	Pacific Ocean Survival Tracking Project
PRISM	Parameter-Elevation Regressions on Independent Slopes Model
PSMFC	Pacific States Marine Fisheries Commission
PTAGIS	PIT-Tag Information System
QA/QC	quality assurance/quality control
Reclamation	U.S. Bureau of Reclamation
RIST	Recovery Science Implementation Team
rkm	river kilometer
RM	river mile
RME	research, monitoring, and evaluation
ROD	Record of Decision
RPA	Reasonable and Prudent Alternative
RRS	relative reproductive success
RSW	removable spillway weir
SAR	smolt-to-adult return
SATURN	Science and Technology University Research Network
SB	Survival Benefit
SBT	Shoshone-Bannock Tribe
SFSR	South Fork Salmon River
SLED	sea lion exclusion device
SNP	single nucleotide polymorphism
SOR	System Operational Request
SRD	Sandy River Delta
SRWG	Studies Review Workgroup
STEM	Status Trend and Effectiveness Monitoring
SYSTDG	System Total Dissolved Gas
TAC	Technical Advisory Committee
TDG	total dissolved gas
TMDL	total maximum daily load
TMT	Technical Management Team
TRT	Technical Recovery Team
TSP	Turbine Survival Program
TSW	top-spill weir
UCR	Upper Columbia River
USDA	U.S. Department of Agriculture
USFS	U.S. Forest Service
USFWS	U.S. Fish and Wildlife Service
USGS	U.S. Geological Survey
VARQ	variable outflow flood control procedures
VSP	viable salmonid population
WDFW	Washington Department of Fish and Wildlife
WDOE	Washington Department of Ecology

WMP	Water Management Plan
WSF	Water Supply Forecast
YN	Yakama Nation

Attachment 1:

Literature review for 2010 citations for BIOP: Biological effects of climate change

Literature review for 2010 citations for BIOP:
Biological effects of climate change

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Table of Contents

1 Executive summary

Nationally and globally, the climate of 2010 continued trends of global warming, being one of the two warmest years on record. New analyses of observational data were generally consistent with previously reported historical trends of climate change. Climate, oceanographic, hydrologic, and stream-temperature models continue to be developed, tested, improved, and applied. Most of their assessments and projections indicated worsening physical conditions for salmon in mid-latitude regions, consistent with previous analyses: rising air temperature, moderately rising precipitation, declining snowpack, declining stream flow (partly due to water withdrawals), and rising sea surface temperature (although at reduced rates in upwelling regions). However, a few of the results could have either beneficial or negative implications for salmon. Historical analyses and predictions of net changes in primary productivity are spatially variable, and increases in the intensity of coastal upwelling (see below) could have positive or negative impacts. New studies on the biological effects of most of these processes were consistent with previous analyses, and showed that where salmon are limited by cool temperatures, warming is beneficial, at least over the short term, but in areas that are already relatively warm or where floods or low flows have negative impacts, climate change scenarios consistently project declines in salmon. In the ocean, several new studies pointed to the importance of sea surface temperature for early marine survival (as opposed to the Pacific Decadal Oscillation or smolt condition), but there were large differences among populations included in the study, and the single Columbia River population included did not show a strong ocean effect in this analysis (Sharma et al. 2009). The most geographically relevant papers include stream temperature analyses of the Boise River Basin (Isaak et al. 2010), the Wenatchee River Basin (Cristea and Burges 2010), and the Touchet Basin (Wiseman et al. 2010); and numerous climatological analyses of the Columbia Basin (see sections 4 and 5).

Several new papers documented historical and projected increases in upwelling intensity in the California Current (Bakun et al. 2010; Garcia-Reyes and Largier 2010; Wang et al. 2010). Although stronger upwelling has been positively associated with Columbia River salmon survival in the 20th century, Bakun et al. (2010) presented some possible scenarios (exacerbated by bad fisheries management) in which anoxia, toxic gas eruptions and jellyfish take over. Furthermore, although increased primary productivity predicted by some models would be expected to benefit salmon, most ecosystem models predict declines in salmon productivity south of the Arctic. Arctic conditions were expected to improve for salmon based on increased nitrate concentration (Rykaczewski and Dunne 2010), primary productivity (Kahru et al. 2010; Steinacher et al. 2010), and fisheries catches generally (Cheung et al. 2010; MacNeil et al. 2010).

A few emerging potential threats were documented for Fraser River salmon, with unknown potential for affecting Columbia River salmon. Algal blooms lowered survival of Chilko sockeye smolts (Rensel et al. 2010), and apparently increasing aggregations of sharks might be increasing predation on returning adults (Williams et al. 2010).

One other highly novel study found that gene flow increased during unfavorable river conditions, suggesting that straying might increase in response to rising temperatures (Valiente et al. 2010).

Three studies documented strong trends in salmonid phenology (one smolt-timing and two spawn-timing studies). Two of these studies also involved declining populations, and the authors suggested that part of the problem was a mismatch between rates of temperature change either in fresh- or saltwater (Kennedy and Crozier 2010) or between spring and summer (Wedekind and Kung 2010). In the 2010 BIOP we mentioned a trend toward earlier smolting in Snake River spring Chinook (Achord et al. 2007), so attention to potential phenological mismatches seem warranted. Several other studies attributed population decline more directly to environmental deterioration (Clews et al. 2010; Wiseman et al. 2010).

A large number of recent studies on Fraser River sockeye found negative impacts of high temperatures on adult migration survival and throughout the life cycle, and warned that a majority of populations within the Fraser River Basin are highly vulnerable to extinction due to climate change, based on both quantitative (Hague et al. 2011; Martins et al. 2011) and qualitative analyses (Jacob et al. 2010; McDaniels et al. 2010). McDaniels et al. (2010) considered possible management actions, but found they were limited. One study found individual variation in the use of thermal refugia during migration that depend on individual condition (Donaldson et al. 2010), while another study found that thermal refuge use corresponded to higher survival (Mathes et al. 2010). Disease morbidity and mortality is being exacerbated by warmer temperatures (Braden et al. 2010; Bradford et al. 2010; Marcos-Lopez et al. 2010) and artificial propagation (especially fish farms, Krkosek 2010; Pulkkinen et al. 2010).

Several theoretical papers described new mathematical methods of detecting impending extinction due to environmental deterioration (Drake and Griffen 2010; Ovaskainen and Meerson 2010) and elevated risks from environmental impacts at particular time scales and life stages (Worden et al. 2010).

Several studies demonstrated strong maternal effects on larval survival, compared with stronger genetic effects on juvenile growth and survival. These studies could possibly imply that negative effects of the hydrosystem could persist into the next generation, whereas evolution might modify juvenile growth and survival.

New studies provided additional details on adaptation strategies, such as those previously described in ISAB (2007), for Pacific salmon. For example, Cristea and Burges (2010) found that the cooling potential of riparian vegetation restoration is likely to postpone stressful temperatures for salmonids in Wenatchee River tributaries through the end of the century. However, vegetation restoration did not significantly reduce temperature in the mainstem Wenatchee. Such studies need to be site specific, because, for example, Null et al (2010) found that restoring and protecting cool springs was more beneficial than increasing riparian shading in the Shasta River. Several papers provided more information on adaptation strategies in general and the practical social and technical considerations for implementing them (e.g., Binder et al. 2010; Brekke et al. 2010).

In conclusion, new information from 2010 publications was generally consistent with previous analyses in reporting ongoing trends in climate consistent with climate change projections and negative implications for salmon at mid-latitudes. Modeling techniques continue to improve. A few studies focused on areas that did not receive much attention in our previous report, and thus provide new information. These areas include predicted and observed intensification of upwelling (compared with various similar and contradictory reports published previously), reduced salmon survival due to algal blooms, climate-induced straying, and climate change-induced mismatches in phenology associated with population declines. Numerous new studies of Fraser River sockeye warn of very severe risk from climate change. Finally, several theoretical papers augment our toolbox for anticipating extinction due to environmental deterioration.

2 Table of acronyms

AO	Arctic Oscillation
BPA	Bonneville Power Administration
CCS	California Current System
ENSO	El Niño-Southern Oscillation
ESU	Evolutionarily Significant Unit
GCM	General Circulation Model
IPCC	Intergovernmental Panel on Climate Change
NPI	North Pacific Index
NPGO	North Pacific Gyre Oscillation
NO	Northern Oscillation
OA	Ocean Acidification
PDO	Pacific Decadal Oscillation
SO	Southern Oscillation or Southern Annual Mode
SST	Sea surface temperature
VIC	Variable Infiltration Capacity model
WACCA	Washington State Climate Change Assessment
WRF	Weather Research and Forecasting

3 Goals and methods of this review

The goal of this review was to identify the literature published in 2010 that is most relevant to predicting impacts of climate change on Columbia River salmon listed under the Endangered Species Act. A large amount of literature related to this topic is not included, because almost anything that affects salmon at all relates to or is altered in some way by changes in temperature, stream flow or marine conditions. We have tried to identify the most directly related papers by combining climatic and salmonid terms in the search criteria. Thus many general principles demonstrated in other taxa or with more general contexts in mind have been omitted. This review also does not include potentially relevant gray literature, because the search engine used only includes the major peer-reviewed scientific journals. Additional references were solicited from NOAA staff and independent scientists. Shallin Busch contributed the ocean acidification section. In total, the methods employed involved review of over 800 papers; 227 are included in this summary.

This search was conducted in ISI Web of Science in June, 2011. Each set of search criteria involved a new search, and results were compared with previous searches to identify missing topics. The specific search criteria all included PY=2010, plus:

1) TS=(climat* OR temperature OR streamflow OR flow OR snowpack OR precipitation OR PDO) AND TS=(salmon OR Oncorhynchus OR steelhead);

2) TS=(climat* OR Temperature OR Precipitation OR streamflow OR flow) AND TS=”Pacific Northwest”;

3) TS=(marine OR sea level OR hyporheic OR groundwater) AND TS=climat* AND TS=(salmon OR Oncorhynchus OR steelhead);

4) TS=(upwelling OR estuary) AND TS=climat* AND TS=Pacific;

5) FT=(“ocean acidification” OR “California current” OR “Columbia River”)

6) TS="prespawn mortality"

The review is organized by first considering physical environmental conditions (historical trends and relationships) and then projections of future climate, snowpack, stream flow, temperature, ocean conditions, etc. A summary follows of the literature on salmonid responses to these environmental conditions, progressing through the life cycle.

4 National Climate Summary of 2010

Nationally and globally, 2010 was at or near record-breaking levels in many respects, based on NOAA's Annual State of the Climate Report (Blunden et al. 2011) Strong El Niño-Southern Oscillation (ENSO), Arctic Oscillation (AO), and Southern Annular Mode (SO) conditions drove very dramatic weather events in many parts of the world, while we emitted greenhouse gases at very high levels (above the average over the past 30 years). Trends consistent with global climate change reported in the 2010 Supplemental Biological Opinion (NMFS 2010) continued: 1) 2010 was one of the two warmest years on record; 2) average global sea surface temperature was the third warmest on record and sea level continued to rise; 3) ocean salinity variations at a global scale showed intensification of the water cycle; and 4) Arctic sea ice shrank to the third smallest area on record, the Greeland ice sheet melted at the highest rate and over the largest area since at least 1958, and alpine glaciers continued to melt.

5 Historical analysis of terrestrial climate, stream flow and stream temperature in the western US and British Columbia

A number of new papers have conducted historical analyses of trends over the past half century or so in air temperature (rising), precipitation (rising), snowpack (declining) and stream flow (declining). Trends in ocean conditions and El Niño events are discussed in the ocean section. These results are generally consistent with trends described in the 2010 Biological Opinion (NMFS 2010). Further, several papers have analyzed how broad-scale climatic conditions such as the Pacific Decadal Oscillation (PDO) and ENSO drive variation in processes with significant biological implications, such as drought, forest fire, landslides, and coastal fog.

Specifically, Fu et al. (2010) showed that in Washington State from 1952 to 2002, annual mean air temperature increased 0.61ºC (daily mean), 0.24ºC (daily maximum), and 0.93ºC (daily minimum), on average (or at a rate of 0.122, 0.048, and 0.185ºC, respectively, per 10 years). Despite increasing annual precipitation, stream flow decreased at a rate of -4.88 cms/yr, with the largest effects in May and June on the west side of the Cascade Mountains. Temperature increased throughout the year (except October and December) across the state, with a small area of maximum temperature cooling in the central-eastern portion of the state. Minimum temperatures rose more than maximum temperatures. To explain the declines in streamflow, the authors suggested that human water use and increased evaporation rates due to rising temperature and more surface area exposure (e.g., from reservoirs) play important roles. Ryu et al. (2010) showed a positive relationship between a drought index based on streamflow and El Niño in the Pacific Northwest. Bumbaco and Mote (2010) studied the role of winter and summer precipitation and temperature in causing three droughts in Washington and Oregon (2001, 2003, and 2005), and found a different driver in each case (low winter precipitation in 2001, low summer precipitation in 2003, and warm winter temperatures during key precipitation events in 2005).

Corresponding to the lower availability of water for biological processes, Meyn et al. (2010) showed that summer drought correlates strongly with the forest area burned in British Columbia. The PDO index the previous winter was related to summer drought in some areas of British Columbia, but is not a very strong driver over most of the province. Johnstone and Dawson (2010) tracked a new index of climate not mentioned in our previous report, which is the frequency of coastal fog along the California coast. They showed that fog levels are correlated with the strength of upwelling and have declined 33% from 1951 to 2008, increasing drought stress for plants.

Intense precipitation events, predicted to increase in winter with climate change, exacerbated by rain on snow events and high wind also increase the risk of landslides (Guthrie et al. 2010).

Average snow depth decreased widely across the western United States, especially at lower-elevation stations (<1000 m, Grundstein and Mote 2010). The vast majority of lower-elevation stations (80%) and a majority of mid-elevation stations (2000-3000m, 62%) showed significantly negative trends. Snow depth was strongly related to the PDO and the North Pacific Index (NPI).

Streamflow reflects both climatic factors and local habitat. For example, recent papers discussed the impact of glacier runoff and projected changes (quantified on Mt Hood by Nolin et al. 2010), and combinations of snow fall and forest integrity, whether due to harvest or fire. Specifically, Jones and Perkins (2010) studied how rain-on-snow events and harvest differentially affected different sized basins, while Eaton et al. (2010) examined changes in peak flows and the timing of the freshet, in addition to channel morphology following fire.

Wetlands are highly dynamic environments. Large scale variability in climate such as oscillations of the PDO can dramatically change local environmental conditions. After the regime shift of 1976, a wetland in southern California experienced a dramatic increase the frequency of extreme storms and floods due to a shift in the storm track across the Pacific. Zedler (2010) classified the types of events and their ecological consequences (mostly for plants) in terms of their relationships, for example, whether the ordering of events matters (e.g., river-mouth closure followed by a drought, that killed many more plants than additive effects would predict. They suggested focusing restoration actions on preparing ecosystems for likely future climates rather than restoring past communities necessarily.

6 Projected changes in terrestrial climate for the 21st century

Some of the most relevant projections of climate change conditions within the Columbia Basin were summarized in the 2010 BIOP based on reports produced for the Washington State Climate Change Assessment (WACCA), but were published in formal climate journals in 2010. In this category, Mote and Salathé (2010) described climate changes in the Pacific Northwest predicted by general circulation models produced for the Intergovernmental Panel on Climate Change (IPCC) fourth assessment report. Salathé et al. (2010) described changes predicted by the regional dynamical climate model Weather Research and Forecasting (WRF) Model. Elsner et al. (2010) summarized the regional hydrological implications of the global model predictions, and Mantua et al. (2010) described projected increases in peak winter flows, lower late summer flows, and high summer stream temperatures that will threaten salmon. A few other sections of the WACCA report were not mentioned in the BIOP, and are summarized in this report.

Predictions of how rising greenhouse gases will affect climate depend on how functional relationships are modeled. A large body of work describes tests and improvements of the climate models, and are mostly beyond the scope of this review. It is worth noting here that work is ongoing on many aspects with especially large levels of uncertainty at the moment, such as the extent of intra-model variability compared with inter-model variability (over half of the variation between models can be explained by variation within models, Deser et al. 2010), how the global circulation models drive ENSO variability (An et al. 2010) and regional downscaling -- i.e., how to convert the large-scale global model output (~200km^2 resolution) to the regional scale (~8 km^2 resolution, Ainslie and Jackson 2010). There are important differences in predictions made by different downscaling approaches. Qian et al. (2010) compare predictions from two dynamical downscaling methods, a subgrid parameterization and a regional climate model. They found that both methods greatly improved the modeled snowpack compared with observations over simpler downscaling methods, but the regional model captured precipitation and snowpack along the coastal mountains much better because of the importance of mountain orientation for wind direction. This model predicted a greater change in snowpack under climate change scenarios than the subgrid approach.

Predictions of changes in snowpack are very sensitive to how temperature changes with elevation. Minder et al. (2010) clarified spatial and temporal variation in the lapse rate in the Cascades, and Minder (2010) studied the effect of different determinants of the snow melting level in physical models. Minder (2010) predicted a loss of 14.8%-18.1% of Cascade snowfall per degree of warming, assuming precipitation increases, and 19.4%-22.6% loss per degree without precipitation increases, with profound impact on accumulated snowpack.

6.1 Stream flow

Many hydrological projections are based on the Variable Infiltration Capacity model (VIC). Wenger et al. (2010) conducted a test of this model in the Pacific Northwest. They found that model predictions were relatively accurate for center of flow timing and mean annual and summer flows, and the frequency of winter floods. However, modeled frequencies of low flows and groundwater-impacted streams did not match observations closely.

Chang and Jung (2010) projected the hydrology of the Willamette River Basin. They considered predictions from 8 general circulation models (GCMs), and downscale to 1/16th degree resolution for their hydrological model. Like previous projections, the models predicted increased winter flow, decreased summer flow, reduced snowpack, and earlier runoff. The different GCMs varied significantly in their predictions, especially later in the century. There was also substantial variation at the subbasin scale, indicating important local controls in hydrology. A new analysis by the Climate Impacts Groups for the Bonneville Power Administration (BPA) showed similar spatial variation, uncertainty, and general trends. This was a comprehensive study in draft form in 2010 (Brekke et al. 2010). It will be summarized more thoroughly in the 2011 report.

Three papers focused on changes in precipitation or hydrologic extremes. Tohver and Hamlet (2010) analyzed shifts in extreme streamflow statistics at 297 sites in the Columbia Basin, based on the Columbia Basin Climate Change Scenarios Project. First they described the same results previously reported: there was a general shift from weakly snow-dominant basins to transient basins, and from transient basins to rain-dominant basins, such that no snow-dominant sources remained in the US portion of the Columbia Basin by 2080, under the A1B scenario, and extremely few even in the highly optimistic B1 scenario. However, they found significant differences between the two downscaling methods employed in flood projections. The “hybrid delta” method predicted flooding increases throughout the Columbia Basin, whereas in Mantua et al. (2010) and the “composite delta” method, increased flooding is more spatially variable. The hydrid delta method is thought to be more accurate in this regard, reflecting the spatial distribution of warming and precipitation increases better than the composite method. Higher winter temperatures and precipitation regimes increase flooding most in transient and rain-dominant basins, but also in snow-dominant basins, despite the reduced accumulation of snowpack. Even greater increases in flooding could be caused by increasing spring storm intensity and more precipitation falling as rain rather than snow. Increased flooding in transitional and rain-dominated basins followed from increased winter precipitation. Low flow risk increased most in rain-dominant and transient basins due to rising summer temperatures and evapotranspiration rates. Snow-dominant basins, so important in the Columbia and Snake tributaries, were relatively resilient to this effect in this analysis possibly because the lowest flows tend to occur in winter, and they did not separate out summer low flows.

Rosenberg et al. (2010) examined precipitation extremes for stormwater infrastructure. They found that uncertainty in projections is too large to make engineering preparations, but that some potential outcomes could be very serious. Towler et al. (2010) similarly examined extreme precipitation events and secondary effects, in this case, turbidity, important for Portland’s water supply. They developed a technique for applying climate change scenarios to detect the impacts of predicted shifts in extreme events.

A study in California (Meyers et al. 2010) found that +2ºC and +4ºC climate warming and altered precipitation are likely to shift floods from spring to winter, and increase the frequency and intensity of floods. Such a change would negatively affect brook trout more than rainbow trout, which would then experience less competition from brook trout.

Another study (Moradkhani et al. 2010) explored climate change scenarios in the Tualatin River in Oregon using a different hydrological model and found that the 50-year floods and the riparian ecotone decreased in low emissions scenarios, but increased in high emissions scenarios. Thus well-established trees along the riparian corridor were flooded in the high-emission scenarios.

Some streams are currently fed by significant amounts of glacier meltwater. Nolin et al. (2010) studied a stream on Mt Hood that currently derives 41-73% of its late summer flow from glaciers. Under climate change scenarios, glaciers retreated, ultimately reducing summer flow.

7 Historical analyses and projections of ocean conditions

A number of studies published in 2010 provided insight into areas of profound importance for salmon that have been especially uncertain in prior climate change analyses. Two papers indicated that over the 20th century, upwelling in the California Current System (CCS) and the Humboldt Current System have become more intense, which is consistent with a new analysis of GCM projections that predicted it will continue to intensify with global warming. Papers focusing on historical sea surface temperatures (SST) addressed previous criticisms that observed trends are due to instrument bias, re-established the global pattern of decadal oscillations overlaid upon a background of rising SST, and documented the shifting character of El Niño events and their impact on long-term SST trends.

7.1 Upwelling

Upwelling dynamics along the Washington and Oregon coasts are a key element in Columbia River salmon marine survival and growth. The impacts of climate change on upwelling dynamics are among the most uncertain of all the predictions of climate change models. Conflicting predictions stem from 1) changes in the various driving processes that affect upwelling are expected to act in opposite directions, necessitating quantitative comparisons for determining net effects (i.e., rising SST should reduce upwelling, while increasing alongshore winds should increase upwelling) and 2) the spatial resolution of both climate models and empirical datasets have generally been too coarse to accurately capture upwelling dynamics.

Two papers published in 2010 basically supported the intensification prediction by documenting empirical trends over the 20th century, and a 3rd paper analyzed GCM reconstruction and projections of upwelling dynamics over the next century. Garcia-Reyes and Largier (2010) analyzed hourly buoy data off the California coast to describe the historical trend at an appropriate spatial and temporal scale. They found strong evidence for intensification of upwelling from 1982 to 2008, especially in central California (35ºN-39ºN). Specifically, they documented trends in the upwelling index (based on pressure fields), the strength of upwelling winds (based on alongshore wind speed), SST directly within the upwelling region (hence a negative trend in absolute temperature during the upwelling season), the number of days of upwelling within the season, a lengthening of the upwelling season (more days in March and October, hence earlier spring and later fall transition), and increased variability in upwelling winds (an increase in the 90th percentile and a decrease in 10% percentile), indicating stronger upwelling alternated with more relaxation in winds. They also found correlations of magnitude 0.6 or 0.7 between upwelling winds and the Northern Oscillation and the North Pacific Gyre Oscillation (NPGO), and between SST and the PDO and ENSO.

The second paper (Bakun et al. 2010) reviewed the basic argument that increasing land temperatures will intensify the pressure gradient between ocean and land, and hence intensify the alongshore wind stress, which initiates upwelling. Bakun et al. (2010) then reviewed previous tests of the hypothesis, and described a new test focusing on the relationship between water vapor and upwelling off Peru. This test showed significant correlations most of the time. Because water vapor acts as a greenhouse gas, they concluded this was consistent with a prediction of intensifying upwelling with rising greenhouse gas concentrations. One very important point they made in this paper, however, is that intensification of upwelling is not necessarily good for fish. They described scenarios in which excessive upwelling advects zooplankton offshore too quickly for effective phytoplankton control. If omnivorous fish such as sardines are overfished or not present for some reason, there could be an ecosystem regime shift toward that currently found off Namibia, in which unconsumed phytoplankton sink and generate hypoxic zones and toxic gas eruptions, which kill fish and leave an ecosystem dominated by jellyfish.

In the third paper, Wang et al. (2010) analyzed the performance of all the major GCMs produced for the 4th IPCC assessment using a number of criteria, including PDO variation across the Pacific and upwelling near the mouth of the Columbia River. Twelve of the 23 GCMs had a reasonable representation of the PDO over the 20th century (i.e., had a spatial correlation coefficient of the first Empirical Orthogonal Function of winter SST of at least 0.7). Half of these models predicted that SST would exceed the variability of the PDO within 50 years under the A1B emissions scenario (the reminder predicted it would happen within 90 years). Averaged over 10 models, SST in the CCS was expected to increase 0.26ºC per decade in the 21st century. Although the GCMs were not designed to characterize dynamics at the spatial scale of coastal upwelling, these models did remarkably well at capturing the seasonality of upwelling, even if they overestimated seasonal variation somewhat. Representation of the California Current was better than the Humboldt Current. In the CCS, 17 models predicted increases in July upwelling while only two models predicted decreases.

7.2 Ocean temperatures

Three studies analyzed historical trends in ocean temperatures. Carson and Harrison (2010) examined the impact of instrument bias in previously reported interdecadal trends at the ocean surface, 50m, 100m, and 300m temperatures. They found coherent signals of interdecadal variability at multiple depths, even with bias correction and comparisons of different datasets. This contrasts with recent work on the global average temperature, which showed reduced decadal variability after bias correction. Schwing et al. (2010) describe global atmospheric and oceanic teleconnections (e.g., the PDO, AO, NO, SO, and major current systems) and the major factors driving large marine ecosystems. Atmospheric teleconnections synchronize much of the decadal variability in the California and Humboldt Current Systems, as well as the Gulf of Alaska. Schwing et al. (2010) showed a persistent warming trend of 1-2ºC over 100 years in SST in all large marine ecosystems, although the rate of warming was weaker in the upwelling (or downwelling) dominated coastal region. The general patterns (overall trend and decadal fluctuations) were similar to global mean surface temperature, despite some regional differences. The western Pacific showed roughly similar trends, but lags behind the eastern Pacific by about 10 years, and was driven by quite different physical processes. Thus they predicted similarities among the eastern Pacific large marine ecosystems in responses to climate change, but less so between eastern and western Pacific large marine ecosystems. Another paper (Moore et al. 2010), made a very interesting point, which is that ENSO warm water events usually only affect winter temperature in Pacific Northwest waters, while the PDO warm phase often persists through summer and fall. This has important implications for the salmonid life stage that is affected by these events, which then has implications for impacts on population dynamics (Worden et al. 2010), as described below in the Population Dynamics Modelling Section.

Finally, Lee and McPhaden (2010) paper parsed out sea surface temperature increases in the central Pacific during El Niño events, and found that the increasing frequency and intensity of these events in this region drove most of the overall trend in sea surface temperature (SST). SST during El Niño events warmed by 0.24ºC/decade, whereas SST warming in neutral and La Niña years was positive, but much smaller (0.05-0.07ºC/decade) and not statistically significant over the 1982-2008 time frame. The reason for this shift in the position of the maximum warm anomaly is not known, but increasing intensity and frequency of El Niño events has been predicted to follow from rising greenhouse gases (Yeh et al. 2009), as cited in the 2010 Biological Opinion.

7.3 Ocean acidification

Two papers found that measured declines in pH near urban areas are faster than expected from CO_2 uptake alone and partially reflect nutrient loading (in the Hood Canal of Puget Sound, Washington, Feely et al. 2010; along the Dutch coast, Provoost et al. 2010). Wong et al. (2010) studied trends in pCO_2 in seawater along line P out from Vancounver Island, and found that it has risen in the oceanic zone at a rate of 1.36 μatm per year, tracking the atmospheric growth rate. The coastal zone pCO_2 rose at a similar rate in winter, but spring levels showed no trend.

8 Impact of stream temperature and flow on juvenile salmon

8.1 Effects of temperature on embryo development

There has been much concern that warmer winter temperatures will increase embryo mortality, cause ealier fry emergence, smaller fry size, and a mismatch between larval needs and food supply. In an experiment on coho survival, Lohmus et al. (2010b) found the optimal temperature for hatching and alevin survival was a relatively high 12ºC; they found substantial survival (40%) still at 16ºC, but very low survival at 18ºC (2.5%). In a review article, Teletchea and Fontaine (2010) found a strong positive relationship between egg size and larval energy reserves, and a strong negative relationship between temperature and time to first mixed feeding (i.e., requiring external food supply) among Pacific salmon. Thus although Pacific salmon have relatively large eggs and hence more flexibility in temporally matching food availability than other fish, higher temperatures are likely to produce smaller, less flexible fry. Janhunen et al. (2010) found that alevins hatched at the higher temperature were developmentally less advanced.

If either egg or larval survival is reduced under future climatic conditions, it is theoretically possible that they might evolve in response to selection. Several studies showed that populations from different climates have locally adapted development rates and thermal tolerances. Narum et al. (2010) found evidence of selection for differing climates by comparing genetic markers in redband trout: temperature was strongly correlated with allele frequencies. And Kavanagh et al. (2010) found evidence of local adapation to cool temperatures and reduced critical maximum temperatures in European grayling within 22 generations. However, Evans et al. (2010) and Janhunen et al. (2010) found similar results in Chinook salmon and Arctic charr, respectively, that genetic variation was relatively weak for embryo survival, but was slightly greater for larval length. Maternal effects were strong in both studies especially at the earlier developmental stages, indicating that adult migration and prespawn condition could have long-lasting effects through the next generation.

The effect of temperature during development might have more complicated effects beyond body size and emergence time. In sticklebacks, developmental temperatures and consequent compensatory growth affected skeletal and muscle morphology, with potential effects on locomotor performance (Lee et al. 2010). In zebra fish, brief exposures to cool developmental temperatures affected dorsal, anal, caudal, and pelvic fin positions, as well as gill cover and the position of the lower jaw (Georga and Koumoundouros 2010). It is not clear whether these shape changes have functional implications, but they were preserved through adulthood. Zabel et al. (2010) showed that different Chinook salmon ESU (fall vs spring/summer life history types) had different otolith/fish length relationships, demonstrating differences in morphology that are not simply explained by different growth rates. The populations do rear in very different environments, but the role of environmental temperature requires further study.

Other effects of high temperature during development include sex reversal. Magerhans and Horstgen-Schwark (2010) reported an experiment that showed that sensitivity to temperature in sex determination in rainbow trout is substantial and heritable. The initial population had a sex ratio of 51.9% female when eggs were reared at 18ºC, and 49.3% female when reared at 12ºC. After one generation of selection, they produced a sex ratio of either 57.6% or 44.5% female at 18ºC, indicating a heritability of 0.63 for this trait. Stelkens and Wedekind (2010) reviewed the various mechanisms of sex determination and sex reversal in teleost fish.

8.2 Effects of temperature and flow on juvenile growth and survival

Many papers have continued to demonstrate strong effects of temperature and flow on juvenile salmon growth and survival. Most papers are consistent in showeding improved growth when relatively cool habitat warms up: spring in Massachusetts, (Xu et al. 2010a), fall in Idaho (Jenkins and Keeley 2010); and a long-term trend of larger smolts in the Baltic (Vainikka et al. 2010). However, negative effects of warming were typical during summer (Xu et al. 2010b) and winter (Xu et al. 2010a), when consumption cannot compensate for increased metabolic demands. In northern Europe, the net effects are expected to still be positive except under the warmest climate change scenario examined (+4ºC). This prediction was consistent with observations of increased size at age over 23 years in Baltic Sea Altantic salmon, although hatchery practices and size-selective fishing also affect these populations. In more southerly locations, the negative effects were predicted to outweigh positive effects even in moderate warming scenarios (Xu et al. 2010a). Changes in growth rates might affect the timing of vulnerability to predators such as bass, which are very size selective (Christensen and Moore 2010).

Similarly, several papers showed that higher flow has positive effects when it is relatively low to start with (e.g., in spring in the heavily water-withdrawn Lemhi Creek, in fall in the more natural Marsh Creek, and higher spring flows in the Columbia for both populations of Chinook salmon (Arthaud et al. 2010), and throughout the brook trout growing season in Massachusetts, (Xu et al. 2010a), and in bringing in more insect drift to cutthroat trout in Jenkins and Keeley (2010), and increasing Atlantic salmon habitat volume (Teichert et al. 2010). However, the highest flows (floods) had negative effects (Hayes et al. 2010; Xu et al. 2010a). Hayes et al. (2010) found that relaxed density-dependent mortality over the following season compensated for the immediate negative effects on brown trout, thus there was no net effect in this case.

The rest of this section provides more detail on the papers mentioned in the previous two paragraphs. Xu et al. (2010a) tracked individual brook trout growth over an 8 year study. They found strongly interacting effects of temperature, flow, season, and density. Highest growth rates occurred in spring, and were positively correlated with temperature and flow. In the warmest season, summer, temperature was negatively correlated with growth. Flow was generally positively correlated with growth, except in winter. Furthermore, density had greater negative effects at high temperatures. Because current climate predictions indicated the greatest increases in temperature and flow are in the winter, and that flow decreases in the summer, the net prediction based on their data was a decrease in mean fish spawner size and fecundity under a moderate (1.5ºC) warming scenario.

Davidson et al. (2010) studied the same study system as Xu et al. (2010a), but analyzed Atlantic salmon growth instead of brook trout growth, and included the impacts of the density of both Atlantic salmon and brook trout. Using a linear mixed model, they found that environmental effects (both temperature and discharge) were much more important than density in driving variation in growth. Warmer temperatures within a season generally had a very small negative effect, while high discharge had a strong positive effect. Interestingly, they found that more variability in temperature (the second principle component in temperature) had a negative impact at low discharge, but a positive impact at high discharge.

Habitat quality depends in part on food availability and the cost of aquiring it, which in turn depend on flow and temperature. Jenkins and Keeley (2010) found that cutthroat trout foraging location matched that predicted by the amount of energy gained (net energy intake NEI), with habitat type (pool versus riffle) and temperature explaining most of the variation among sites. Using an energetic model, they concluded that warmer temperatures will have negative effects on smaller fish, but will lengthen the growing season for larger fish.

Hayes et al. (2010) used changes in the relationship between weight and density in a New Zealand brown trout population over time to assess the impact of unusually low flows and one flood on population dynamics. They argued that although the flood caused substantial emigration or mortality, survival after the flood was higher than in other years (i.e., reduced density-dependent mortality), such that the population recovered quickly. The low-flow events had no effect on survival or biomass.

Arthaud et al. (2010) examined how well variation in flow during freshwater stages affected egg-smolt and egg-adult rates in a pristine stream (Marsh Creek, Idaho) and a stream subject to very high rates of water withdrawal (Lemhi Creek, Idaho). In

Lemhi Creek, water withdrawals are so severe that spring flows during the parr year strongly limited production and drove variation in both egg-smolt and egg-adult survival. In Marsh Creek, egg-smolt survival was correlated with parr-year August flow, but the cumulative impact on egg-adult survival was much weaker. In both populations, smolt-adult return rates were best predicted by Columbia River spring flow and ENSO.

Rising temperatures increase not only the metabolic rate of salmonids, but that of their predators, and potentially the risk from warm-adapted invasives such as bass. Christensen and Moore (2010) documented levels of bass predation on stocked rainbow trout in Twin Lakes, Washington.They found that trout sizes in fall (100-160mm) made them vulnerable to predation by large largemouth bass, but larger trout (>210mm) escaped predation. This suggests that changing growth rates due to temperature might affect not just total predation, but also the temporal period salmon are vulnerable to bass predation.

Westley et al. (2010) considered the affects of dispersal of anadromous fish through lake systems and discover a consequent lag in the community response to environmental forcing, in addition to habitat change and fishing mortality. By examining fish composition over 46 years, they found an immediate response and a 1-year time lagged response to the PDO in an upper lake where sockeye rear their first year, but just a 1-year time-lagged response in a lower lake. They emphasized these processes are important for anticipating the impact of environmental variability on community composition.

Lohmus et al. (2010a) studied variation in juvenile growth among wild-type and growth-enhanced coho salmon at 3 temperatures. They saw little evidence of compensatory growth, perhaps because fish were fed to satiation, so rank order in size was relatively consistent throughout the experiment. The fish grew more at 16ºC than at 12ºC, which is consistent with previous studies that found 15ºC to be the optimal temperature for growth.

8.2.1 Local adaptation/genetic control in growth rates

Growth rate in general and the growth response to temperature in particular is a heritable trait, and several papers showed differences between populations consistent with a history of different selection pressures. Latitudinal gradients are especially useful for demonstrating evolutionary effects of different thermal regimes. In general, colder temperatures slow growth rate within populations, producing a latitudinal gradient of smaller size at age in cooler locations (Chavarie et al. 2010; Morita and Nagasawa 2010). However, over evolutionary time populations in cooler environments have compensated for this effect by evolving faster growth rates and better tolerance of adverse conditions at northern latitudes. Chavarie et al. (2010) demonstrated these higher growth rates in northern populations across 66 populations of lacustrine Arctic charr in eastern North America, although their anadromous forms did not showed the same strong effect. Finstad et al. (2010) showed that compared to southern Norwegian populations, northern populations of Atlantic salmon have adapted higher feeding activity and reduced metabolic expenditures to sustain them over a longer winter.

Although these patterns prove that fish evolve to different thermal regimes over long time periods, potential evolutionary responses to rapid climate change are a very different matter. Understanding the roles of phenotypic plasticity, genetic variability, and maternal effects controlling larval survival and fry growth is key to predicting plastic and evolutionary responses to climate change. In a carefully controlled breeding design plus translocation experiment, Evans et al. (2010) quantify the strengths of these various effects in Chinook salmon from Quinsam and Big Qualicum rivers. They found that all processes were important for explaining their results, but that maternal effects were the most important process for larval survival, while additive genetic effects dominated fry survival and fry growth. These results suggest that maternal condition is very important for cross-generational effects, and that there is substantial genetic variation available for an evolutionary response to environmental change.

Van Doorslaer et al. (2010) explored rapid evolution in Daphnia, which are a major prey item of lake-dwelling salmonids, to increased temperature through artificial selection. They compared these newly evolved populations to Daphnia from a historically warmer climate. After only six months of exposure to unusually warm conditions, size at maturity had evolved. In this semi-natural experiment, the intrinsic population growth rate did not evolve. However, in a previous study (Van Doorslaer et al. 2009a) they showed the reverse effect, where population growth rate evolved but not size at maturity, demonstrating that either response is feasible, depending on ecological conditions. Furthermore, another previous study (Van Doorslaer et al. 2009b) showed that *in situ* evolution might reduce the competitive advantage and hence likelihood of invasion of more southerly, warm-adapted genotypes.Thus rapid evolution is possible, at least in Daphnia and perhaps other planktonic prey of salmonids, but it remains to be seen how this will pan out in natural communities and longer-lived species like salmon.

8.2.2 The timing of growth

In addition to total growth in a season being important, the rate of growth early in the season can have complex repercussions for smolting decisions, negative consequences of compensatory growth, and the ability to capitalize on ephemeral resources with large potential benefits. By manipulating the timing of food supply for California steelhead, Beakes et al. (2010) confirmed previous work indicating that the decision whether to smolt in a given year is based on growth rates the previous year, and that early size advantages are maintained over the year. Lee et al. (2010) showed that in three-spined sticklebacks, compensatory growth after cool temperature-induced slow growth negatively impacted swimming endurance, especially when it occurred near to the breeding season. Armstrong et al. (2010) found that juvenile coho salmon in the Wood River system in Alaska can only benefit from eating sockeye eggs if they are large enough to swallow them. Because growth rates are very temperature-dependent, coho juveniles in warmer streams were able to exceed the 70mm size limit necessary for eating the highly nutritious eggs. This enormous nutrient gain led to a highly non-linear response of growth rate to temperature.

8.2.3 Assessment of survival and growth risks from climate change in European salmonids

Elliott and Elliott (2010) reviewed the temperature limits for European salmonids in regard to survival, feeding and growth. They did not found evidence of local adaptation (within species) in temperature tolerance, although there were marked differences in the upper thermal limits among species. They described the relationship between the North Atlantic Oscillation and emergence dates and adult return ages and rates. Using a growth model under climate change conditions, they predicted improved growth and earlier smolting in brown trout (age 1 instead of 2) except under the most extreme conditions (>4ºC), but suggested eggs of Arctic charr in some streams in southern Britain and Ireland might be at risk from high temperatures and low oxygen content. They noted several examples in which fish preferred cooler temperatures despite low oxygen levels over warmer temperatures with more oxygen, and emphasized the importance of maintaining deep pool refugia.

8.3 Behavioral and survival responses to winter conditions

Several papers described *in situ* behavioral responses to environmental conditions, especially concealment behavior and nocturnality. Winter (cold) temperatures tend to induce concealment behavior in both Grande Ronde River Chinook salmon (Van Dyke et al. 2010) and Oregon steelhead (Reeves et al. 2010), but Reeves et al. (2010) found that the response was stronger in a montane population than a coastal population. Reeves et al. (2010) also found an increase in nocturnality was more pronounced in winter in the montane population. Orpwood et al. (2010) found that riparian cover increased concealment and nocturnality in both summer and winter, regardless of food supply.

Linnansaari and Cunjak (2010) found that juvenile Atlantic salmon mortality or emigration over winter in New Brunswick, Canada was highest in early winter, before ice formation, and mortality was low during ice cover. They noted that this suggests that warmer winters that have shorter ice cover will not necessarily improve survival. Furthermore, they found that high discharge events and early maturation lowered apparent survival, although the latter might have been related to spawning-related dispersal.

One additional study (Pettersson et al. 2010) compared the suitability of different diets for aquaculture, but found that swimming ability at low temperature can be greatly impaired by an inadequate composition of fatty acids. This could have implications for wild fish if prey availability changes.

8.4 Juvenile residency, migration timing and straying responses to growth and environmental conditions

Life history diversity is a profoundly important issue in relation to environmental variability, both in facilitating a rapid response to directional environmental change and in maintaining bet-hedging strategies in case of unpredictable environmental conditions. One key trait in salmonids that is very sensitive to environmental conditions is the decision of whether to migrate to sea or not, and if they do migrate, when do they do it, and do they return to the natal rearing grounds to spawn or do they stray to a new location. Papers published in 2010 addressed all of these issues.

Johnson et al. (2010) showed that resident and migratory life-history forms of cutthroat trout were not genetically differentiated in two lower Columbia River tributaries (Abernathy Creek and the Chinook River). This study showed that resident and migratory families were not reproductively isolated, but not whether there is genetic basis to the behavior (a genetic basis has been found with brook and rainbow trout). Thus it is still not completely resolved whether the long-term trend in these populations toward residency is an evolutionary or plastic response.

Steelhead/rainbow trout also have significant variation among populations in the probability of migrating to sea. Satterthwaite et al. (2010) built on previous models to argued that reduced smolt survival is the most important vital rate that could drive anadromous populations toward residency. The next most important rate was freshwater survival and growth.

Reed et al. (2010a) also found a strong relationship between smolt size and timing and growth opportunities. They found that sockeye salmon outplants from the same hatchery smolted earlier and at a larger size when they reared in a more productive lake, despite negative density dependence. They also had higher marine survival.

Morita and Nagasawa (2010) focused on the rate of maturation of age 0+ males and females in relation to temperature and latitude within Japan. Masu salmon matured as parr at higher rates in warmer streams, and May stream temperature was the best predictor of maturation rates across 12 populations. Furthermore, masu matured at smaller sizes in warmer streams.

8.5 Freshwater ecosystem processes

A variety of studies explored the effects of changes in temperature and flow on freshwater plankton communities. For example, raising the temperature reduced mean body size and prevalence of smaller phytoplankton, and total phytoplankton biomass (but not zooplankton, Yvon-Durocher et al. 2010), affected trophic dynamics (predator impact) and carrying capacities in bacteria-protist mesocosms (Beveridge et al. 2010) and increaseed overall productivity (Stich and Brinker 2010). Variation in the seasonality of flow (increased winter and decrease summer flow) increased phytoplankton abundance (Jones et al. 2010).

Moore and Schindler (2010) showed that insects in Alaskan streams with large salmon populations have adapted to salmon phenology by developing faster than insects in non-salmon streams so that they emerge prior to spawning, and the enormous habitat disturbance salmon create by digging redds.

McDermott et al. (2010) studied the development of hyporheic communities in recently de-glaciated streams in Alaska. These communities were negatively affected by redd-digging.

9 Environmental impacts on salmon marine stages and marine ecosystems

9.1 Smolt timing and early ocean survival

When salmon migrate from fresh to saltwater, they must balance the opportunities and constraints in both habitats. As discussed above, growth rates strongly influence whether and when to smolt from a freshwater perspective, and better growth might lead to earlier smolting or larger smolts (or both, e.g., Reed et al. 2010a). Similarly, some interference with the natural growth or behavioral pattern by stocking at an inappropriate time can lead to delayed smolting (Skilbrei et al. 2010). Kennedy and Crozier (2010) showed a trend from 1978 to 2008 toward earlier smolting in wild Atlantic salmon in the River Bush, Northern Ireland. The emigration has shifted 10-14 days (depending on whether one tracks the start of the emigration or the peak emigration date), which correlates with the 5th day of river temperatures over 10ºC. Nonetheless, marine survival has declined dramatically (from 30-35% early in the time series to 5-10% more recently), which the authors attributed to increasing disparity between river and ocean temperatures. Thus despite apparent tracking of some thermal cue for smolting, river temperatures still increased too fast to avoid a potentially dangerous differential (2.5ºC) between river and ocean temperatures. It is not clear whether other aspects of marine conditions could be driving the population decline.

Smolt timing is well-known to be population-specific, presumably reflecting adaptation to the particular balance of trade-offs between freshwater and marine growth and survival at a given location. Spence and Hall (2010) analyzed the large scale geographic patterns in smolt timing across 53 coho populations from Alaska to central California, and found very strong geographic clustering of smolt timing, duration and variability with oceanographic zones. They suggested links to the predictability of ocean conditions. Because climate change might directly alter the timing of maximal ocean productivity and predictability, meaning specifically interannual variation in the optimal arrival time for smolts, these observations have important implications. Spence and Hall (2010) found that high latitude (mostly Alaskan) populations smolt relatively late, over a short temporal window, and with very little variability from year to year. They argued this is adaptive given the high predictability of the photoperiod-driven increases in productivity characteristic of the Arctic ocean. Southern populations (mostly Oregonian and Californian) that migrate into an ocean dominated by upwelling dynamics tend to enter earlier, but over a much larger temporal window. They argued that this is a bet-hedging strategy given the high interannual variability and unpredictability (from freshwater locations) of the spring transition. They also identified a third cluster in a transitional area mostly from British Columbia and Washington that were intermediate in smolt characteristics, and mostly migrated into buffered areas of Puget Sound and the Strait of Georgia. Although they also discussed alternative explanations and additional important factors, such as natal site elevation, migration distance, and watershed and stream size, these other factors are less likely to change with climate change.

What determines optimal ocean arrival timing is not well understood. Nonetheless, juvenile salmon survival is correlated with forage fish abundance, possibly because they provide alternative prey for predators. Zooplankton or food supply has also been identified as important. Kaltenberg et al. (2010) described the phenology and patterns of variability of forage fish and mesozooplankton populations near the Columbia River plume in 2008 and 2009. Kaltenberg et al. (2010) found a very sudden appearance in mid-May both years of large schools of forage fish which corresponded with similar sea surface temperature, salinity, and river flow (from the Columbia) each year. Zooplankton peaks occurred throughout the spring and summer as fronts passed over the sampling stations, and thus did not showed strong seasonality compared with the forage fish. Litz et al. (2010) found that forage fish switched from eating mainly dinoflagellates early in 2005, during the very delayed upwelling season, to a mostly diatom-based food source after the more normal upwelling season of 2006. They based this conclusion on lipid and fatty acid composition of the forage fish.

Chittenden et al. (2010) analyzed the survival of coho from Seymour and Quinsam Rivers, British Columbia 2007-2009, as a function of release date and marine plankton productivity. They found that coho stayed in the estuary during low marine productivity. Fish that arrived during zooplankton blooms passed quickly through the estuary and had the highest marine detection rates and smolt-adult survival (1.5-3x higher). The optimal time in both years was intermediate among the release groups.

MacFarlane (2010) measured growth in the San Fransisco Bay estuary and coastal ocean over 11 cohorts. They found that the first month following ocean entry was critical for subyearling Chinook. They found very little growth accrued in the estuary, but far better growth upon arrival in the ocean. Higher salinity and lower freshwater outflow produced better growth in the estuary, while cooler temperatures, lower sea level, and greater upwelling improved growth in the ocean. They concluded that climate change conditions would yield reduced growth.

Juvenile salmon presumably do not always encounter adequate food resources. To develop a reference point for interpreting the amount of deprivation that marine fish experience, Fergusson et al. (2010) conducted a laboratory starvation experiment and compared various indices of condition with that usually observed in wild-caught Southeast Alaskan chum salmon in 2003. They found that whole body energy content, percent moisture content, and condition residuals were better indicators of starvation than weight or length, and that after 10-15 days of starvation, laboratory fish fell outside the range normally observed in wild fish.

Two studies found that sea surface temperatures during the first year in the ocean best explained adult returns. Focusing on 24 stocks of northwest Pacific Chinook salmon, Sharma and Liermann (2010) found that the PDO and ENSO indices explained much less variation in recruitment than local sea surface temperatures, which were strongly affected by the strength of upwelling and hence reflected more information about ocean productivity than basin-wide average temperatures. They simulated the effect of a 1°C change in SST, and found a 13% decline in productivity on average across populations. However, the only one population from the Columbia River was included in this analysis, Deschutes River fall Chinook, and this population showed a minimal effect of ocean predictors (SST, PDO and ENSO). Saito et al. (2010) studied the factors that best predicted smolt-adult return rates of chum salmon in Nemuro Strait in Hokkaido, Japan, 1999-2002. They found that somatic condition and growth rates during the coastal residency period (first 2-3 months in the ocean) did <u>not</u> predicted adult returns. Instead, sea surface temperatures during the first year (especially winter) in the ocean and the size of smolts at release best explained variation in smolt-adult returns.

Petrosky and Schaller (2010) found that warm ocean conditions in March, reduced upwelling in April, and slower river velocity (or additional trips through powerhouses at dams) during the spring migration period were the best predictors of poor ocean survival for both Chinook and steelhead. They recommended increasing spill to help compensate for lower flows and poorer ocean conditions due to climate change.

9.1.1 Algal bloom lowers survival

Although most studies of early marine survival focused on food availability and predation, algal blooms can cause high mortality in Fraser River sockeye salmon. Rensel et al. (2010) found that earlier and larger spring and early summer Fraser River flows were linked to major blooms of harmful raphidophyte flagellate *Heterosigma akashiwo* in the Strait of Georgia. Chilko sockeye salmon survival declined from 10.9% in non-bloom years to 2.7% in bloom years.

9.2 Marine habitat usage

Several studies have focused on ocean habitat usage, especially thermal preference. NOAA scientists have documented a strong aversion to temperatures over 19ºC in the Columbia estuary. This is a strong limitation on habitat usage in the late summer, when juvenile salmon were once abundant (Dan Bottom, personal comm., technical reports). Peterson et al. (2010) synthesized 15 years of survey data to describe the distribution of yearling coho and Chinook salmon distribution and abundance in June and September (after leaving the estuary). The species differed in depth preference and distance offshore. Higher catches correlated positively with chlorophyll and copepod biomass in both species, and with temperature in Chinook salmon. Duffy et al. (2010) described Chinook salmon diet and habitat usage in Puget Sound. “At nearshore sites, insects (all months) and gammarid amphipods (July) were dominant prey sources, whereas in offshore diets decapods (primarily crab larvae; July) and fish (September) were most important.” They emphasized that the terrestrial sources of many of the prey items demonstrates an important link between waterfront landuse and salmon survival.

Based on trawl data, Morita et al. (2010a) found that larger and older adult sockeye, chum, and pink salmon inhabited cooler areas than smaller and younger salmon. Using this information, Morita et al. (2010b) developed a bioenergetic model explaining this pattern as a function of the optimal temperature for growth decreasing with body size, which was validated with a laboratory experiment. They concluded that the negative effects of climate warming on growth will be more severe for larger fish. Radchenko et al. (2010) described the results from surveys in the eastern Pacific, documenting the location of salmon and many other ecosystem components in 2009.

Using a combined bioenergetic-ecosystem model, Kishi et al. (2010) explained trends of declining body size in chum from 1970 to 2000 in terms of reduced densities of zooplankton and rising sea surface temperatures. They then characterized suitable potential ocean habitat for Hokkaido chum as 8-12ºC in the summer and 4-6ºC in the winter, based on survival studies and relationships between CPUE and SST. Using global circulation models to simulate global warming conditions, they predicted future distribution shifts: loss of habitat in the eastern North Pacific (Gulf of Alaska), and a northward shift in the Arctic Ocean. Furthermore, they predicted a lower carrying capacity in several areas. Finally, they predicted the current migration route to the Sea of Okhotsk will become unsuitable by 2050. Somewhat along similar lines, Genner et al. (2010) analyzed trends in size and abundance in the English Channel from 1911 to 2007, and found that smaller-sized fish fluctuated in abundance with temperature, showeding quick responses to environmental change. Larger-sized fish, however, showed persistent declines in the larger size classes and overall abundance, perhaps due to size-selective overharvesting.

9.3 Biological Implications of ocean acidification

Literature on how ocean acidification (OA) will affect marine species and communities is exploding, making a complete review beyond of the scope of this report. A recent meta-analysis of the impacts of OA on marine species indicated that there is significant variation in how sensitive marine species are to OA, and, if sensitive, what aspect of organismal biology changes in the face of low pH (Kroeker et al. 2010). However, in general, when all taxa are pooled, OA had negative impacts on survival, calcification, growth and reproduction (Kroeker et al. 2010). Here, we focused on laboratory experiments that explored the sensitivity of fish and salmon prey to OA.

Given the paucity of research, it is impossible to concluded whether the direct and indirect impacts of OA on salmon prey, as a whole, will be positive, negative, or neutral. Development timing of amphipods increased in response to low pH conditions, which may negatively impact population dynamics of this important food source (Egilsdottir et al. 2009; Hauton et al. 2009). Pteropod calcification rate declined with ocean pH, although pteropods can calcify below an aragonite saturation state of 1 (Comeau et al. 2010a; Comeau et al. 2009a; Comeau et al. 2009b; Comeau et al. 2010b). Pteropods in the laboratory survived without shells (Comeau et al. 2010a), though their ability to do this in the field is unknown. How OA affects pteropod population dynamics is also unknown, but energetic challenges (e.g., respiration rates) increase (Comeau et al. 2010b). A study on Antarctic krill indicated that OA is unlikely to affect the progression of early development until CO_2 levels exceed 1000ppm (effect observed at 2000ppm; Kawaguchi et al. 2011). Surface oceans may reach this level by 2100, though deep, cold water may exceed it sooner. The impact of OA on copepods varied with species and life stage, but includes evidence for increased nauplius mortality and decreased egg hatching rate (Kurihara and Ishimatsu 2008; Kurihara et al. 2004a; Kurihara et al. 2004b; Mayor et al. 2007; Pascal et al. 2010). In addition, high CO_2 levels countered some toxic effects of cadmium and copper ions on benthic copepods (Pascal et al. 2010). However, mercury and silver accumulation in *Loligo* squid paralarvae increased with CO_2 levels, which has implications for transfer of metals through food webs (Lacoue-Labarthe et al. 2011).

The role of gelatinous zooplankton in North Pacific ecosystems is steadily increasing. Analysis of time series data from the North Sea showed a negative correlation between gelatinous zooplankton and pH (Attrill and Edwards 2008; Richardson et al. 2009; Richardson and Gibbons 2008), although asexual reproduction and polyp survival in *Aurelia labiata* were not affected by OA in the laboratory (Winans and Purcell 2010).

The direct impacts of OA on salmonids are uncertain, especially because the species group spends its early life stages in fresh, not marine, waters. In the last BiOp, we reported no effect of pH 7.0 on *Salmo salar* mortality, growth, condition, metabolism, or plasma pH, hematocrit, sodium, or chloride (Fivelstad et al. 1998) and impairment of olfactory abilities in tropical clownfish (Dixson et al. 2010; Munday et al. 2009b). Recent research provides more insight on how fishes may respond (or not) to OA: 1) increased otolith size in some but not all species (Checkley Jr. et al. 2009; Franke and Clemmesen

2011; Munday et al. 2011a; Munday et al. 2011b), 2) erosion of auditory based behavior and induction of behavior linked with higher mortality due to predation in a tropical clownfish (Munday et al. 2010; Simpson et al. 2011), 3) decrease in aerobic scope in two tropical coral reef fishes (Munday et al. 2009a), 4) upregulation of some proteins in stickleback and cod and RNA expression in Atlantic herring (Franke and Clemmesen 2011), 5) no impact on early development (survival, growth, skeletal deveopment) in a tropical damselfish and Atlantic herring (Franke and Clemmesen 2011; Munday et al. 2011a).

Two recent modeling papers explored the ecological impacts of OA and other aspects of climate change. Ainsworth et al. (2011) predicted that ocean acidification may cause salmon landings to decrease in Southeast Alaska and Prince Williams Sound food webs and increase in Northern British Columbia and Northern California Current food webs. However, when the authors applied five impacts of global change to these food webs simultaneously (primary productivity, species range shifts, zooplankton community size structure, ocean acidification, and ocean deoxygenation), projected salmon landings decreased in all locales (Ainsworth et al. 2011). Incorporating ocean acidification and ocean deoxygenation into bioclimatic envelop models for harvested fishes in the Northeast Atlantic caused 20-30% declines in projected future harvest, likely due to reduced growth performance and faster range shifts (Cheung et al. 2011). This study is informative to Pacific salmon management as it indicates how changes in physiological performance of finfishes due to ocean acidification may impact harvested populations.

9.4 Ocean ecosystem effects

9.4.1 Evidence of changes in Arctic marine ecosystems

Of the global reviews of documented changes in biota that appear to be responses to climate change, very few have focused on marine ecosystems. Thus the review of the “footprint” of climate change in Arctic marine biota by Wassmann et al. (2010) fills a very important hole. Wassmann reviewed 13 studies of benthos, 9 studies of fish (5 on cod, 2 on pollock, 1 each for turbot and pipefish), 7 studies of birds (5 species), 9 studies of polar bears, 2 seals and 1 whale. Responses ranged from behavioral to growth to range shifts and community reorganization (Greenland cod and shrimp). Most observations are consistent with predictions from climate change simulations: increased primary productivity, declines in endemic, ice-associated species, and invasions or increases in more temperate zone species. One study documenting a change in primary producers was Kahru et al. (2010), who showed that the annual phytoplankton bloom maximum has advanced by up to 50 days in certain areas of the Arctic, with significant trends in 11% of the Arctic Ocean, primarily reflecting the reduction in sea ice. Bloom timing has also advance in the North Pacific.

9.4.2 Ecosystem models

Several very complex models explored the ocean ecosystem dynamics of climate forcing and climate change. Popova et al. (2010) focused on the Arctic Ocean under current conditions, and found that two key processes drove variability in primary production: the extent of winter mixing and short-wave radiation at the ocean surface, which controls phytoplankton blooms.

Two studies analyzed climate change simulations. Rykaczewski and Dunne (2010) used NOAA's Geophysical Fluid Dynamics Laboratory earth system model to study changes in nutrient supply and productivity of the California Current Ecosystem. They focused on nitrate because it is the main nutrient limiting primary production in the CCE. The model predicted a 2ºC rise in ocean temperatures across the basin from 1860 to 2100 under the SRES A2 scenario. They found weaker wind-stress curl, which reduced the strength of upwelling (and downwelling, in the subtropical gyre), but other changes produced a modest increase in upwelling. They note, however, that global models might not have sufficient resolution to fully represent upwelling dynamics. Despite increased stratification, they predicted an 80% increase in nitrate concentration by 2100 in the upper 200m of the CCE, but decreases elsewhere in the Pacific. The increased nitrate concentration in the CCE comes mainly from longer transit times of deep water that are subsequently upwelled.This water is also more depleted in oxygen (18%) and more acidic (0.5 pH units). This produced a net increase in productivity of 10% in the CCE presumably benefitting surface feeding fish, but more frequent hypoxic events threatening benthic and mid-water fauna.

Steinacher et al. (2010) compared four coupled global carbon cycle-climate models that incorporated marine biogeochemcial-ecosystem models. All four models predicted a decreasing trend in global net primary production and particulate organic carbon export. The models all predicted increasing temperature and stratification in all regions and increasing light in the Arctic where sea ice retreats. The high-latitude ocean retained sufficient nutrients to increase primary production and particulate organic carbon export (with increases in the Bering Sea). Nonetheless, they still projected declines in biomass throughout the north Pacific. They discussed differences among the models compared in quantitative predictions. Despite broad agreement on a regional scale, none of the models appear to do exceptionally well at modeling the coastal Pacific Northwest and Alaska (hence the upwelling-specific analyses described previously). Brown et al. (2010a) also predicted increases in primary productivity around Australia, benefitting fisheries and threatened turtles and sharks. They cautioned that the ecological benefit is sensitive to species interactions, which could reverse the benefit for some species.

Several studies in the San Francisco Bay estuary described complex physical and biological processes. MacNally et al. (2010) analyzed the factors affecting the decline of four pelagic fish in the San Francisco estuary. A combination of physical and food web driven factors suggested a diverse array of factors are responsible, but changes in freshwater flow and water clarity had strong effects. The results suggested a relatively good understanding of the ecosystem, but few management options. Cloern et al. (2010) described strong effects of the PDO and the NPGO on demersal fish, crabs and shrimp in San Francisco Bay. They emphasized the interconnectedness of the estuary in linking oceanography and watershed hydrology.

9.4.3 Seabirds, rockfish, and sharks

Several studies explored potential impacts of climate on seabird populations. Wolf et al. (2010) predicted 11-45% declines in Cassin's auklet in response to climate change. Ainley and Hyrenbach (2010) explored bottom-up and top-down drivers of a large number of seabird species in the California Current. Black et al. (2010) analyzed ocean drivers of seabird and rockfish dynamics, emphasizing the importance of February ocean conditions.

Williams et al.(2010) documented very large aggregations of 20,000 sharks in the western Queen Charlotte Sound, British Columbia in a 2004-2006 study. Although it is not absolutely certain that this is a new phenomenon, it has not been documented until recently, and they suggested that the aggregations might be a response to rising sea temperatures. The sharks might present a “feeding gauntlet” deadly for Fraser River salmon, that typically prefer the northern migration route through Queen Charlotte Sound during warm years.

In addition to sharks, other marine fish are likely to shift their distribution in response to rising ocean temperatures. In Australia, coral reef fishes usually limited by winter temperature are predicted to survive as far south as Sydney by 2080 (Figueira and Booth 2010).

9.5 Effects on fisheries

Cheung et al. (2010) combined models that predicted increases in primary productivity with bioclimatic envelop models of species distribution to predicted the impact of climate change on fisheries catch for 1066 species of fish and invertebrates (assuming the geographic location of the fishery doesn’t change). They predicted a 30–70% increase in high-latitude catches, including Alaska, a decline of about 10% in the contiguous US, and a drop of up to 40% in the tropics. MacNeil et al.(2010) similarly concluded that Arctic fisheries will benefit from invasions of southern species and increased primary productivity, while there will be species turnover in the temperate zone and significant losses in the tropics.

9.6 Review of hypotheses/frameworks for ocean climate forcing fish populations

Two papers present overviews of the prevailing physical and ecological hypotheses or conceptual frameworks currently in the literature on climate-ocean interactions. Ottersen et al. (2010) focused on three major oceanographic phenomena that drive variability in fish recruitment: temperature, mixing, and advection. They discussed the debate on bottom-up versus top-down population regulation, and trophic cascades, and the key role of forage fish as having both effects. They described immediate and delayed effects of climate, and factors that differentiate local climate drivers from large-scale climate processes such as the NAO and the PDO. They discussed direct, indirect, integrated (i.e., processes that occur over longer time scales than a particular extreme climate event) and translation (i.e., organism movement) effects of climate drivers. Any of these responses might be linear or nonlinear, at the individual or community level. They then detailed specific geographic regions and their particular climate-ecological dynamics. In the Northeast Pacific they emphasized ENSO and the PDO and biological responses. They finally discussed teleconnections and regional differences between the Atlantic and the Pacific.

Bakun (2010) reviews a number of different concepts of population regulation, such as the match-mismatch hypothesis, issues with schooling fish, and the predation risk-nutrient level trade-off (which he calls “loopholes”). Bakun emphasized three major physical processes that provided favorable conditions for fish: nutrient enrichment through upwelling or mixing, concentration through convergence or front formation, for example, and retention processes, such as eddies. Overall this paper emphasized that oceans are complex adaptive systems, and cautioned against assuming simpler concepts from the terrestrial literature adequately capture their complexity.

10 Impact of temperature and flow on adult migrants

10.1 Migration bioenergetic cost

Upstream migrating salmon face several additional stresses due to climate change. Most importantly, rising temperatures increases the metabolic cost of swimming and holding prior to spawning. Cumulative energetic costs or acute thermal stress also increase prespawn mortality. Several papers studied the bioenergetics of migration, which are relevant for calculating these costs. Clark et al. (2010) developed a biologging tag technique for measuring energy expenditure and heart rate in actively migrating sockeye. Cook and Coughlin (2010) found that rainbow trout alter their kinematics around obstructions in the water in a way that improves their efficiency. Forgan and Forster (2010) explored the physiology of oxygen consumption in different tissues. Nadeau et al. (2010) analyzed the relative costs of swimming in the lab against low and high flows that span much of the range typical for Fraser River sockeye. They found that higher flows elevated stress, but not mortality. However, overall females had higher mortality than males. Roscoe et al. (2010) studied the behavior of natural migrants through a lake with cooler bottom water. They found that more mature females with lower energy content preferred the cooler water, while other females and males showed less preference. They posited that use of the thermal refuge slowed maturation and helped maintain energy reserves.

10.2 Migration survival and timing

Migrating upstream is an energetic and thermal bottleneck for many salmon populations. New papers clarified the role of temperature in stimulating upstream migration in a very warm river (the Klamath), and the relationship between timing, temperature, flow, and survival in the cooler Fraser River. Projections in the Fraser River of the consequences of warming over the next century are especially dire.

In the Klamath River, Strange et al. (2010) found that Chinook volitionally migrated through much warmer water than previously thought. Chinook initiated migration at 21.8-24ºC. These high river temperatures produced a mean average body temperature of 21.9ºC, and mean average maximum body temperature of 23.1ºC over the first week of the migration. These temperatures usually cause migration blockages in the Columbia River, but apparently reflect adaptation to the much warmer conditions in the Klamath. Declining temperatures triggered migration, even when the river was still very hot. It is not known whether these fish experienced high prespawn mortality or reduced fecudity or fertility. In the Fraser River, several new papers showed a positive correlation between river temperature and mortality. MacDonald et al. (2010) developed a forecasting model for fisheries managers to facilitate real time predictions of migration survival for various groups of populations. They found that temperature, flow, the timing of entry relative to the average for that population, and fish abundance were good predictors of migration survival. Interestingly, the best predictors did not necessarily match the *a priori* prediction based on the absolute environmental conditions. For example, temperature was an important predictor for Early Stuart sockeye, even though these fish encounter relativley lower temperatures than other fish. The authors point out that these fish still encounter high temperatures upstream, and that they might have lower thermal tolerances than other populations.

Several papers simulating future conditions in the Fraser River predicted signficant declines in sockeye salmon. Hague et al. (2011) found that a 1.0 °C increase in average summer water temperature tripled the number of days per year exceeding critical salmonid thermal thresholds (i.e. 19.0 °C). Martins et al. (2011) found evidence of thermal stress-induced mortality during the migration in three of the four stock-aggregates examined. Under warming scenarios, migration survival in these stocks was projected to decline 9-16%.

Particular attention has focused on the unusual behavior among some Fraser River sockeye populations of migrating much earlier than the historical norm. The early migrants experience much higher temperautres than normally-timed fish, and have significantly lower survival. Mathes et al. (2010) found that early migrants that utilized cool lake habitat as a thermal refuge during their migration had much higher survival than fish that took the river corridor directly to spawning grounds. The early-entry river migrants accumulated extraordinarily high cumulative temperatures and none survived. The early-entry lake migrants had similar cumulative thermal exposure to normally-timed fish that stayed in the river, and similar survival. Donaldson et al. (2010) compared physiological responses to stress (gillnet capture), migration rate and survival in Adams-Shuswap and Chilko populations. The unusually early migrants of the former migrate at the same time as the normal-timed migrants of the latter population. They found delayed effects (near spawning grounds) on survival that differed between the populations. Although the two groups had similar physiological condition when they entered the river, survival among the early-entry Adams-Shuswap group correlated with migration rate (slower migrants had lower survival) and physiological condition (metabolic and osmoregulatory impairment), but not among the Chilko fish.

In the Columbia River, Jepson et al. (2010) studied the migration timing of fall Chinook. They found clear differentiation between the Upper Columbia River and Hanford Reach populations, but Deschutes, Yakima, and Snake River populations migrated throughout the season. They also found harvest was concentrated in late August and early September, and preferentially selected larger fish.

10.2.1 Traditional tribal knowledge and effects of climate change on migration survival and timing

Jacob et al. (2010) described the effects of changes in the salmon runs on native people, and the very serious long-term implications of climate change for both people and fish. Through interviews, they identified changes in salmon abundance (diminished), timing (later in summer and fall), and condition (much less healthy, both in fat content and disease prevalence) from people's recollections of traditional conditions. They discussed potential adaptations, but predicted relatively poor prospects for both people and fish.

11 Impact of high temperatures on prespawn mortality and spawning behavior

11.1 Diseases

The prevalence and virulence of many diseases in fish are much more severe under warmer conditions, and several papers reported disease spread over recent years. Marcos-Lopez et al. (2010) reviewed the increasing risk from a number of diseases (e.g. enteric red mouth, furunculosis, proliferative kidney disease and white spot) due to climate change. The risk from some exotic pathogens that prefer cool water declines (e.g., viral haemorrhagic septicaemia (VHSV), infectious haematopoietic necrosis virus (IHNV) and spring viraemia of carp virus (SVCV), while the risk from warm-loving exotic pathogens (epizootic haematopoietic necrosis and epizootic ulcerative syndrome) increases. They recommended revising management actions to control disease to take into account changing risk levels due to climate change.

Braden et al. (2010) reported spread of proliferative kidney disease (PKD) in natural populations of pink salmon in Quinsam river, Vancouver Island. Bradford et al. (2010) reported widespread prevalence (70% of samples) of the myxozoan parasite *Parvicapsula minibicornis* throughout the Fraser River watershed, and a very advanced stage of infection in most fish on spawning grounds. Ray et al. (2010) quantified levels of *Ceratomyxa shasta* that kill juvenile Chinook salmon in the Klamath River, improving our understanding of this disease. Tonteri et al. (2010) found selection on immune related genes more common than selection on non-immune-related genes in Atlantic salmon, and that allelle frequencies were related to temperature and latitude, suggesting an important role of climate in driving this selection pressure.

Although not directly related to climate change, Koel et al. (2010) reported that Great Blue herons are viable vectors of whirling disease, which affects salmonids in 25 states. Krkosek (2010) warned that sea lice are an increasing threat from farmed salmon in the Pacific, and that the abiotic and biotic factors affecting this disease are not well studied. Pulkkinen et al. (2010) found that fish farms actually select for more virulent strains of *Flavobacterium columnare*, a disease exacerbated by warmer temperatures.

11.2 Prespawn behavior and mortality

Keefer et al. (2010) documented a strong correlation between prespawn mortality in Willamette River Chinook and water temperature and fish condition. Mortality ranged from 0-90%, depending on year and release group. Fish in poor or fair condition had twice the mortality risk of fish in good condition. These fish were transported above a dam, and thus do not represent a natural migration. Nonetheless, they do reflect a dramatic increase in risk due to high temperatures.

Young et al. (2010) found that over summer, brown trout adults in New Zealand tended to hold in deep pools, and only moved during higher flow events and cooler temperatures (below 19ºC). A severe flood killed 60-70% of the tagged population.

11.2.1 A correlation between gene flow and the NAO

Valiente et al. (2010) addressed the population genetic consequences of increased male parr maturation in response to climate change. In addition to describing effects on maturation, they discovered a strong pattern in straying. Specifically, they found a strong correlation between the North Altantic Oscillation Index and immigration from a neighoring stream. I believe that this is the first study system to document this phenomenon, and hence is especially interesting. They found that straying increased linearly when conditions in the natal stream deteriorated (became too warm). This paper is also especially notable in referring specifically to adverse conditions induced by global warming at the southern edge of a species range.

11.3 Spawning behavior

The timing of reproduction is often crucial in determining successful population growth. How climate change will affect spawn timing raises concern because of high risks of prespawn mortality with lengthening freshwater residence, extreme sensitivity of eggs to high temperature (compared to other life stages), and the potential for a mismatch between emergence suitable environmental conditions for fry. Two studies documented long-term shifts in spawn timing in freshwater fish. Wedekind and Kung (2010) showed that European grayling have advanced their spawn timing by more than 3 weeks since 1948, which they attributed to rising temperature. However, a difference between spring and summer warming rates exposed fry to inappropriate temperatures, possibly contributing to population decline. Schneider et al.(2010) showed that walleye are now spawning up to 2 weeks earlier throughout Minnesota (26 populations), with a 0.5-1 day advance for every 1 day advance in ice break up.

Several studies explored the stimulus for spawning. Wilkinson et al. (2010) experimentally manipulated temperature and photoperiod for rainbow trout, and found that under natural photoperiods, elevated winter-spring temperatures only slightly increased maturation rates. Under advanced photoperiod, temperature had a much larger relative effect, but the overall maturation rate was much lower. O'Malley et al. (2010) studied the genetic basis of variation in spawn timing. They compared geographical variation in a gene (OtsClock1b) associated with photoperiod among 53 populations of chum, coho and pink salmon. Combined with a previous study of Chinook salmon, they found that daylength at spawn timing explained much of the variation in allele frequencies of OtsClock1b in chum and Chinook, but not coho and pink salmon.

In addition to affecting juvenile survival and migration success, temperature and flow affect access to and quality of spawning sites. Taylor et al. (2010) documented the distribution of redds over 12 years in a Nova Scotia stream in relation to the timing and intensity of fall rains and beaver dams. They found that stream usage by salmon was linearly related to precipitation, except when blocked by beaver dams. Moir and Pasternack (2010) described a strong positive relationship between substrate coarseness and faster flow in Chinook salmon spawning site selection, demonstrating interactions between habitat characteristics that are not always included in habitat suitability analysis.

12 Direct heat stress

Several papers studied direct heat stress, population variation in heat tolerance, and its genetic basis. Bellgraph et al. (2010) found that juvenile Chinook salmon survived temperatures up to 23.2ºC. The fish increased swimming behavior and heart rate under higher temperatures. Brook char reduced swimming performance at temperatures over 15ºC, especially in combination with ammonia (Tudorache et al. 2010). Feldhaus et al. (2010) found that redband trout amplify production of heat shock proteins (hsp70) between 19 and 22ºC, indicating thermal stress. Healy et al. (2010) studied the genetic basis of variation in the heat shock response in killifish, and found a fairly complicated pattern. They concluded that variation among subspecies must be due to more than simple upregulation of a particular regulator, but involves evolution in a variety of genes. In a comprehensive review, Pankhurst and King (2010) explained the physiological processes mediating the negative effects of high temperature on reproduction.

Sublethal temperature effects interact with other stressors. Boyd et al. (2010) found higher mortality after catch-and-release under elevated temperatures in the evening in rainbow trout. A very large fish kill (25,000 carp) occurred in the St. Lawrence River in 2001, which Ouellet et al. (2010) attributed to a combination of high air temperature and low flow, which depleted oxygen in the lake. They also discussed indirect effects of long-term stress, such as immunosuppression.

Pörtner (2010) reviewed the concept of oxygen supply to the tissues being the fundamental process that determines thermal windows, and as a means for understanding the synergistic effects of multiple stressors. Ocean hypercapnia and acidification interact with warming temperature to further reduce oxygen availability. On the other hand, exposure to high CO_2 also depresses metabolic rates, which might help tolerate reduced availability of oxygen.This fundamental process is general, and hence not species-specific. Seebacher et al. (2010) made an analogous argument that the fundamental limiting factor is cellular damage from the production of reactive oxygen byproducts of metabolism.

13 Higher-level processes

13.1 Population-dynamics modeling

Key to understanding the factors regulating salmon populations (which is essential for predicting effects of climate change) is an appreciation of how different scales of variability interact with the internal periods of variation inherent in populations with overlapping generations. Worden et al. (2010) studied the frequencies of population variability as a function of 1) environmentally-induced variation in survival in the first ocean year only, 2) environmentally-induced variation in survival in all ocean years, and 3) environmentally-induced variation in the age at reproduction. They considered these effects within the larger context of increased variability due to fishing mortality, and different censusing techniques. They found different patterns of fluctuations in all the different scenarios explored. Salmon are more sensitive to some time scales of environmental variability than others, and with fishing they are doubly sensitive to low frequency environmental variability. Long-term changes in climate could thus interact with additional fishing-induced variability to induce fluctuations that pose much greater risks of population collapse than that induced by reduced abundance alone.

Two papers focused on the mathematical properties of population decline to extinction when environmental factors are driving the decline, and provide tools for identifying this trajectory. Drake and Griffen (2010) identified an early warning signal that anticipates a tipping point, beyond which extinction is almost inevitable. The early warning signal is a “critical slowing down”. They demonstrated the statistical properties of this signal using an experimental Daphnia population. A reliable baseline prior to environmental degradation is crucial for successful application of this technique. Ovaskainen and Meerson (2010) reviewed recent advances in theoretical physics that characterized the properties of stochasticity useful for determining mean extinction times under various conditions.

Animals often compensate for environmental variability through phenotypic plasticity, i.e., modifying their behavior or physiology in response to environmental conditions. Reed et al. (2010b) focused on the adaptiveness of phenotypic plasticity. Specifically, they demonstrated that plasticity is only adaptive when there is a reliable cue that anticipates environmental conditions. When the cue becomes less reliable (which might result from different aspects of climate changing at different rates, for example), plasticity shifts from being adaptive to increasing population extinction risk. They emphasized that population models will need to explicitly incorporate plasticity to include this potential effect.

13.2 Population-level effects

13.2.1 Population declines attributed to climatic factors

Clews et al. (2010) studied how environmental variation correlated with population fluctuations of Atlantic salmon and brown trout in Wales from 1985 to 2004. Local catchment processes were not useful in explaining population decline, but broader scale climatic variables correlated strongly with population densities. They found that weather conditions in the previous summer explained most of the variation. Specifically, a principle component analysis showed that reductions in density were highest following hotter, sunnier, and drier conditions. Over the course of the study, summer stream temperatures were estimated to have increased by 0.5ºC in headwaters and 0.6ºC in larger tributaries, and in winter by 0.7ºC and 1ºC, respectively. This amount of warming could explain on the order of a 40% decline in density (or ~3-3.5 fewer salmon per 100m^2), based on the principle component score (which also includes discharge). Winter warmed more than summer due in part to trends in the NAO, but was not strongly correlated with salmon abundance. The similarity in response between the anadromous salmon and freshwater resident brown trout indicates that freshwater indices are either driving the declines in both species, or are correlated with ocean phenomena in salmon.

After a comprehensive physical and biological assessment, Wiseman et al. (2010) found that warm water tempeature and sedimentation were the primary drivers of habitat decline in the Touchet River in Washington, contributing to contraction of spring Chinook, summer steelhead, and bull trout.

Robinson et al. (2010) reported that stressful summer temperatures (determined by cumulative degree days over 20ºC measured at the bottom of an Adirondack lake) reduced stomach fullness, reproductive activity, and survival of brook trout over one year old, and especially fish over two years old. Like Crozier et al. (2010), they found a positive correlation between temperature and growth at low fish density, and a negative correlation at high fish density.

13.2.2 Expert judgment of overall risks to Fraser River sockeye

A synthetic, expert-opinion analysis of the threat of climate change over the entire life cycle of Fraser River sockeye salmon (McDaniels et al. 2010) found that the cumulative threats are very high. A substantial proportion of responses indicated the fish were highly vulnerable (the highest threat level) at all life stages except the overwintering fry stage. They identified the most vulnerable life stages to be the egg and returning adult stage for populations throughout the Fraser River drainage, especially under a +4ºC warming scenario. They also considered the prospect of reducing the threat through management quite limited.

13.2.3 Paleological perspective

Finney et al. (2010) conducted a major review of the paleological literature on fluctuations in fish abundance (including salmon) over thousands of years. The most relevant topics focused on positive correlations between SST and salmon abundance in Alaska both recently and over most of the past 300 years and again over 2500 years based on sedimentary collection of marine-derived nitrogen carried into freshwater by anadromous salmon. Anomalies in the SST-salmon correlation occurred in several sections of the long-term record, which the authors attributed to changes in ocean-atmosphere circulation during these periods, producing alternate patterns of North Pacific climate variability relative to the PDO and variation in the Aleutian Low. The longer time series showed a bimodel pattern of fluctuations between low and high abundance, with high abundance during the 1250-1890 AD cooler period of the Little Ice Age. This suggests different longer term patterns than suggested from recent data. They also discussed patterns driving anchovy, sardines, and other major ecosystem players throughout the world, and synchronous shifts in all ecosystems. However, specific relationships varied across the time series between in-phase and out-of-phase correlations, indicating alternative modes of climatic forcing of ecosystem dynamics.

13.3 Trends in phenology worldwide

Worth noting here is that phenological responses to climate change have been observed across all taxa, worldwide. A new review out in 2010 (Thackeray et al. 2010) assessed 25,532 rates of phenological change for 726 UK terrestrial, freshwater, and marine taxa. Most taxa showed earlier spring phenomena at rates higher than previously reported. They separated out taxa at different trophic levels, and found that secondary consumers were responding the slowest, and hence were at most risk of a mismatch in timing between predator and prey. Because this trend was so widespread and not restricted to individual species, it highlights a growing risk of the disruption of ecosystem function and services.

14 Habitat

14.1 Stream flow habitat models

Quite a few papers used models of stream flow (or temperature, covered in the next section) to quantify habitat availability for salmonids. Hilker and Lewis (2010) developed a theoretical model of how water velocity affects potential prey populations subject to advection and diffusion downstream, and the minimum flow requirements for drift-feeders like juvenile salmon. Cover et al. (2010) examined the impact of debris flows and debris floods on headwater stream communities. They found that debris flows raised stream temperature, reduced large wood and benthic communities and most vertebrates, with the exception of rainbow trout, which were abundant in recent debris-flooded areas. Escobar-Arias and Pasternack (2010) developed a functional flows model based on shear stress dynamics to characterize fall Chinook spawning habitat; the model could be parameterized for other species. High flow events provided access to new habitat, which can have both positive and negative impacts on salmon. Access to a floodplain that contains pollutants could be detrimental for juvenile salmon. Henery et al. (2010) showed that growth was higher in free swimming Chinook that utilized the Yolo Bypass floodplain than fish that stayed in the Sacramento River, but that the fish in the floodplain accumulated 3.2% more methylmercury per day than fish in the river.

A large group of scientists worked on a new framework for assessing environmental flow needs for many streams and rivers simultaneously to foster development and implementation of environmental flow standards at the regional scale (Poff et al. 2010), and this can be a basis for initiating an adaptive management program.

14.2 Thermally-suitable habitat models and trends

Enhancing riparian vegetation is a major conservation tool recommended for reducing maximum stream temperatures. Two studies showed strong empirical effects of vegetation on stream temperature. In response to high temperature-induced disease-related fish kills, Roth et al. (2010) developed a physical model of stream temperature in Switzerland. They found that existing vegetation (mostly in-stream reeds) lowered the expected temperature by 0.7ºC, but a further decrease of 1.2ºC could be achieved by a mature riparian forest. Brown et al. (2010b) found that coniferous forest plantations lowered summer temperatures in a comparison of 3 forested and 3 moorland sites in northern England.

Statistical models of stream temperature have been used to quantify habitat area that meets particular criteria for species of interest, and to track trends in habitat area over time. Larnier et al. (2010) developed and compared models to identify conditions in the Garonne River in France that are thermally stressful for salmonid migration and survival. Isaak et al. (2010) developed a spatial autocorrelation model to predicted stream temperature throughout the 2500 km^2 upper Boise River Basin in Idaho based on temperatures measured at particular sites. The model performed well against observed temperatures. Historical analysis showed a trend of mean basin stream temperature from 1993 to 2006 rising at a rate of 0.27ºC/decade, and maximum temperatures rose by 0.34ºC/decade. They detected a strong thermal signature of wildfires in the basin: stream temperatures in affected reaches rose 2-3 times more than the basin average due largely to increases in radiation. Rising temperatures shifted rainbow trout habitat to slightly higher elevations but caused 11-20% loss of bull trout habitat.

High temperature already threatens some populations in warmer climates. Null et al. (2010) explored restoration alternatives to migitate stressful temperatures in California's Shasta River. They found that a focused on restoring and protecting cool springs provided the most benefit for salmon (much greater benefit than increasing riparian shading, for example). This conclusion might apply to regions anticipating increasing temperature stress.

14.3 Habitat projections

Wiley et al. (2010) developed a series of models to explore the effects of land cover and climate change on fish habitat in the Great Lakes. They found very significant climate change impacts, and that these impacts were very sensitive to land management. Increasing forest cover and limiting urban development had very large impacts on projected flows, temperatures, and consequently modeled fish habitat. Nonetheless, even the best-case land use scenarios involved destabilization of 57%-76% of the channel system by the end of this century due to increasing rainfall and discharge rates. Summer temperatures rose sharply, with severe consequences for cold-water fish. They projected a loss of ~74% of adult Chinook habitat (but little impact on juvenile Chinook habitat), and the reverse for steelhead: a loss of ~50% of juvenile steelhead habitat, but only ~15% loss of adult habitat. They projected large benefits of climate change for smallmouth bass and walleye.

Several papers explored the potential for riparian vegetation to mitigate future warming. Cristea and Burges (2010) explored climate change impacts in the Wenatchee watershed, a tributary to the Columbia River. They found greater potential for mitigation in smaller tributaries (-1.5ºC in Icicle Creek and -2.8ºC in Nason Creek) compared with the mainstem Wenatchee River (-0.3ºC), due to stream width. The cooling benefit of vegetation restoration will be surpassed by climate change by the 2020s in the mainstem, but postpone stressful temperatures for salmonids in the tributaries until the end of the century, which is a significant benefit.

A study in Scotland (Hrachowitz et al. 2010) produced a comparable result. In this case, however, the highest mean weekly temperatures currently occur in small exposed streams, and these streams are projected to reach extremely stressful temperatures for salmonids in a + 4ºC climate change scenario, which raised the catchment-wide mean stream temperature by 1.4ºC. They suggested that vegetation restoration would ameliorate these stresses.

Hill et al. (2010) showed that certain pristine and environmentally heterogeneous areas in northern coastal British Columbia with salmon have high potential resilience, but relatively low productivity, and hence might not be sufficient to maintain a “salmon stronghold”.

14.4 Temperature-driven air pollution

Although mountain areas often support relatively pristine habitat, they are vulnerable to transport of pollutants generated long distances away. In particular, they are especially vulnerable to chemicals that are globally distributed by atmospheric deposition in a temperature-dependent way. Persistent organic pollutants, polycyclic aromatic hydrocarbons, and organochlorine compounds are concentrated in alpine streams because of the strong temperature gradients over short distances. Jarque et al. (2010) studied the reponse to organochlorine compounds in brown trout from the Pyrenees to Norway. They found biologically significant concentrations of pollutants in fish muscle correlated negatively with lake temperature, but biological activity might increase their negative consequences for fish with climate change

15 Policy/human social factors

Several papers addressed policy and management issues in adapting to climate change. All emphasized the need for more applied science and dialogue between researchers, managers, and the public. Some discussed specific climatic and biological information gaps and agreement, and the need for priority setting (Wilby et al. 2010), while others focused more on human social processes (Perry et al. 2010; Slaughter et al. 2010).

More specifically, Wilby et al. (2010) claim there is a lot of confusion about how best to proceed due to uncertainty in regional climate projections, biological responses, and environmental objectives. They emphasized that certain taxonomic groups are underrepresented in baseline data and impact studies, such as macrophytes, and that whole ecosystem responses need to be understood. Environmental objectives differ across managers, the public, conservation groups, etc., who further have different time frames of concern. They argued that even standard advice, such as increasing riparian shading to lower water temperatures and reducing abstraction from river flows, needs site-specific analysis and comparison with alternative actions before implementation. They argued that information gaps include site-specific information, underrepresented taxa, ecosystem goods and services, and risks and definitions of invasive species, given recommendations for increased connectedness. Overall they recommended more applied interdisciplinary research, adaptive management and cost-benefit analysis, in addition to reevaluation of goals and priorities.

Binder et al. (2010) summarized implications for adapation based on the Washington State Climate Change Assessment. They summarized key ingredients in successful adaptation planning, such as political leadership, money, stakeholder engagement, actionable science, tiggering extreme climatic events that motivate action and a long-term perspective. To adapt to changing water resources, they recommended expanding and diversifying water supplies, reducing demand, implementing operational changes, increasing summer drought and winter flood preparedness. To protect salmon, they recommended reducing summer stream temperatures, increasing minimum stream flows, and reducing peak winter flows by various means. They warned that these actions will involve more tradeoffs between water for fish and people.

Perry et al. (2010) emphasized that marine ecosystems and human behaviors are interconnected and showed similar features such as variability at many time scales. They suggested that fisheries focused on opportunistic species (e.g., anchovy) provide a model of flexibility that should be adopted by fisheries focussed on traditionally more stable species (e.g., cod) to adapt to increasing variability due to climate change. They cautioned that spontaneous human responses to increasing ocean variability might further de-stabilize marine ecosystem (e.g., switching to un-fished species). They recommended proactive, flexible management and communication among a broad group of stakeholders to prepare for the diversity of stresses coming to marine ecosystems.

Slaughter et al. (2010) argued that the free market (and reduced subsidies) is a better way to address over-allocation of Pacific Northwest water resources than court or regulator mandates in some respects, although both will be necessary.

The Washington State Integrated Climate Change Response Strategy: Species, Habitats and Ecosystems (Brekke et al. 2010) outlines an integrated approach to climate adaptation strategies that applies to a very wide range of ecosystems and threats. They focused on three conceptual approaches – resistance, resilience and response to faciliate natural system responses, and then building scientific and institutional readiness to support adaptation.

In their book, Climate Savvy, Hansen and Hoffman (2010) considered how a wide range of resource conservation issues—such as managing invasive species, harvest management, or ecological restoration—will need to change in response to climate change. Climate responses of ecosystems or organisms can be one of three types: resistance (stays the same), resilience (recovers after a disturbance), and response (e.g., movement or change). Key adaptation strategies for managing ecosystems in a changing climate included (1) protect adequate and appropriate space, (2) reduce non-climate stressors, (3) manage for uncertainty, (4) reduce local and regional climate effects, and (5) reduce the rate and extent of global climate change.

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