Appendix I

Integration of Recommended Recovery Actions

Introduction

At this time it is very difficult to assess the cumulative beneficial effects of actions across all sectors (Hs), because regionally accepted tools for assessing effects across sectors are currently not available. Therefore, this appendix describes a simple analytical approach to integrating the effects of actions recommended in the recovery plan. There is no attempt at this time to account for confidence intervals around any of the parameters or in the integrated estimates. Consequently, the certainty of the preliminary results presented in this appendix remains unknown. However, despite these deficiencies, it is important to estimate how much the status of Upper Columbia steelhead and spring Chinook might improve with implementation of the recommended actions within this plan. Because there is currently not enough information on bull trout within the Upper Columbia populations to estimate abundance and productivity, bull trout were omitted from this appendix. However, we recognize that implementation of the actions proposed in the plan will have a positive effect on bull trout habitat and subsequent population dynamics.

In this appendix we refer to the “gap,” analysis which estimates how much survival improvement is needed to move the current status of the populations toward recovery. The gap analysis was prepared by the ICBTRT (2006) for the Federal Columbia River Power System (FCRPS) remand process. We then summarize out-of-basin factors that affect the survival of Upper Columbia stocks. NOAA Fisheries prepared hydro, harvest, and estuary modules that describe limiting factors and threats, and expected actions or strategies to address those threats. Finally, we use a simple analytical approach to assess the potential benefits of recovery actions across sectors and compare the results to the gap identified by the ICBTRT.

Gap Analysis

The ICBTRT (2006) recently estimated survival rate changes needed to meet their abundance and productivity viability criteria for a 5% risk of extinction for Upper Columbia ESUs. The change in survival from current conditions to viability is referred to as the “gap.” Productivity is a key component of the gap and it relates directly to the ability of a population to be self sustaining. The ICBTRT expressed productivity as recruits per spawner or the rate at which spawning adults in one generation are replaced by spawning adults in the next generation. Importantly, gaps do not identify or target a particular life stage. Gaps can therefore be addressed by improvements to survival rates at any life stage (e.g., tributary residence, migration, estuarine, early ocean, upstream migration).

Survival changes estimated to meet abundance and productivity viability criteria for Upper Columbia spring Chinook and steelhead are presented in Table 1. The numbers in the table represent survival multipliers for both good (historical) and poor (pessimistic) ocean conditions.[1] For example,

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[1] Good or historical ocean conditions assume that ocean survival over the next 100 years will have the same characteristics as those experienced over the past 50-100 years. Poor or pessimistic ocean conditions assume that ocean survival over the next 100 years will have the same characteristics as those experienced by the 1975-1997 brood years.

in Table 1, a survival multiplier of 1.67 for Entiat spring Chinook requires increasing average life-cycle survivals by 67% over current levels, assuming good ocean conditions over the next 100 years. A 178% increase (2.78 survival multiplier) is needed if poor ocean conditions prevail for the next 100 years. Note that these survival estimates incorporate many of the improvements in hydropower survivals estimated from current management strategies.[2] Thus, the survival multipliers in Table 1 represent the portion of the gap that should be filled largely by habitat, harvest, and hatchery actions.

Table 1. Survival multipliers needed to meet abundance and productivity criteria for Upper Columbia spring Chinook and steelhead ESUs (from ICBTRT 2006). A survival multiplier of 2.56 requires increasing average life-cycle survivals by 156% over current levels.

Species	Population	Survival increase needed to achieve 5% extinction risk under relatively good (historical) ocean conditions (adjusted for Hydro)	Survival increase needed to achieve 5% extinction risk under poor ocean conditions (adjusted for Hydro)
Spring Chinook	Wenatchee	1.53	2.56
	Entiat	1.67	2.78
	Methow	1.29	2.15
Steelhead	Wenatchee	2.83	4.72
	Entiat	4.12	6.87
	Methow	4.46	7.45
	Okanogan	5.67	9.46

It is important to point out that NOAA Fisheries advises that these gaps do not constitute a legal determination of the status of Upper Columbia ESUs nor of the adequacy of any particular set of actions under the ESA. Rather, the gap provides a sense of how much effort is needed for planning purposes.

Although the ICBTRT (2006) did not identify a gap for spatial structure and diversity in the FCRPS Remand Process, they have identified necessary improvements in spatial structure and diversity needed to meet viability criteria (ICBTRT 2005). Needed improvements in these VSP parameters are identified in Appendix B and Section 4 of the Plan.

Out-of-Basin Modules

NOAA Fisheries recently developed modules that describe limiting factors, threats, and expected actions to address those threats for out-of-basin factors (i.e., hydro, harvest, and estuary). In addition, where possible, they also estimated potential survival improvements that may be realized if the

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[2] These estimates do not include the estimated long-term survival improvements for spring Chinook and steelhead at the four federal projects, nor do they include the estimated survival improvements associated with dams owned by Grant County Public Utility District.

recovery actions are implemented. Summarized below is information contained in those modules that relate to Upper Columbia spring Chinook and steelhead. Those who desire greater detail than what is presented here should consult the modules.

Hydro Module

The hydro module summarizes the effects of present management of the Columbia River mainstem hydropower projects on ESA-listed ESUs in the Columbia Basin. These effects could be subject to some changes as a result of new or amended strategies or actions through the redevelopment of the FCRPS section 7 biological opinion. The area addressed in the module that affects Upper Columbia ESUs includes the accessible habitat from the tailrace of Chief Joseph Dam downstream to the tailrace of Bonneville Dam (the area downstream from Bonneville Dam is covered in the estuary module). The two Upper Columbia ESUs use the mainstem Columbia River for migration to and from freshwater natal areas to the Pacific Ocean. Survival through the migration corridor declines with distance traveled, whether because of hazards (including predation), mortality because of passage at hydroelectric projects, or other factors associated with development (exotic predators, habitat conditions that make native predators more efficient, water quality, etc.).

Upper Columbia ESUs migrate through four federally owned projects and three to five projects owned by public utility districts. The four federally owned projects include McNary, John Day, The Dalles, and Bonneville dams, power plants, and reservoirs in the lower Columbia River. These projects are part of the Federal Columbia River Power System (FCRPS). Projects owned and operated by public utility districts (PUD) include Wells (Douglas County PUD), Rocky Reach and Rock Island (Chelan County PUD), and Wanapum and Priest Rapids (Grant County PUD). These projects are licensed by the Federal Energy Regulatory Commission.

Hydropower development in the Columbia Basin has affected salmonid migrations, altered habitats, and increased predation on juvenile salmonids. For example, hydropower development can (1) alter flows, which affect fish migration and survival both directly and indirectly; (2) increase average water temperatures beyond optimums for fish migration, behavior, and survival; (3) modify riverine habitat resulting in changes in habitat availability, migration patterns, feeding ecology, predation, and competition; and (4) impede juvenile and adult fish migration. These factors acting in concert reduce the survival of listed populations in the Upper Columbia Basin.

The operation of projects owned by Chelan (Rocky Reach and Rock Island dams) and Douglas PUDs (Wells Dam) fall under 50-year anadromous fish agreements and habitat conservation plans (HCPs) that set a “no net impact” standard to protect salmon and steelhead at the projects. The HCPs established a standard of 91% combined adult and juvenile passage survival at each project.[3] The combined survival standard is comprised of 93% juvenile and 98% adult project passage survival for all anadromous salmonids. At the time the Incidental Take Permits were issued (August 20, 2003), NOAA Fisheries estimated that the HCPs represented a 22 to 45% survival improvement potential over the survival levels observed under the historical operations of these three hydroelectric projects.

[3] The HCPs allowed the PUDs to compensate for up to 9% project passage mortality through up to 7% hatchery production and up to 2% funding of tributary habitat enhancement projects. That is, the mitigation is intended to match the level of impact.

The modified IPP for projects owned and operated by Grant County (Priest Rapids and Wanapum dams) sets survival standards that are identical to those described above for the HCPs. The following measures will be implemented to strengthen the likelihood that the standards are met:

- Downstream passage measures, including spill through existing and top spill through future units; turbine operations and the installation of advanced turbines; total dissolved gas abatement; avian predator control; and a Northern Pikeminnow removal program.
- Continued operation and maintenance, and where needed, improvements to adult. fishways at both Priest Rapids and Wanapum dams.
- Design and construction of an off-ladder trap and fish-handling facilities at Priest Rapids Dam.
- Sluiceway operations for steelhead fallbacks (kelts).

The plan of operation of the FCRPS through 2014 includes the following general hydrosystem actions.

- Continue adult fish passage operations.
- Improve juvenile fish passage.
- Continue and enhance spill for juvenile fish passage.
- Continue reservoir operations and river flows to benefit migrating fish.
- Modify fish transportation to improve juvenile survival.

The level of juvenile and adult survival expected for the near-term (2004-2009), mid-term (2010-2013), and long-term (2014), per the updated proposed actions are shown in Table 2a and 2b. The levels of survival are those the NOAA Fisheries estimated will occur as the FCRPS action agencies (U.S. Army Corps of Engineers, U.S. Bureau of Reclamation, and Bonneville Power Administration) carry out the hydro operations and system configuration improvements they proposed in 2004.

Table 2a. Near-term (2004-2009), mid-term (2010-2013), and long-term (2014) average and range (in parentheses) juvenile survival estimates for Upper Columbia populations migrating through the mainstem hydropower system. At this time there are no estimates for Okanogan steelhead.

Species	Population	Juvenile Survival		
		Near-Term	Mid-Term	Long-Term
Spring Chinook	Wenatchee	0.554 (0.447-0.625)	0.592 (0.583-0.665)	0.605 (0.489-0.690)
	Entiat	0.509 (0.407-0.580)	0.550 (0.449-0.618)	0.562 (0.480-0.640)
	Methow	0.490 (0.384-0.577)	0.549 (0.423-0.616)	0.541 (0.422-0.638)
Steelhead	Wenatchee	0.340 (0.115-0.461)	0.406 (0.139-0.548)	0.412 (0.428-0.618)
	Entiat	0.326 (0.107-0.452)	0.389 (0.129-0.538)	0.395 (0.400-0.607)
	Methow	0.314 (0.101-0.451)	0.374 (0.139-0.536)	0.380 (0.376-0.605)

Table 2b. Near-term (2004-2009), mid-term (2010-2013), and long-term (2014) average and range (in parentheses) adult survival estimates for Upper Columbia populations migrating through the mainstem hydropower system. At this time there are no estimates for Okanogan steelhead.

Species	Population	Adult Survival		
		Near-Term	Mid-Term	Long-Term
Spring Chinook	Wenatchee	0.904 (0.895-0.918)	0.904 (0.895-0918)	0.904 (0.895-0.944)
	Entiat	0.897 (0.889-0.912)	0.898 (0.889-0.918)	0.900 (0.899-0.913)
	Methow	0.892 (0.884-0.907)	0.892 (0.884-0.907)	0.892 (0.884-0.907)
Steelhead	Wenatchee	0.907 (0.889-0.926)	0.907 (0.889-0.926)	0.907 (0.889-0.926)
	Entiat	0.897 (0.879-0.916)	0.897 (0.879-0.916)	0.897 (0.879-0.916)
	Methow	0.885 (0.868-0.904)	0.885 (0.868-0.904)	0.885 (0.868-0.904)

Harvest Module

The harvest module describes mortality resulting from current, historic, and expected future fisheries based on present management strategies. It also summarizes the complexities of management programs and describes different fisheries (e.g., ocean, mainstem, tributary, tribal, commercial, and recreational). Managing the various fisheries is very complex and readers should refer to the harvest module or Sections 3.4 and 5.2 in the recovery plan for more details. Here we only summarize the salient points that relate to Upper Columbia stocks.

Salmon and steelhead from the Upper Columbia Basin may be caught in ocean, mainstem Columbia River, or tributary fisheries depending on their timing and distribution relative to fishery openings. Although Upper Columbia stocks are subject to little or no ocean fishing mortality, they are affected to some degree by fisheries in the mainstem Columbia River. Characterizing harvest mortality associated with tributary fisheries is more complicated. Ocean and mainstem fisheries are assumed to affect all populations in the ESU equally. Because of their location, tributary fisheries generally affect one or sometimes a few populations, but have no affect on the remainder of the ESU. As a result, estimates of mortality to populations in tributary fisheries cannot simply be added to estimates of mortality to the ESU in the mixed-stock ocean and mainstem fisheries unless it is clear that the additional impacts are population specific. Harvest mortality estimates described below therefore refer to impacts in ocean and mainstem fisheries.

As noted above, the current ocean fishery mortality on Upper Columbia spring Chinook is very low and assumed to be zero based on the rare occurrence of coded wire tag (CWT) recoveries in ocean fisheries. Fisheries in the mainstem Columbia River are subject to a harvest rate schedule ranging from 5.5-17% as described in the 2005-2007 Interim Management Agreement. The harvest rate varies depending on the total abundance of upriver spring Chinook including the summer component of the Snake River spring/summer Chinook ESU. The harvest rate also depends on the abundance of naturally produced Upper Columbia River spring Chinook and Snake River spring/summer Chinook. The harvest rate schedule was modified slightly before the 2005 season to accommodate the inclusion of the summer component of the Snake River spring/summer Chinook ESU, but is otherwise the same as that used in the 2001 Interim Agreement. Under the terms of the 2005-2007 Agreement, survival may range from 83-94.5%. The observed harvest rate on naturally produced Upper Columbia spring Chinook from 2000-2004 averaged 10.7% (an 89% survival rate). Historically (based on the 1960-1964 period)[4], harvest rates on Upper Columbia spring Chinook averaged 46.4% (a 54% survival rate).

The current ocean fishery mortality on Upper Columbia steelhead is assumed to be zero. Harvest management constraints and harvest rates for naturally produced steelhead in Columbia River mainstem fisheries are similar to those for Snake River A-run steelhead. This fishery is currently managed subject to the terms of the *U.S. v Oregon* Interim Management Agreement for 2005-2007. The expected harvest rates on Upper Columbia steelhead in non-Indian and treaty Indian fisheries are 1.0-1.8% and 3.5-8.2%, respectively. The combined harvest rate on Upper Columbia River steelhead is therefore expected to range from 4.5-10% (a 90-95% survival rate). Historical mainstem harvest rates on steelhead were 21% (a 79% survival rate) and if these fish were subject to an additional 50% tributary harvest rate the resulting survival would be 40%.

For the near term, harvest impacts will likely be similar to current levels. Any changes in harvest strategies would be determined through the *U.S. v Oregon* forum. Provisions of the Pacific Salmon Treaty that relate to management of Chinook fisheries will be in place through 2008. Fisheries managed under the jurisdiction of the Pacific Fishery Management Council are subject to long-term biological opinions that are in place until changed. Fisheries in the mainstem Columbia River will be managed subject to the *U.S. v Oregon* Interim Management Agreement through at least 2007. If and how these fisheries will change thereafter is unclear. The existing fishery regimes have developed over the years since the first listings in the Columbia River Basin in 1991, and include substantial reductions in fisheries considered necessary to comply with ESA requirements to date. Fishery management provisions will continue to evolve in response to new information including recommendations developed through the recovery planning process. At this time it is not possible to predict the direction or magnitude of change for any particular ESU. Given these uncertainties, a reasonable assumption is that future harvest impacts will be similar to current levels.

Estuary Module

The estuary module discusses the estuary, lower mainstem, and plume as they relate to salmon and steelhead recovery. The module identifies limiting factors and threats, focusing on flow, tidal effects, ecological interactions, and toxics. The module includes options for management actions or strategies that link the estuary to species life-history characteristics and survivals. The area addressed by the module extends from Bonneville Dam downstream to the plume.

The estuary serves an important role beyond simply providing a corridor that Upper Columbia populations use to migrate between freshwater and the ocean. It is well established that the habitat in the estuary is part of the continuum of ecosystems that salmon and steelhead use to complete their life cycles. Throughout the estuary, the distribution and quality of habitat has been negatively affected by a variety of anthropogenic factors and natural changes. These alterations have not only

[4] The period from 1960-1964 is used to represent the period before reduction in harvest for conservation reasons.

affected the abundance and productivity of populations, but have also affected their spatial structure and diversity.

Of the many factors in the estuary that affect salmon and steelhead viability, four appear to be the most important: flow, habitat, contaminants/toxics, and predation. Alterations in flows, loss of emergent marsh, tidal swamp, and forested wetlands, shifts in organic matter important to estuarine food webs, and changes in the plume have affected population productivity and diversity. Changes in the plume may have a greater effect on yearling life-history strategies (e.g., Upper Columbia ESUs) than changes in shallow-water habitat. Exposure to waterborne and sediment-associated chemical contaminants can also affect productivity of salmon and steelhead. Upper Columbia populations are likely to be most affected by short-term exposure to waterborne contaminants such as pesticides and dissolved metals. Finally, predation is a major source of mortality on all listed populations. Both adults and juveniles suffer relatively high predation loss in the estuary. Upper Columbia populations, because of their life-history characteristics, are especially susceptible to Caspian tern predation.

Flow changes in the estuary are primarily a result of dam operations, whereas habitat changes are a function of both hydropower operations and other, non-hydro issues, notably the construction of dikes and levees in the estuary. The main effects of flow on Upper Columbia populations are associated with changes in the plume. Thus, actions that affect the plume, decrease exposure to toxicants, and decrease predation (especially Caspian tern predation) should improve the abundance/productivity and diversity of Upper Columbia ESUs.

The estuary module assumes a 20% improvement that might be realized through the implementation of actions in the estuary. The 20% improvement is a hypothetical target that is plausible if constraints to implementation can be overcome and that threats and limiting factors can effectively be reduced. The improvement level is based on overall estimates of juvenile mortality in the estuary, known mortality that can be attributed to specific threats, and professional judgment regarding the efficacy of the different management actions and the likelihood that constraints to their implementation can be overcome.

Integration Approach

The simple analytical approach used in this plan relied on information from Sections 2, 3, and 5 to provide an estimate of the likelihood that the actions recommended within the plan would meet viability criteria for a 5% risk of extinction. The simulation also used additional information and assumptions (which are outlined below) to evaluate the actions that have either been recently enacted, or recommended within the recovery plan. Below, we outline by sector the associated assumptions and information that were used to estimate the increase in productivity and spatial structure/diversity. Potential changes in abundance were not estimated because the “gap” was expressed in terms of productivity, not abundance.

Productivity

For all sectors, we assumed a 50% hatchery effectiveness (reproductive success) rate for steelhead. As such, the values for productivity reported for steelhead within this appendix differ from those reported in Section 2 of the recovery plan.[5] The run was reconstructed using 50% of the hatchery fish included with naturally produced fish to determine productivity values. We estimated for all sectors a low and high potential increase in productivity. The lower and upper estimates were determined by modeling (e.g., EDT for habitat) or professional judgment.

Potential productivity (productivity that may be achieved if recovery actions are implemented) of naturally produced fish was estimated from the sum of the percent increase in a particular sector, multiplied by the current estimate of productivity. Productivity was based on the latest year of data for a particular brood year of fish (1999 for spring Chinook and 1996 or 1997 for steelhead).

Harvest Sector

As discussed in detail in Section 5.2 of the recovery plan and in the Harvest Module, harvest on Upper Columbia steelhead and spring Chinook has been significantly reduced over the last several decades. As a result, there is limited opportunity to reduce harvest rates beyond their current limits. The recovery actions identified in the Plan may result in a small reduction in harvest through improved management strategies, harvest methods, and marking techniques. Therefore, for the purposes of this exercise, we assumed a range of change in potential productivity from 0% (lower potential) to 1% (upper potential) (Table 3).

We also estimated potential survival benefits associated with terminating all harvest on spring Chinook and steelhead. The results indicated a potential increase of 9-10% in productivity of spring Chinook, but steelhead productivity actually decreased. This is because a large number of hatchery produced steelhead would escape to spawning grounds and “swamp” the spawning population. Hatchery produced steelhead currently have a lower reproductive success than naturally produced fish (we optimistically assumed a reproductive success of 0.5 for hatchery steelhead) and therefore would drive the productivity of the population down to low levels. Harvest on hatchery produced steelhead means fewer hatchery fish escape to spawning grounds. This results in a greater percentage of the spawning escapement consisting of naturally produced fish that are more productive than hatchery steelhead.

Hatchery Sector

To determine hatchery changes that contribute to productivity, we used the theoretical difference between the productivities for steelhead estimated in Section 2 of the recovery plan. As described in Section 2, we reconstructed the historical steelhead run using two different reproductive success scenarios for hatchery spawners: (1) hatchery spawners were as effective as wild spawners (100%; H = 1) and (2) hatchery spawners did not contribute to returning spawners at all (0%; H = 0).

In the Wenatchee and Entiat rivers[6], there is a 63% difference between zero contribution of hatchery spawners (return per spawner is 0.81) and 100% effectiveness (return per spawner is 0.25). In the

[5] In Section 2 and Appendix C we modeled steelhead runs assuming two different reproductive successes. The first scenario assumed that steelhead were equally as effective in producing returning spawners as naturally produced steelhead (reproductive success = 100%), while the second scenario assumed that hatchery fish contributed no returning spawners (reproductive success = 0%). In the absence of empirical data, we assumed in this exercise that hatchery steelhead were half as effective in producing returning spawners as naturally produced steelhead (reproductive success = 50%).

[6] Wenatchee-Entiat, and Methow-Okanogan returns per spawner cannot be separated because the base population (dam counts) is the same (see Appendix C for further details).

Methow and Okanogan rivers the difference is 89% (0.89 if H = 0 and 0.09 for H = 1). Because no data currently exist in the Upper Columbia[7] to determine true hatchery spawner effectiveness, we assumed in this exercise that hatchery spawners are half (50%; H = 0.5) as effective as naturally produced spawners for both steelhead and spring Chinook. We also assumed that the relationship between 100% hatchery spawner effectiveness and 0% hatchery spawner effectiveness for steelhead also applies to spring Chinook within the Wenatchee, Entiat, and Methow rivers.

In the absence of empirical data, we estimated that improvements in hatchery practices would result in a 3-5% survival increase in naturally produced spring Chinook and steelhead in the Wenatchee-Entiat populations, and a 5-10% increase in the Methow-Okanogan populations (Table 3). The greater increase in the Methow-Okanogan populations reflects the recommended action of collecting local broodstock within tributaries rather than composite fish at Wells Dam. These survival changes also appear to be supported by AHA modeling results (see Appendix J).

Hydro Sector

We applied the calculated increases in juvenile survival from the draft QAR (Cooney et al. 2000) to the calculated geo-mean of returns per spawner from Section 2 for spring Chinook and steelhead. This was applied basin-specific, where applicable. We used the estimated increase in juvenile survival from Table 24 in Cooney et al. (2000) for all five PUD dams, and also applied their estimated increase in juvenile survival in the lower Columbia River from McNary to downstream from Bonneville dam (14.5% improvement; Table 27 in Cooney et al. 2000) to the estimated increases from the HCPs on local hydro dams. We assume 1:1 increase in spawners from an increase in juvenile survival from the proposed actions (i.e., if juvenile survival increased 10%, we assumed a 10% increase in spawners). Based on this information, productivity could increase between 35-51% for spring Chinook populations and 30-40% for steelhead populations (Table 3). We used these estimates for both low and high productivity potentials.

Habitat Sector

We applied the EDT results for the Wenatchee, Entiat[8], Methow, and Okanogan to determine what percent increase in productivity could be expected from implementing habitat actions recommended in the Plan (from Section 5.5). Using the EDT results in Appendix F, we estimated density-independent survival changes as smolts per spawner across a range of spawner abundances less than 2,000 spawners (the minimum recovery abundance for large populations established by the ICBTRT). Because we did not know the extent to which the proposed habitat actions would be implemented, EDT modeled two different scenarios: (1) implementation intensity of 33% and (2) implementation intensity of 100% (see Appendix F). This allowed us to show a potential range of effects from recommended habitat actions. It is important to understand that the 100% intensity may not be reasonable or feasible. The habitat actions proposed in the Plan have not been evaluated for social/economic feasibility.

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[7] There is currently a study underway to estimate spring Chinook hatchery spawner effectiveness in the Wenatchee River, and Chelan and Douglas PUDs will be determining the same for steelhead through their HCP hatchery M&E programs.

[8] In the Entiat, a different model run was used. Since the Entiat Watershed Plan has run EDT for various scenarios (see Plan for details), we used Scenario 5, as described in the Watershed Plan, and compared it to the "33%" run from the other subbasins. The Entiat Watershed Plan did not model steelhead and there has been no attempt to model steelhead in the Entiat.

Under the 33% intensity scenario (lower potential), productivity of spring Chinook populations could increase 3-25% (Table 3). Under 100% intensity (upper potential), productivity of spring Chinook populations could increase 3-36% (Table 3). Productivity of Upper Columbia steelhead populations under the 33% scenario could increase 14-47%, while steelhead productivities under the 100% scenario could increase 31-64% (Table 3). Note that there is no estimate for Entiat steelhead because there was no EDT analysis completed for this population.

Integration Across Sectors

To determine the total change in survival for each population, we multiplied the changes in productivity (calculated as the ratio of proposed productivity to current productivity within a sector) across sectors to estimate the total survival multiplier from the proposed actions. For Upper Columbia spring Chinook populations, survival could increase 99-137% under the lower potential productivity scenario to 107-198% under the higher potential productivity scenario (Table 3). Survival for steelhead populations could increase 85-178% under the low productivity scenario to 90-226% under the higher productivity scenario (Table 3).

We compared these survival changes with the gap analysis to see if the estimated changes met recovery criteria (i.e., filled the gap). Table 4 compares the survival changes needed to meet abundance and productivity viability criteria for Upper Columbia ESUs. It is important to note that the survival improvements in the gap analysis are already adjusted for most hydro effects.

Table 3. Summary of possible increases in productivity from recommended actions identified in the recovery plan. The numbers in red indicate minimum estimates for Entiat steelhead, because there are no productivity estimates from recommended habitat actions.

Sector	Area	Spring Chinook Productivity					Steelhead Productivity[1]				
		Current (C)	Low Potential (P)	High Potential (P)	Low P/C	High P/C	Current (C)	Low Potential (P)	High Potential (P)	Low P/C	High P/C
Harvest	Wenatchee	0.74	0.74	0.75	1.00	1.01	0.69	0.69	0.70	1.00	1.01
	Entiat	0.76	0.76	0.77	1.00	1.01	0.69	0.69	0.70	1.00	1.01
	Methow	0.51	0.51	0.52	1.00	1.01	0.91	0.91	0.92	1.00	1.01
	Okanogan	---	---	---	---	---	0.91	0.91	0.92	1.00	1.01
Hatchery	Wenatchee	0.74	0.76	0.78	1.03	1.05	0.69	0.71	0.72	1.03	1.05
	Entiat	0.76	0.78	0.80	1.03	1.05	0.69	0.71	0.72	1.03	1.05
	Methow	0.51	0.54	0.56	1.05	1.10	0.91	0.96	1.00	1.05	1.10
	Okanogan	---	---	---	---	---	0.91	0.96	1.00	1.05	1.10
Hydro[2]	Wenatchee	0.74	1.09	1.09	1.47	1.47	0.69	0.97	0.97	1.40	1.40
	Entiat	0.76	1.20	1.20	1.58	1.58	0.69	1.03	1.03	1.49	1.49
	Methow	0.51	0.84	0.84	1.65	1.65	0.91	1.36	1.36	1.49	1.49
	Okanogan	---	---	---	---	---	0.91	1.36	1.36	1.49	1.49
Habitat (33%-100%)[3]	Wenatchee	0.74	0.93	1.00	1.25	1.35	0.69	0.87	0.90	1.26	1.31
	Entiat[4]	0.76	0.78	0.78	1.03	1.03	0.69	---	---	---	---
	Methow	0.51	0.58	0.69	1.14	1.36	0.91	1.04	1.24	1.14	1.36
	Okanogan	---	---	---	---	---	0.91	1.34	1.49	1.47	1.64
Integration across all sectors[5]	Wenatchee	0.74	1.69	1.89	2.29	2.56	0.69	1.51	1.61	2.19	2.33
	Entiat	0.76	1.51	1.57	1.99	2.07	0.69	1.28	1.31	1.85	1.90
	Methow	0.51	1.21	1.52	2.37	2.98	0.91	1.97	2.47	2.16	2.71
	Okanogan	---	---	---	---	---	0.91	2.53	2.97	2.78	3.26

[1] Productivity was based on a hatchery effectiveness of H = 0.5.

[2] The survival estimates provided here were based on the draft Quantitative Analysis Report (QAR). Survival estimates include improvements associated with long-term benefits from the FCRPS. The method used here (QAR) differed from those in the Gap Analysis.

[3] EDT modeled two habitat improvement scenarios for the Wenatchee, Methow, and Okanogan populations: (1) 33% intensity and (2) 100% intensity (See Appendix F). The 100% intensity may not be feasible to implement because of social/economic factors.

[4] Because the Entiat was not modeled the same as the other subbasins, the total increase in productivity would be greater than shown here (See Appendix F). There was no 100% intensity scenario for the Entiat.

[5] Includes an estimated 20% survival benefit from the implementation of estuary actions.

Table 4. Comparison of survival multipliers needed to meet abundance and productivity criteria for Upper Columbia spring Chinook and steelhead populations and those expected from implementing recommended actions within the recovery plan. A survival multiplier of 2.56 requires increasing average life-cycle survivals by 156% over current levels.

Species	Population	Gap Analysis		Recovery Plan	
		Survival increase needed to achieve 5% extinction risk under relatively good (historical) ocean conditions (adjusted for Hydro)	Survival increase needed to achieve 5% extinction risk under poor ocean conditions (adjusted for Hydro)	Lower survival increase expected from plan (not counting hydro)[1]	Upper survival increase expected from plan (not counting hydro)[1]
Spring Chinook	Wenatchee	1.53	2.56	1.69	1.89
	Entiat	1.67	2.78	1.37	1.43
	Methow	1.29	2.15	1.57	1.97
Steelhead	Wenatchee	2.83	4.72	1.89	2.01
	Entiat	4.12	6.87	---	---
	Methow	4.46	7.45	1.75	2.19
	Okanogan	5.67	9.46	2.25	2.64

[1] These survival estimates include a 12% increase for steelhead resulting from actions that will be implemented at Priest Rapids and Wanapum dams (owned by Grant County Public Utility District) and an 8% and 9% increase for steelhead and spring Chinook, respectively, from long-term actions taken at the four federal dams on the lower Columbia River. They also include an estimated 20% survival benefit associated with the implementation of proposed actions in the estuary.

Except for perhaps the Wenatchee and Methow spring Chinook populations, these results suggest that the recommended actions within the recovery plan may not fill the gap between the ESUs' present status and the 5% extinction risk viability criteria. There are a number of reasons why this may have occurred.

(1) Methods used by the ICBTRT to calculate productivities for the gap analysis were different than those used in the recovery plan. In the recovery plan, productivity was calculated as the 12-yr geometric mean of consecutive brood years. The ICBTRT calculated a 20-yr geometric mean that was adjusted for SAR and delimited at the median. This means that they excluded any spawner/return pair where the spawner number exceeded the median. The intent was to remove density-dependent effects that may influence the productivity estimate.

(2) Our inability to estimate accurately the probable survival changes associated with each recommended action identified in the plan may have greatly underestimated the expected survival change for each population. For example, there is no method currently available that

calculates expected survival changes associated with hatchery actions. If the actions recommended in the plan significantly contribute to natural production, then the survival changes assumed here may greatly underestimate the contribution of hatchery actions.[9]

(3) The integration analysis included a hypothetical improvement level associated with management actions in the estuary. Actions that reduce toxics and predation may translate into a relatively large survival benefit for Upper Columbia populations. Benefits associated with changes in flow and the plume were included in the hydro sector under the ICBTRT gap analysis.

(4) The potential survival gains associated with hatchery actions may be greatly underestimated. Current analyses indicate that Methow steelhead require a 4-7 fold increase in survival to meet viability criteria, while Methow spring Chinook only need a 1-2 fold increase in survival. This indicates that the productivity of Methow steelhead has been much more affected by hatchery programs than Methow spring Chinook.[10] Changes in the hatchery programs could close the gap between current and desired productivities.

Recovery planning for salmonids in the Upper Columbia suffers, as recovery planning for nearly all species does, by a lack of information that ties human actions explicitly to a quantitative response in stage-specific survival, life-cycle productivity or abundance. While a recovery plan is not required by the ESA to provide such a quantitative evaluation, recovery planners and stakeholders in the Upper Columbia would like a sense of how much is enough for their planning purposes. The lack of quantitative information makes it challenging to provide this estimate of “how much is enough” robustly. This is particularly true for the Upper Columbia steelhead and similar ESUs, where the difference between current abundance and productivity and ICBTRT viability targets for abundance and productivity appears to be very large.

However, this apparent difference between current status and abundance and productivity targets is affected by at least two additional factors. First, for all ESUs, population modeling and other analysis conducted by the ICBTRT, the NWFSC, and by other researchers (ICBTRT and Zabel 2006; Zabel et al. 2006; McClure et al. 2004; Mantua et al. 1997) indicates that climate and associated ocean conditions have a very large impact on overall population productivity, likely by affecting estuarine and early ocean survival. The proportion of the difference between current status and abundance and productivity viability targets that has to be “made up” by human actions changes dramatically under different climate or ocean scenarios. While this proportion is quite large under scenarios that impose poor estuarine and early ocean survival, scenarios that incorporate early ocean survival more like those seen over the last 60 to 100 years appear to require much less human action (ICBTRT 2006).

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[9] Upper Columbia steelhead have been heavily affected by out-of-basin hatchery stocks and past harvest management. Such hatchery stocks generally have productivities (reproductive success) that are much lower than native spawners. Thus, there is potential to improve the productivity of the populations through management strategies that include the use of locally-derived broodstock and promote adaptation of natural spawners to local conditions. Such a change has the potential to reduce the difference between current productivity and desired productivity. Currently, however, there is no way to estimate what the potential change in productivity would be if the hatchery actions identified in the plan were implemented.

Second, the Upper Columbia steelhead ESU has been heavily affected by use of out-of-ESU hatchery broodstock and past harvest management. As a result of these past practices, current natural spawners may be nearly entirely derived from those out-of-ESU sources. Exogenous hatchery stocks such as these often have reproductive success that is lower than that of native wild populations (review in Berejikian and Ford 2006). Thus, there may be potential to improve the productivity of the populations within this ESU through a management strategy that includes the use of locally-derived broodstock and promotes adaptation of natural spawners to local conditions. Such a change has the potential (although it is not guaranteed) to reduce the difference between current observed productivity and desired population productivity.

Although we cannot demonstrate conclusively at this time that the actions identified in the Plan will meet the 5% viability criteria identified by the ICBTRT, neither can we demonstrate conclusively that they will not. We do believe that the actions identified in the Plan will move the populations to a more viable state and that there is an opportunity to significantly reduce extinction risk. The monitoring and adaptive management program outlined in Section 8 of the Plan will be used to demonstrate progress toward recovery of Upper Columbia ESUs.

Spatial Structure and Diversity

The spatial structure and diversity of each population of steelhead and spring Chinook in the Upper Columbia Basin was discussed in Appendix B and Section 2 in the Plan. The status of spatial structure and future improvements are most relevant in the habitat sector, except that low abundance can lead to functional habitat being unoccupied. We did not attempt to integrate future abundance increases with suitable but unoccupied habitat, but assumed that more fish would “fully seed” the available functioning habitat. Species diversity, on the other hand, is affected by multiple sectors, primarily hatchery operations.

Spatial Structure

Six of the seven populations were at low to moderate risk for goal A (spatially mediated processes), which dealt primarily with distribution across major spawning areas (See Table 2.2 in the Plan and Appendix B). This conclusion was based on the presence of natural origin spawners and/or functional habitat within the major and minor spawning areas consistent with the ICBTRT guidance. Okanogan steelhead was the exception, and the high risk rating for goal A was because only 1 of 2 major spawning areas was occupied. In order to achieve low or moderate risk, the Okanogan population will need to occupy both MSAs.

The intended actions in the habitat sector will improve the spatial distribution and habitat quality within the major spawning areas, so we expect the status of spatial structure to continue to improve. The ICBTRT has suggested that a population and ESU could be viable with moderate risk for spatial structure and diversity so no further actions would be required. Our conceptual representation of current and future status with respect to spatial structure for the ESU can be seen in Figure 1. We chose to leave the emphasis on providing access to suitable habitat, although we recognize that hatcheries could contribute by seeding unoccupied habitat and hydro and harvest could contribute by helping to increase abundance, which should lead to more occupied areas.

Diversity

Our risk assessment for goal B (maintaining natural levels of variation) concluded that all spring Chinook and steelhead populations were at high risk (See Table 2.2 in the Plan and Appendix B). Past and current hatchery operations were largely responsible for the high risk ratings for both species (Appendix B). Addressing these hatchery issues would remove the threats to diversity and likely lead to a diversity status that would meet the requirements of a VSP. We generated a conceptual graphic of the relative contribution of each sector to the current and future status of diversity for the ESU (Figure 2). Small gains could be made by reducing the risk of selective pressures that select for or against phenotypic traits in the harvest and hydro sectors; however, the emphasis was on habitat and hatcheries. Although some gains can be made in the habitat sector, VSP levels cannot be achieved without adequate contributions in the hatchery sector (Figure 2).

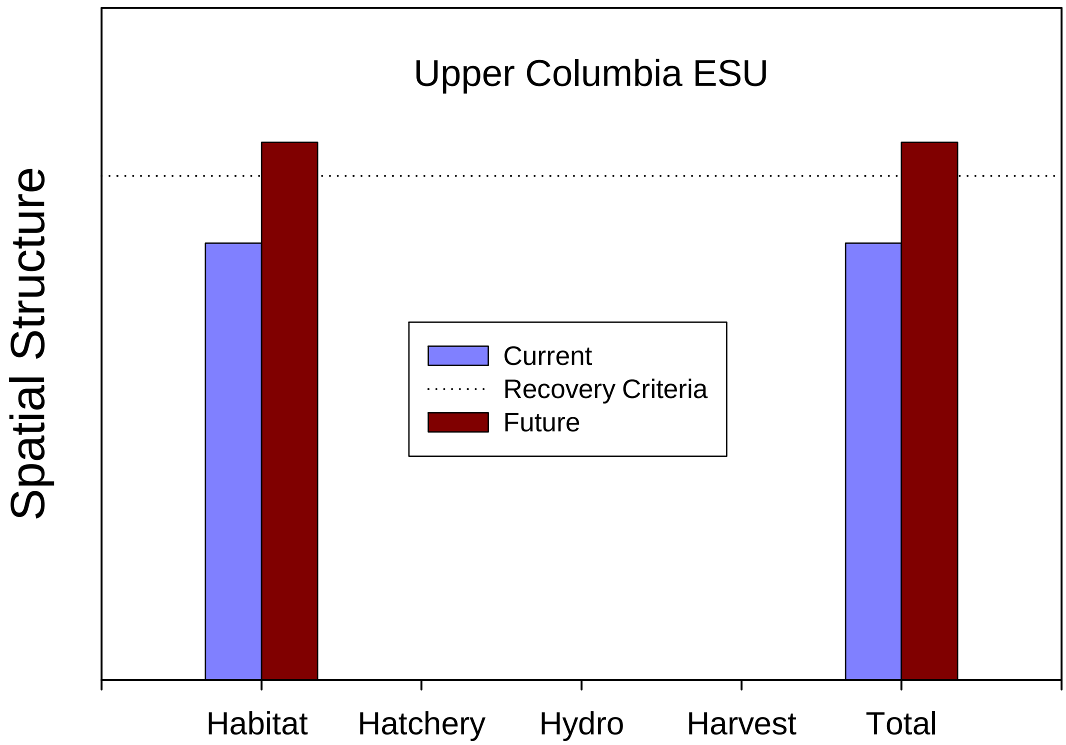

Figure 1. Conceptual representation of the current and future contribution of the four sectors to spatial structure for the Upper Columbia ESU.

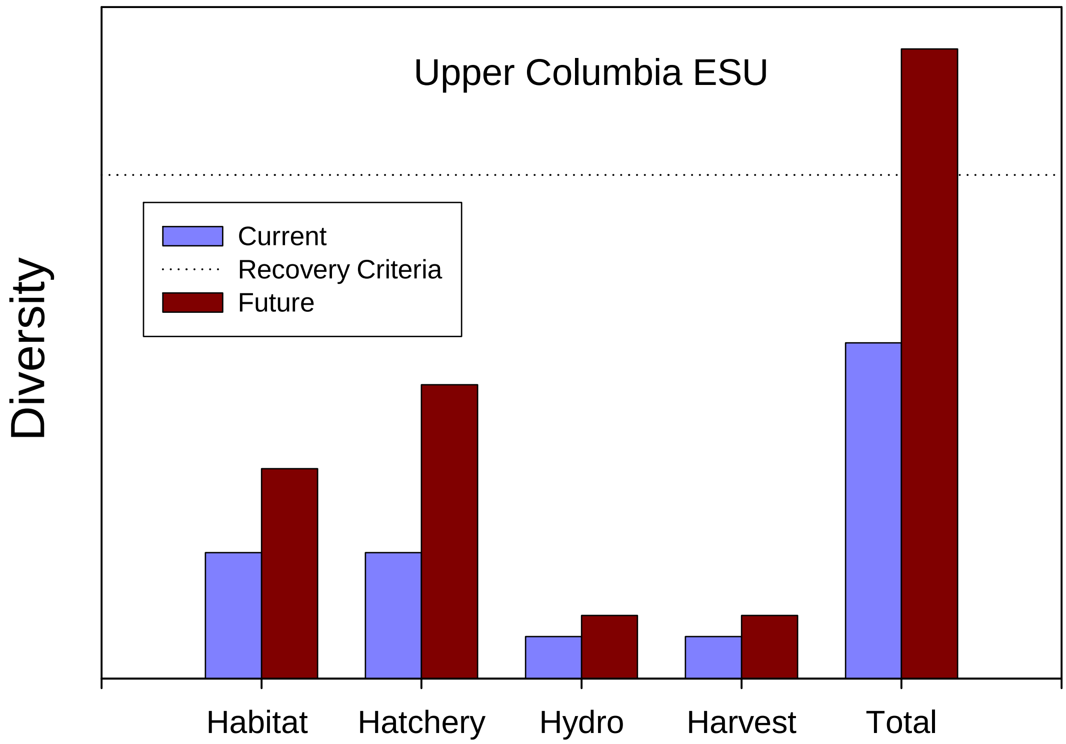

Figure 2. Contribution of different sectors to recovery of the diversity attributes for Viable Salmonid Populations of spring Chinook and steelhead in the Upper Columbia ESU. Units were intentionally left off the y-axis because diversity is not a quantitative attribute. Although the relative length of the bars might shift slightly for each population, the concept for each is the same throughout the ESU. Some gains can be made in the habitat sector, but recovery cannot be achieved without changes to hatchery operations that will decrease the risk to diversity.