Appendix C
Analysis of the Effects of Tributary Habitat Actions

TABLE OF CONTENTS

LIST OF ATTACHMENTS

C.1. INTRODUCTION

This appendix addresses the effects of the tributary habitat actions that are included as part of the Federal Columbia River Power System (FCRPS) Proposed Reasonable and Prudent Alternative (RPA). The appendix consists of the following attachments:

Attachment C-1 - Tributary Habitat Benefits

This attachment is briefly described below.

Attachment C-1 describes the specific approach used to determine the potential benefits for each Evolutionarily Significant Unit (ESU). The analysis is based on two time periods: a base-to-current period and a current-to-prospective period. Attachment C-1 includes three annexes that provide additional details about the specific approach. These annexes are:

Annex 1 - Tributary Habitat Benefits and Methods
Annex 2 - Approach to Estimating Survival Benefits of Habitat Actions
Annex 3 - Understanding the Habitat Workgroup Approach to Estimating Habitat Quality and Freshwater Survival Benefits

Attachment C-1
Tributary Habitat Benefits

TABLE OF CONTENTS

LIST OF TABLES

ANNEXES

ACRONYMS AND ABBREVIATIONS

BiOp	biological opinion
BPA	Bonneville Power Administration
CHW	Collaboration Habitat Workgroup
CRITFC	Columbia River Inter-Tribal Fish Commission
DPS	Distinct Population Segment
EDT	Ecosystem Diagnosis and Treatment
ESU	Evolutionarily Significant Unit
FCRPS	Federal Columbia River Power System
HEP	Habitat Evaluation Procedure
HQI	Habitat Quality Index
ISAB	Independent Scientific Advisory Board
MPG	Major Population Group
NMFS	National Marine Fisheries Service
NOAA	National Oceanic and Atmospheric Administration
NRC	National Research Council
PHABSIM	Physical Habitat Simulation Model
PFC	properly functioning condition
PWG	Policy Work Group
RHW	Remand Habitat Workgroup
RPA	Reasonable and Prudent Alternative
TRT	Technical Recovery Team
WDFW	Washington Department of Fish and Wild

1. ESTIMATING POPULATION SURVIVAL ASSOCIATED WITH COMPLETED AND PLANNED TRIBUTARY HABITAT ACTIONS

1.1 SUMMARY

This paper describes the specific approach used and results for estimating tributary habitat survival improvement benefits for each Evolutionarily Significant Unit (ESU)/Distinct Population Segment (DPS). These tributary action benefits fall into the two time periods that were used for the base-to-current and current-to-prospective biological analysis (Chapters 5 and 7 through 10 of this Comprehensive Analysis document):

1. **2000 to 2006**: survival estimates for completed actions adjusted for accrued future benefits through 2017
2. **2007 to 2017**: survival estimates attributable to the specific Tributary Habitat Actions for 2007 to 2009 (an expanded level of effort compared to 2000 to 2006) plus additional 2008 and 2009 actions described in the Tributary Habitat Action.

1.2 SUMMARY OF METHODOLOGY

The Action Agencies estimated survival benefits attributable to tributary habitat actions that are implemented in partnership with States, Tribes, and others with funding and/or technical assistance from the Action Agencies. These actions were described in the draft Tributary Habitat Action. Survival improvement estimates were made for actions completed from 2000 to 2006 and planned for 2007 to 2009. Survival improvement estimates described in this report correspond with values for the base-to-current (2000 to 2006) and the current- to- prospective periods represented in the biological analysis.

To compile these estimates, the Action Agencies used information and methods produced in conjunction with the tributary Remand Collaboration Habitat Workgroup process. The Remand Collaboration Habitat Workgroup was charged by the Policy Work Group to evaluate the method used in Appendix E of the 2004 Federal Columbia River Power System (FCRPS) Biological Opinion (BiOp) (NMFS 2004) and decided to update the method used in Appendix E of the 2004 FCRPS BiOp (see Annex 1 to this attachment). The Action Agencies applied two main approaches to use data and information from the Remand Collaboration Habitat Workgroup to produce survival estimates for salmon and steelhead populations. Further detail on the procedures and components utilized are available in Annex 2 to this attachment.

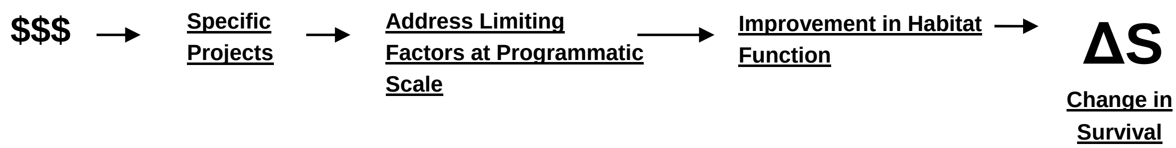
In the first approach, called the Hybrid Method, Remand Collaboration Habitat Workgroup products were supplemented with information obtained in meetings with local biologists (Federal, State, and Tribal) and tributary habitat project sponsors. Local biologists have the most knowledge about local watershed processes, habitat conditions, and fish populations in their respective areas. For a number of populations, local biologists helped define:

1. reference habitat functions:
   (a) current, existing habitat function and
   (b) habitat functions associated with implementing all planned tributary habitat actions by 2017;
2. habitat functions associated with tributary habitat actions implemented in partnership with States, Tribes, and others with funding and/or technical assistance from the Action Agencies.

Habitat functions were expressed with numerical values. The Action Agencies used this information and calculated survival estimates from them using the method developed in conjunction with the Remand Collaboration Habitat Workgroup.

In the second approach, referred to as the Appendix E method, the Action Agencies used base information from Appendix E of the 2004 FCRPS BiOp, the tables of limiting factor information provided to the Remand Collaboration Habitat Workgroup, and best professional judgment to estimate survival estimates for another set of salmon and steelhead populations. The second approach is likely to be conservative (low) in estimating habitat benefits compared to the first method.

Both of these approaches are based on the linkages between improvements to limiting factors, improvements to habitat quality and survival improvements. The logic path that demonstrates this determination of biological effectiveness is shown below:



This methodology utilizes the best available information regarding key limiting factors, habitat improvement potential, habitat action effectiveness, and the expert views of local biologists. The particular component of this method used by the Action Agencies to quantify habitat changes and to calculate survival estimates was not formally endorsed by the Remand Collaboration Habitat Workgroup. Some critics did not endorse a numerical approach to expressing habitat functionality and potential improvements.

1.3 SUMMARY OF RESULTS

The following tables (Tables 1 through 5) display estimated survival improvement percentages by population for each ESU that are used in the biological analysis. The percentages indicate the incremental survival improvement estimated to accrue by 2017 for actions implemented for each time period shown. These time periods correspond to the base-to current (2000 to 2006) and current- to-prospective (2007 to 2017) periods represented in the biological analysis. The actions identified represent an increase in Action Agency tributary habitat effort compared to efforts for the 2000 and 2004 FCRPS BiOps. Shaded populations were estimated using the Hybrid method; unshaded populations were estimated using the Appendix E method.

Table 1. Upper Columbia River Spring Chinook Salmon Estimated Survival Improvement Percentages for Action Agencies Actions

		Estimated Percentage Survival Improvement		
MPG[1/]	**Population[2/]**	**By 2017 for Actions Completed from 2000 to 2006 (Base-to-current)**	**By 2017 for Actions Completed from 2007-2017 (Prospective)**	**After 2017 for Actions Completed from 2007-2009 (within 25 years)**
Upper Columbia - Below Chief Joseph	Entiat River	2	22	2
	Methow River	2	6	1
	Wenatchee River	2	3	

Notes:
[1/] MPG—Major Population Group
[2/] All populations were estimated using the Hybrid method.

Table 2. Upper Columbia River Steelhead Estimated Survival Improvement Percentages for Action Agencies Actions

		Estimated Percentage Survival Improvement		
MPG[1/]	**Population[2/]**	**By 2017 for Actions Completed from 2000 to 2006 (Base-to-current)**	**By 2017 for Actions Completed from 2007-2017 (Prospective)**	**After 2017 for Actions Completed from 2007-2009 (within 25 years)**
Upper Columbia River - Below Chief Joseph	Entiat River	2	8	3
	Methow River	2	4	1
	Okanogan River	6	14	3
	Wenatchee River	2	4	1

Notes:
[1/] MPG—Major Population Group
[2/]All populations were estimated using the Hybrid method.

Table 3. Mid-Columbia River Steelhead Estimated Survival Improvement Percentages for Action Agencies Actions

		Estimated Percentage Survival Improvement		
MPG[1/]	**Population[2/]**	**By 2017 for Actions Completed from 2000 to 2006 (Base-to-current)**	**By 2017 for Actions Completed from 2007-2017 (Prospective)**	**After 2017 for Actions Completed from 2007-2009 (within 25 years)**
Cascades Eastern Slope Tributaries	Deschutes River - eastside	**1**	**1**	
	Deschutes River - westside	**0.2**	**<1**	
	Fifteenmile Creek (winter run)	**0.1**	**<1**	
	Klickitat River	**4**	**4**	
	Rock Creek			
John Day River	John Day River lower mainstem tributaries	**0.2**	**<1**	
	John Day River upper mainstem	**0.2**	**<1**	
	Middle Fork John Day River	**0.2**	**<1**	
	North Fork John Day River	**0.3**	**<1**	
	South Fork John Day River	**0.7**	**1**	
Umatilla and Walla Walla River	Touchet River	**4**	**4**	
	Umatilla River	**4**	**4**	
	Walla Walla River	**4**	**4**	
Yakima River Group	Naches River	**4**	**4**	
	Satus Creek	**4**	**4**	
	Toppenish	**4**	**4**	
	Yakima River upper mainstem	**4**	**4**	

Notes:
[1/] MPG—Major Population Group
[2/] All populations were estimated using the Appendix E method.

BR002695

Table 4. Snake River Spring/Summer Chinook Salmon Action Agencies Actions

MPG[1/]	Population[2/]	Estimated Percentage Survival Improvement: By 2017 for Actions Completed from 2000 to 2006 (Base-to-current)	By 2017 for Actions Completed from 2007-2017 (Prospective)	After 2017for Actions Completed from 2007-2009 (within 25 years)
Grande Ronde / Imnaha	Catherine Creek	4	23	10
	Lostine/Wallowa River	1	2	1
	Minam River			
	Grande Ronde River upper mainstem	4	23	2
	Wenaha River			
	Big Sheep Creek			
	Imnaha River mainstem	1	1	2
Middle Fork Salmon River	Bear Valley Creek			
	Big Creek		1	1
	Camas Creek			
	Loon Creek			
	Marsh Creek			
	Sulphur Creek			
	Middle Fork Salmon River above Indian Creek			
	Chamberlain Creek			
	Middle Fork Salmon River below Indian Creek			
South Fork Salmon River	East Fork South Fork Salmon River			
	Little Salmon River			
	Secesh River		1	1
	South Fork Salmon River mainstem		<1	<1
Lower Snake	Tucannon River	3.5	17	13
Upper Salmon River	East Fork Salmon River	0.5	1	
	Lemhi River	0.5	7	
	North Fork Salmon River			
	Pahsimeroi River	0.5	41	

BR002696

Table 4. Snake River Spring/Summer Chinook Salmon Action Agencies Actions

MPG[1/]	Population[2/]	Estimated Percentage Survival Improvement: By 2017 for Actions Completed from 2000 to 2006 (Base-to-current)	By 2017 for Actions Completed from 2007-2017 (Prospective)	After 2017for Actions Completed from 2007-2009 (within 25 years)
	Salmon River lower mainstem below Redfish Lake	0.5	1	
	Salmon River upper mainstem above Redfish Lake	0.5	14	
	Valley Creek	0.5	1	
	Yankee Fork	0	30	32

Notes:
[1/] MPG—Major Population Group
[2/] Shaded populations were estimated using the Hybrid method; unshaded populations were estimated using the Appendix E method.

Table 5. Snake River Steelhead Estimated Survival Improvement Percentages for Action Agencies Actions

MPG[1/]	Population[2/]	Estimated Percentage Survival Improvement: By 2017 for Actions Completed from 2000 to 2006 (Base-to-current)	By 2017 for Actions Completed from 2007-2017 (Prospective)	After 2017 for Actions Completed from 2007-2009 (within 25 years)
Clearwater River	Clearwater River lower mainstem			
	Lochsa River	0.5	17	5
	Lolo Creek	0.5	8	2
	Selway River	0.7	<1	<1
	South Fork Clearwater River	1.5	14	3
Grande Ronde River	Grande Ronde River lower mainstem tributaries	0.1	<1	
	Grande Ronde River upper mainstem	2	4	5
	Joseph Creek (Oregon)	0.1	<1	
	Joseph Creek (Washington)	4	4	
	Wallowa River	2	<1	<1

Table 5. Snake River Steelhead Estimated Survival Improvement Percentages for Action Agencies Actions

		Estimated Percentage Survival Improvement		
MPG[1/]	**Population[2/]**	**By 2017 for Actions Completed from 2000 to 2006 (Base-to-current)**	**By 2017 for Actions Completed from 2007-2017 (Prospective)**	**After 2017 for Actions Completed from 2007-2009 (within 25 years)**
Hells Canyon	Hells Canyon	0		
Imnaha River	Imnaha River	0.1	1	1
Lower Snake	Asotin Creek	8.5	4	8
	Tucannon River	6.5	5	8
Salmon River	Lower Middle Fork mainstem and tribs (Big, Camas, and Loon Creeks)		1	1
	Chamberlain Creek			
	East Fork Salmon River	0.5	2	1
	Lemhi River	0.5	3	
	Little Salmon and Rapid River			
	Upper Middle Fork mainstem and tribs			
	North Fork Salmon River			
	Pahsimeroi River	6.5	9	
	Panther Creek			
	Salmon River upper mainstem	0.5	6	15
	Secesh River		1	1
	South Fork Salmon River		<1	<1

Notes:
[1/] MPG—Major Population Group
[2/] Shaded populations were estimated using the Hybrid method; unshaded populations were estimated using the Appendix E method.

ANNEX 1: TRIBUTARY HABITAT BENEFITS AND METHODS

1. INTRODUCTION

This report describes the methods used to calculated benefits associated with implementing habitat projects as proposed by the Action Agencies. The report describes the nature of the collaboration on habitat benefits, the two separate methods used (hybrid and Appendix E), and the actual application of these methods. The actual application of the methods is detailed, but is presented here for transparency.

The National Marine Fisheries Service (NMFS, also known as the National Oceanic and Atmospheric Administration [NOAA] Fisheries) described a method to identify the status and potential to improve survival and recovery of listed salmon and steelhead through improvement of tributary habitat conditions (Appendix E of the 2004 FCRPS BiOp [NMFS 2004]). This method identified qualitative very high (VH), high (H), medium (M), low (L), and very low (VL) estimates for status and potential for improvement. This method is hereafter referred to as the “Appendix E method.” The Action Agencies utilized the Appendix E framework to implement their tributary habitat proposed action in 2004 (Updated Proposed Action 2004) and continue to rely heavily on the biological rationale articulated in Appendix E.

The Appendix E method employed by NMFS in 2004 used the best available information at the time to estimate effects of the tributary habitat proposed action for the 2004 FCRPS BiOp. However, additional information has become available from recovery planning and other efforts that have occurred since the 2004 FCRPS BiOp was issued.

The Remand Collaboration Habitat Workgroup (CHW) convened at the request of the Policy Work Group (PWG). The PWG tasked the CHW to review the Appendix E method and (1) decide whether the method needed to be updated, and (2) if that were the case, describe an approach to update Appendix E. The CHW met regularly during the spring and summer of 2006. CHW members included representatives from the sovereign States and Tribes and Federal Agencies involved in the Collaboration process. Meeting schedules, agendas, notes, and products are available at the “step 5 habitat” webpage on the secure Collaboration website maintained by BPA. The CHW determined that Appendix E needed to be updated. Furthermore, the group developed a process and provided information that could be used to update the Appendix E method.

The CHW explored possible approaches to update the qualitative estimates in Appendix E such as using the best available data since 2004 to update Appendix E, conduct Ecosystem Diagnosis and Treatment (EDT) or other modeling, or seek more recent estimates from field biologists. The CHW determined that the Appendix E method could be updated by taking a series of steps:

1. Identify the primary factors limiting the recovery of salmon and steelhead populations,
2. Identify the tributary habitat actions (or types of actions) that could be implemented to address those limiting factors,
3. Estimate the current habitat function,
4. Estimate the habitat function that could be obtained by 2017 (within 10 years) by implementing all tributary habitat restoration actions that were identified as planned by 2017,
5. Estimate the habitat function that could be obtained after 2017 (within 25 years) by implementing all tributary habitat restoration actions that were identified as planned by 2017, and
6. Convert estimated overall habitat functions to survival estimates.

CHW sought assistance from local biologists on steps 1-5, and reviewed methods, which the Action Agencies used to complete step 6.

The CHW determined it would be beneficial to create a logical path to obtain estimates of the habitat condition and survival improvement potential from habitat actions. After several meetings and revisions, the CHW settled on developing tables that included columns to consider the population, assessment unit, limiting factors, potential actions that could be implemented to address primary limiting factors, and the current and potential future habitat function.

The CHW developed a template and instructions to obtain the data and information that were provided by each State from field biologists. This table template provided the basis for estimating changes in habitat function for salmon and steelhead populations, which Remand Collaboration Habitat Workgroup members solicited from local field biologists and recovery planners.

Although data and information obtained by CHW participants varied by location, they represented the following general conditions. Local biologists[2] and recovery planning processes were enlisted by CHW members to identify primary limiting factors, tributary habitat actions needed to address those limiting factors, and to estimate habitat functions. Local biologists identified limiting factors and actions needed to reach recovery.

Information used to determine habitat functions varied by location. Local biologists determined habitat function utilizing their professional judgment and any other data and information at their disposal, including EDT or any other data- analysis tools. Most CHW participants recognized that empirical data and information provides the best insight for determining habitat function. However, most CHW participants acknowledged that the extent of readily- available empirical data and information was not adequate at the time to make a precise determination of habitat function uniformly throughout the Columbia River Basin. Most CHW participants acknowledged that regardless of the amount of empirical data and information available, professional judgment by expert scientists provided a large part of the determination of habitat function in all locations simply because of the limited extent of readily-available empirical data and information.

The States of Washington, Idaho, and Oregon each provided tables of information in slightly different formats from the original template. Tables received from Washington were reformatted by the Action Agencies to conform to the original template.

The Action Agencies used base information from Appendix E, limiting factors, actions, and habitat functions provided by the CHW in the tables described above, and professional judgment to develop survival estimates attributable to tributary habitat actions to be implemented in partnership with States, Tribes, and others with funding and/or technical assistance from the Action Agencies. Specific tributary habitat actions are described in the Tributary Habitat Action. The following sections describe the methods the Action Agencies used to convert this information to survival improvement estimates.

2. METHODS

Two methods were used to estimate survival improvements— the Appendix E method and the Hybrid method. These methods were used to estimate survival improvements for actions completed from 2000 to

[2] Local biologists enlisted in these efforts were employed by sovereign tribes and State and Federal agencies and were intimately familiar with the biological and physical status and needs of anadromous fish as well as the salient details entailed in subbasin and recovery planning and project funding processes for the salmon and steelhead populations they addressed. In Washington, these specialists were sponsored by experts and persons responsible for developing regional recovery plans

2006, and actions to be implemented from 2007-2017. The following sections generally describe these methods.

2.1 Appendix E Method

To estimate survival estimates based on Appendix E, the following steps were involved:

1a) Assembling lists of completed projects with habitat work element actions for the 2000 to 2006 timeframe for the respective ESU populations.

1b) Assembling lists of proposed projects that will be funded for 2007 to 2009 with habitat work element actions for the respective ESU populations.

2) Linking the projects to the populations to the extent enabled by database information.

3) Considering the project work elements linkage to beneficial on-the-ground habitat work to address important limiting factors for a population.

4) If habitat work element actions that help address limiting factors to benefit the population occur in the population area, then Appendix E estimate is possible. If no habitat work element actions that benefit the population occur in the population area, then no estimate of benefit is made.

5) Appendix E used a qualitative system of benefits associated with a quantitative range to estimate "adjusted improvement potential based on practical constraints" (Very Low: 0; Low: > 0 > 2; Medium: 2-24; High: 25 < 100; Very High: 100). This estimate that considers practical constraints is a conservative Appendix E estimate (Very low=0; Low=1; Medium=4; High=25; Very High=100).

Using Low-end Appendix E Ranges in each timeframe, and develop rationale for supporting higher estimates for populations with gaps: This approach uses the low end of Appendix E ranges as the total survival estimate possible from implementing tributary habitat actions in each of the three timeframes (2000 to 2006; 2007 to 2009; 2010 to 2017), with the total capped by the maximum potential from recovery actions calculated by states for the Remand Workgroup Process.

6) In using Appendix E for estimating population survival, a low end (conservative estimate) was initially used as follows: Very low=0; Low=1; Medium=4; High=25; Very High=100. Thus, if a population area had beneficial habitat work elements from projects in 2000 to 2006 or 2007 to 2009 and the Appendix E improvement potential was Medium, then a survival estimate of 4 percent was used in the tables. This survival estimate was expressed as a 1.04 survival multiplier in each of the first two timeframes of 2000 to 2006 and 2007 to 2009 if there were beneficial work element habitat actions for the respective time period. The total from multiplying the values from each of the timeframes should not exceed the "survival improvement (juvenile) potential from current condition (recovery plan actions estimated by remand habitat workgroup (25 yrs)" (see numbers in Draft NMFS staff product: Possible recovery scenarios based on Interior Columbia Basin Technical Recovery Team [TRT] criteria).

7) Use only if maximum potential is exceeded: If the Appendix E estimate results from combining the low end estimates in each timeframe results in a value that exceeds the maximum potential, then the Appendix E estimate was adjusted downward to not exceed the maximum survival improvement potential from the remand habitat workgroup process. A number of maximum potential values were provided by the CHW and were used in the following order: 10-

year maximum potential, 25-year maximum potential, and "survival improvement (juvenile) potential from current condition (recovery plan actions estimated by remand habitat workgroup (25 years)" (see numbers in Draft NMFS staff product: Possible recovery scenarios based on Interior Columbia Basin TRT criteria).

8) Potential to increase estimates may exist based on any additional actions and input from local biologists, project sponsors, and recovery planners: The estimates using the Appendix E based approach could potentially be increased after additional input from local biologists and project sponsors. If more information about the limiting factors and the actions to be implemented for specific populations is added and the Habitat Workgroup estimate is used with a potential to recalculate the maximum potential for a population, many estimates would be expected to increase.

2.2 Hybrid Method

A number of methods to convert habitat function to survival estimates were discussed by the CHW. These methods included habitat models and a simplified general approach. The habitat models included EDT (Independent Scientific Advisory Board [ISAB] 2001), Shiraz (Scheuerell and others 2006), McHugh (McHugh and others 2004), and an approach presented by one of the members of the HWC. Although each of these models have strong and weak points, most, but not all, HWC participants concluded that each model required a significant amount of empirical data and information that was not consistently and readily available for all salmon and steelhead populations throughout the Columbia River Basin.

A simplified general approach (Remand Collaboration Habitat Workgroup 2006) was developed by the HWC (Attachment 1).[3] This method uses the habitat functions provided in the CHW tables and averages available, generalized, empirically-derived egg-smolt survival relations to produce linear relations between overall habitat function and egg-smolt survival for salmon and steelhead. This method is certainly not precise; however, it provides a method that:

1. uses habitat function information provided in the CHW tables,
2. is derived from the egg-smolt survival literature and
3. can be applied for all salmon and steelhead populations in the Columbia River Basin. This method is referred to as the Hybrid Method in the remainder of this report.

Survival estimates by 2017 and 25 years after 2017 calculated using the Hybrid Method for all planned tributary habitat restoration actions that could be implemented by 2017 were provided to the HWC for salmon and steelhead populations in Washington**.** Survival estimates 25 years after 2017 calculated using this approach for all planned tributary habitat restoration actions that could be implemented by 2017 were provided to the HWC for salmon and steelhead populations in Idaho.

The Action Agencies used the Hybrid Method to calculate survival estimates by 2017 and 25 years after 2017 for tributary habitat actions implemented in partnership with States, Tribes, and others with funding and/or technical assistance from the Action Agencies from 2000 to 2006 and tributary habitat actions expected to be implemented in partnership with States, Tribes, and others with funding and/or technical assistance from the Action Agencies from 2007 to 2009 with information provided by local biologists and project sponsors described below.

[3] Note that not all participants in the CHW fully agreed to the methods develop by the Workgroup.

Action Agency representatives met with local biologists, project sponsors, and other CHW members in October and November, 2006, and in May, 2007, to obtain input about the effects on habitat function by 2017 and continuing effects after 2017 resulting from tributary habitat actions implemented in partnership with States, Tribes, and others with funding and/or technical assistance from the Action Agencies from 2000 to 2006 and habitat actions expected to be implemented in partnership with States, Tribes, and others with funding and/or technical assistance from the Action Agencies from 2007 to 2009.

In some cases the effects of tributary habitat actions completed from 2000 to 2006 were already included in the estimate of current habitat function. However, in some cases (most notably riparian protection and enhancement actions) habitat function could continue to improve for decades as a consequence of actions already completed. The objective of identifying habitat function associated with actions completed from 2000 to 2006 was to capture the continuing effects associated with those completed actions that continue to improve habitat function after completion. For example, riparian planting actions that occurred in 2002 may have small survival improvement benefits the first few years after planting, but shading, cooling, and habitat benefits accrue as the vegetation grows and matures in later years, sometimes continuing to accumulate additional survival improvement benefits for several decades.

Actions expected to be implemented from 2007 to 2009 are those that 1) have been identified for funding by BPA based on biological priorities and recommendations from the Northwest Power and Conservation Council, and 2) are already "in the pipeline" for implementation in partnership with States, Tribes, and others with funding and/or technical assistance from the Action Agencies by the Action Agencies. Specific actions are described in the Tributary Habitat Action.

Identifying effects by 2017 of both actions completed from 2000 to 2006 and actions expected to be implemented in partnership with States, Tribes, and others with funding and/or technical assistance from the Action Agencies from 2007 to 2009 quantifies those effects within the 10 year time frame of a Biological Opinion. Identifying effects after 2017 of both actions completed from 2000 to 2006 and expected to be implemented from 2007 to 2009 quantifies the continuing effects that some actions (most notably riparian protection and enhancement actions) could continue to provide after the initial 10-year time frame.

2.2.1 Meetings

2.2.1.1 Walla Walla Meeting

Tributary habitat actions for Tucannon and Asotin spring Chinook salmon and steelhead were discussed at a meeting held in Walla Walla, Washington on October 18, 2006. Meeting participants provided habitat function estimates and comments associated with tributary habitat actions implemented in partnership with States, Tribes, and others with funding and/or technical assistance from the Action Agencies. Estimates were reviewed and updated by biologists at the Lower Snake River Salmon Recovery Technical Team meeting on October 24.

2.2.1.2 Wenatchee Meetings

Actions for Methow, Wenatchee, and Entiat spring Chinook salmon and steelhead and Okanogan steelhead were discussed at an initial meeting in Wenatchee, Washington on October 19, 2006. Follow-up meetings for Upper Columbia populations of spring Chinook salmon and steelhead populations were held in Wenatchee for Entiat populations on November 7, 2006, Methow populations on November 13, 2006, and Wenatchee populations on November 14, 2006. Participants at the initial October 19 meeting had questions about derivation of the original current and resulting 10- and 25-year habitat functions. Working tables produced at this meeting included comments and indicated relative changes in habitat function that fell between the original references of current and resulting 10- and 25-year habitat functions. Some of the original reference current and resulting 10- and 25-year habitat functions were revised and absolute habitat functions were provided at follow-up meetings.

2.2.1.3 Boise Meetings

Actions for Snake River steelhead in the Clearwater and Little Salmon subbasins were discussed at a meeting held in Boise, Idaho on November 16, 2006. Actions for Snake River spring Chinook salmon and steelhead in the Salmon River Basin were discussed at a meeting held in Boise, Idaho on November 17, 2006. Meeting participants provided habitat function estimates and comments associated with tributary habitat actions implemented in partnership with States, Tribes, and others with funding and/or technical assistance from the Action Agencies in the Clearwater subbasin and the Salmon basin.

2.2.1.4 La Grande Meeting

Actions for Upper Grande Ronde and Catherine Creek Chinook salmon and Upper Grande Ronde steelhead were discussed at a meeting in La Grande, Oregon, on May 2 and 3, 2007. Meeting participants provided habitat function estimates for 2007 to 2009 tributary habitat actions funded through the Northwest Power and Conservation Council (Council) 2007 to 2009 solicitation, which were implemented in partnership with States, Tribes, and others with funding and/or technical assistance from the Action Agencies in the Grande Ronde subbasin.

2.2.1.5 Spokane Meeting

Additional actions for Okanogan steelhead were discussed at a meeting in Spokane, Washington, on May 4, 2007. Participants identified additional 2007 to 2017 actions and associated changes in habitat function for Okanogan steelhead for Action Agency consideration.

2.2.2 Survival Improvement Estimates for Actions Completed from 2000 to 2006 and Actions to be Implemented from 2007 to 2009

Survival improvement estimates were calculated with the Hybrid Method in a series of steps by applying information obtained from the original habitat tables and from information obtained at field verification meetings held with local biologists and project sponsors in October and November, 2006, and May, 2007. Information used from the original habitat tables included population name, assessment unit weight, assessment unit area, limiting factor, and reference habitat functions (current habitat function and the resulting habitat functions that could be obtained by 2017 and after 2031 by implementing all planned actions identified to address limiting factors by 2017). Information used from the field verification meetings included any revised reference habitat functions and estimated habitat function by 2017 and after 2017 associated with tributary habitat actions implemented in partnership with States, Tribes, and others with funding and/or technical assistance from the Action Agencies from 2000 to 2006 and actions expected to be implemented from 2007 to 2009.

Numerical survival estimates were calculated using the method described by the Remand Collaboration Habitat Workgroup (2006) as follows:

1) For each assessment unit in a population:

    a) The average habitat function was calculated as the sum of the habitat functions for each limiting factor in the assessment unit and dividing by the number of limiting factors

    b) Survival within an assessment unit was calculated by multiplying the average habitat function determined in step 1a by the assessment unit weight and by the slope of the egg-smolt survival function (0.0018 for Chinook salmon; 0.0004 for steelhead, Remand Collaboration Habitat Workgroup [2006]).

2) For each population:

The resulting assessment unit survival estimates calculated in step 1b were summed to obtain the population survival estimate.

The calculation of habitat function described in step 1a is the same approach used by state and tribal participants in the CHW who provided the original tables that included limiting factors, actions to address those limiting factors, and calculation of current and resulting habitat functions from implementing all planned actions by 2017.

Numerical survival estimates were calculated in this fashion for six different representations of habitat function:

1. current habitat function;
2. habitat function by 2017 resulting from implementing all tributary habitat restoration actions that were identified as planned by 2017;
3. resulting habitat function by 2017 associated with tributary habitat actions implemented in partnership with States, Tribes, and others with funding and/or technical assistance from the Action Agencies from 2000 to 2006;
4. resulting habitat function by 2017 associated with tributary habitat actions expected to be implemented in partnership with States, Tribes, and others with funding and/or technical assistance from the Action Agencies from 2007 to 2009;
5. resulting habitat function after 2017 (within 25 years) associated with tributary habitat actions implemented in partnership with States, Tribes, and others with funding and/or technical assistance from the Action Agencies from 2000 to 2006 and actions expected to be implemented in partnership with States, Tribes, and others with funding and/or technical assistance from the Action Agencies from 2007 to 2009; and
6. habitat function after 2017 (within 25 years) resulting from implementing all tributary habitat restoration actions that were identified as planned by 2017.

Numerical changes in estimated survival were calculated for each of the six different representations of habitat function described above by dividing the resulting population survival estimate by the numerical survival estimate for current habitat function.

3. APPLICATION OF METHODS AND RESULTS

The methods described above were applied to obtain survival improvement estimates for three sets of actions completed or to be implemented from: 2000 to 2006, 2007 to 2009, and 2010 to 2017. Furthermore, survival improvement estimates were obtained for these three sets of actions by 2017 (the term of the BiOp) and after 2017 (to account for survival improvement benefits that accrue in the long term, such as riparian actions).

During development of these documents, the Action Agencies decided to report 2007 to 2017 tributary habitat results simply as the combination of the 2007 to 2009 and 2010 to 2017 results to be consistent with reporting for the other components described in the Action and biological analysis. Follow-up meetings identified additional 2008 and 2009 actions for some populations. Survival improvement by 2017 (within 10 years) and after 2017 (within 25 years) estimated for these populations using the Hybrid Method were combined with survival estimates obtained for the other 2007 to 2017 actions described above. In some cases a combination of both methods was used to estimate survival improvements as described below. Survival improvement estimates described in this annex are presented in Attachment 2.2-1, Table 1 of the Biological Assessment and were used in the biological analysis described in separate reports.

3.1 Survival Improvement Estimates Through 2017 for Actions Completed from 2000 to 2006

The Appendix E method described in an earlier section of this annex was used to estimate survival improvement associated with actions completed from 2000 to 2006 for the unshaded salmon and steelhead populations in Attachment 2.2-1, Table 1 of the Biological Assessment and for upper Grande Ronde and Catherine Creek Chinook salmon and upper Grande Ronde steelhead populations.

The following method was used to estimate survival improvement associated with actions completed from 2000 to 2006 for salmon and steelhead populations which are shaded in Attachment 2.2-1, Table 1 of the Biological Assessment except for upper Grande Ronde and Catherine Creek Chinook salmon and upper Grande Ronde steelhead populations for which the Appendix E method was used. A combination of the Appendix E and Hybrid method was used to calculate these estimates as follows.

1. Referred to qualitative biological benefits identified in the 2004 Updated Proposed Action (UPA) for "Tributary Habitat Actions Implemented under the 2000 RPA." This indicated the survival improvement benefits expected by the Action Agencies for 2000-2003 actions.
2. Referred to qualitative biological benefits identified in the 2004 UPA for "Tributary Habitat Actions" associated with the UPA. This indicated the survival improvement benefits expected by the Action Agencies for actions after 2004.
3. Referred to the qualitative determination of benefits associated with tributary habitat actions for each ESU contained in the "Conclusion" section of the 2004 FCRPS BiOp. This indicated the survival improvement benefits NMFS associated with tributary habitat actions to be implemented after 2004.
4. Referred to tables of metrics for 2000 to 2006 completed actions associated with the 2000 and 2004 BiOps compiled by BPA and Reclamation.
5. Referred to the Appendix E qualitative potential values (VL to VH) and associated numerical ranges.
6. Converted the qualitative Appendix E values to the following numeric values:

Appendix E Qualitative Value	Appendix E Numeric Range	Representative Numeric Value (RNV)
Very Low	0	0
Low	0-2	1
Low end of Medium	N/A	4
Medium	2-24	N/A
High	25-100	N/A
Very High	100	N/A

Single numeric values were assigned to represent each numeric ranges cited in Appendix E. The qualitative value "Low" was assigned a midpoint value of 1 and "Low end of Medium" was assigned a value of 4.

Information from step 4 was reviewed to validate metrics associated with completed 2000 to 2006 actions for respective ESUs. The survival estimate for 2000 to 2006 completed actions was calculated by averaging the representative numeric values associated with step 1 and for step 5 for each ESU. This approach incorporates available information about expected biological benefits before 2004 (step 1) and after 2003 (step 5). The resulting value represented survival improvement associated with the 2000 to 2006 time period and was added to the survival improvement value obtained from the Hybrid Method for 2000 to 2006 completed actions, which represented survival improvement benefits accrued from 2007 to 2017.

3.2 Survival Improvement Estimates After 2017 for Actions Completed from 2000 to 2006 Funded for 2008 and 2009

Survival improvements after 2017 (within 25 years) were not estimated for populations for which the Appendix E method was used. The Hybrid method described in an earlier section of this annex was used to estimate survival improvement after 2017 associated with actions completed from 2000 to 2006, actions to be implemented from 2007 to 2009, and additional actions funded for 2008 and 2009 (for populations for which follow-up meetings were held) for the shaded salmon and steelhead populations in Tables 1 through 5 of Attachment C-1.

REFERENCES

ISAB (Independent Scientific Advisory Board). 2001. Model synthesis report. Independent Scientific Advisory Board for the Northwest Power Planning Council and the National Marine Fisheries Service, Portland, Oregon. Report No. ISAB 2001-1. March 2001.

ISAB. 2001. A review of salmon recovery strategies for the Columbia River Basin. Independent Scientific Advisory Board for the Northwest Power Planning Council and the National Marine Fisheries Service, Portland, Oregon. Report No. ISAB 2001-7. 22. August 2001.

McHugh, P., P, Budy, and H. Schaller. 2004. A model-based assessment of the potential response of Snake River spring-summer Chinook salmon to habitat improvements. Transactions of the American Fisheries Society 133:622-638.

NMFS (National Marine Fisheries Service). 2004. Biological Opinion (Log Number:F/NWR/2004/00727). Consultation on Remand for Operation of the Columbia River Power system and 19 Bureau of Reclamation Projects in the Columbia Basin. Appendix E: Habitat Improvements as Offsite Mitigation for FCRPS Operations: A qualitative Assessment.

Remand Collaboration Habitat Workgroup. 2006. Approach to estimating survival benefits of habitat actions. August 2006 (updated on March 27, 2007).

Scheuerell, M.D., R. Hillborn, M.H. Ruckelshaus, K.K. Bartz, K.M. Lagueux, A.D. Haa, and K. Rawson. 2006. The Shiraz model: a tool for incorporating anthropogenic effects and fish-habitat relationships in conservation planning. Canadian Journal of Fisheries and Aquatic Sciences 63:1596-1607.

U.S. Army Corps of Engineers, Bureau of Reclamation, and Bonneville Power Administration. 2004. Final Updated Proposed Action for the FCRPS Biological Opinion Remand. November 24, 2004.

ANNEX 2
APPROACH TO ESTIMATING SURVIVAL BENEFITS OF HABITAT ACTIONS

1. INTRODUCTION

Over the decade, many books on salmon conservation have emerged (e.g., National Research Council (NRC) 1996; Stouder et al. 1997; Lichatowich 1999; Knudsen et al. 2000; Lynch et al. 2002; Montgomery et al. 2003; Wissmar and Bisson 2003), and all agree that habitat restoration should be a cornerstone of any recovery program. As such, it is important to identify locations where current habitat conditions would benefit from protection or restoration. In addition, it is also important to assess the potential benefits of habitat actions to target fish populations and Evolutionarily Significant Units (ESUs).

Estimating potential biological benefits (e.g., increased survival or productivity) is a difficult task because most habitat actions do not affect biological parameters directly. The usual approach is to manipulate the environment (e.g., add wood, rock, vegetation, nutrients, passage) in the hope that the change in the environment will result in a desired change in the population (biological parameters). For example, one may add woody debris to a stream to increase the abundance and survival (productivity) of juvenile Chinook salmon in a stream reach. In the chain-of-causation, the "cause" is the addition of wood (treatment), which directly "affects" the stream environment (presence of woody debris is the first link in the chain). The presence of woody debris should then "affect" the abundance and survival of juvenile Chinook salmon (biological response is the second link). Note that abundance and survival of Chinook salmon (biological response) is more than one link from the treatment (Figure 1).

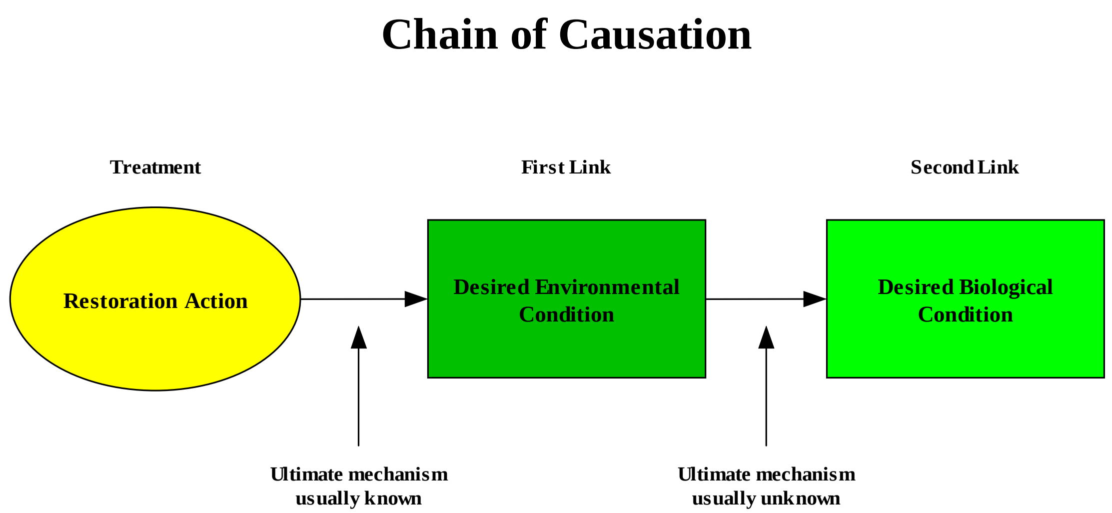


Figure 1. Conceptual Model Showing the Chain-of-Causation from the Restoration Action (treatment) to the Environmental and Biological Responses

Note: The mechanism(s) resulting in a biological change is (are) less well understood as more links are added to the chain.

BR002708

As a general rule, the more links there are between the treatment and desired effect, the more difficult it will be to detect or predict a treatment effect. Stated another way, the more links between the treatment and the desired effect, the less confidence one has that the treatment will actually result in a desired effect. This is because several other factors (extraneous or nuisance factors) may have a greater effect on the desired outcome than the treatment. For example, it is unlikely that one can predict with any confidence what affect rock weirs will have on the abundance and productivity of adult Chinook salmon within a stream. Not only is adult abundance several links removed from the treatment, Chinook salmon, like other anadromous species, use multiple ecosystems (tributary, mainstem, estuary, ocean systems) that are each replete with extraneous factors acting upon the survival of the fish (Figure 2). As the number of links between the action and the desired response increase, the number of extraneous factors increases making predictions about biological responses uncertain.

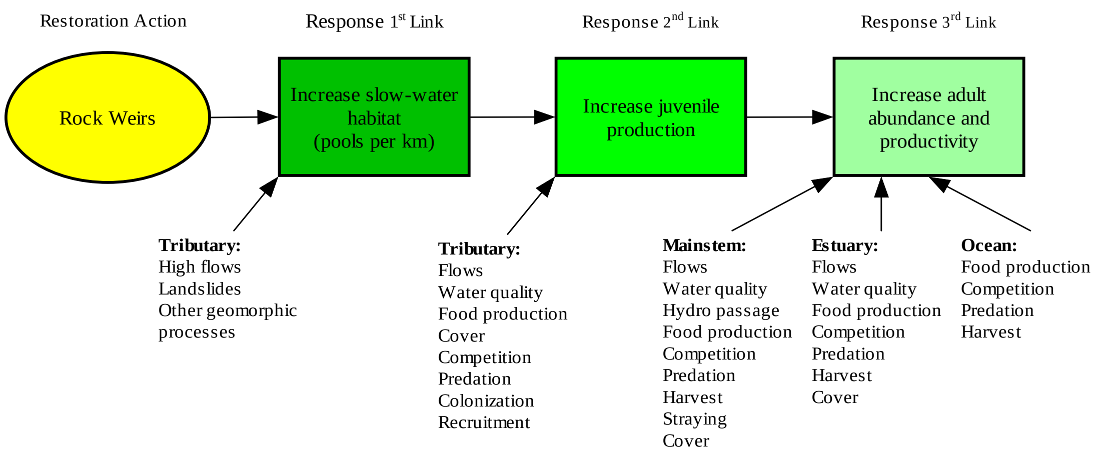


Figure 2. Relationship between a Restoration Action (rock weirs) and Physical and Biological Responses

Note: As the number of links increase, the number of extraneous factors (those listed below the causal chain) increase, making it more difficult to identify a treatment effect. The ability to predict desired outcomes decreases as more links are added to the chain (reflected in the decreasing shades of green).

For these reasons, it is very difficult to estimate with any certainty the potential benefits of habitat actions on adult abundance or productivity. Therefore, the Habitat Workgroup estimated survival benefits for only two life-stages, juvenile and pre-spawning adult.

There were two general approaches that the Habitat Workgroup explored: (1) lifecycle models and (2) professional judgment (similar to the Appendix E approach used in the 2004 BiOp [see Annex 1 to this attachment]). The workgroup considered models such as Ecosystem Diagnosis and Treatment (EDT), Habitat Quality Index (HQI), Habitat Evaluation Procedures (HEP), Physical Habitat Simulation Model (PHABSIM), Shiraz, and a simple model developed by the Columbia River Inter-Tribal Fish Commission (CRITFC). One model, EDT, has been used by some recovery planning groups to estimate survival benefits associated with recovery actions. Although the model was used to generate hypotheses in draft recovery plans, it is very complex, relies on many assumptions, and requires considerable input based on empirical data, derived data, and/or professional judgment. In addition, outputs lack confidence limits and therefore sensitivity analysis is needed to estimate certainty. Populating and running the model is time-consuming. Other models (e.g., HQI, HEP, PHABSIM, and Shiraz) can be used to generate hypotheses about potential benefits, but, like EDT, these tools require significant input and time to run. Given the lack of time and information or data, such analytical tools or models were not an option in the Remand Process. The workgroup did use results from models used in other forums (e.g., recovery plans and subbasin plans).

The second approach relied on professional judgment. This method was deemed the most reasonable approach given the lack of time and information available. This approach relied heavily upon the expertise of local biologists. Local biologists with the most knowledge about local watershed processes, habitat conditions, and fish populations in their respective areas provided the workgroup with estimates of current habitat conditions, primary limiting factors, restoration actions needed to fix limiting factors, and potential habitat conditions that would result if the primary limiting factors were addressed.

In an attempt to standardize the habitat assessment process, the Habitat Workgroup provided local biologists with a guidance document and standardized matrices to aid in estimating current conditions, limiting factors, restoration actions, and potential habitat conditions. Local biologists, with guidance from the Habitat Workgroup, populated the habitat matrices. Data within these matrices were used by the Habitat Workgroup to estimate overall habitat quality and potential survival benefits associated with implementing proposed tributary habitat actions.

2. ESTIMATING HABITAT QUALITY

Habitat quality is dependent on more than one habitat variable (e.g., stream flows, temperature, water quality, fine sediments, pools, woody debris, and off-channel habitat). Local biologists provided the Habitat Workgroup with estimates of current and potential conditions[3] for each habitat variable that was currently limiting fish productivity. The workgroup then combined the condition scores for each individual variable into a composite habitat quality score. The workgroup evaluated several different methods for combining conditions of individual habitat variables to obtain a composite score.

1. The first method was multiplication (i.e., multiply the individual habitat scores to obtain a composite score). This method assumes that fish select each particular habitat variable independently of other variables (assumes no interaction or compensation). One problem with this method is that the product equation yields zero habitat quality for any given habitat variable of unsuitable condition. For example, a stream reach with no woody debris (0 percent function) would result in a composite habitat quality score of 0 percent.
2. The second approach used the lowest condition habitat variable as the composite habitat quality score. This assumes that the most limiting factor (habitat variable with the lowest condition score) determines the upper limit of habitat quality and the fact that variables with high condition cannot compensate for low condition variables.
3. The third approach was the geometric mean of individual habitat scores. This method provides some compensation, but like the product equation, it yields zero habitat quality for any zero-valued habitat variable.
4. The final approach was the arithmetic mean of individual habitat scores. This approach assumes that good habitat conditions on one variable can compensate for poor conditions on other variables.

[3] Current and potential conditions were given as percentages of optimal conditions. NMFS definition of properly functioning condition (PFC) was used to help local biologist understand what was meant by optimal condition (see NMFS 1996).

After evaluating these methods, the Habitat Workgroup concluded that a combination of the second and fourth approaches was reasonable. The second method was used when a limiting habitat variable was considered a lethal factor. Lethal factors included variables that at certain concentrations or levels kill fish (e.g., temperature and other water quality parameters, fine sediment, and flows).[4] Thus, overall habitat quality was based only on the condition of the lethal factor if its concentration was at a level that would kill fish. The arithmetic mean (fourth approach) was used if no lethal factors were identified by the local biologists.

Following this exercise, the Habitat Workgroup then identified "functional relationships" that would aid in estimating potential survival benefits corresponding to projected changes in habitat quality. The intent was to find a simple function or functions that would allow the workgroup to estimate how much juvenile or pre-spawning adult survival would increase if habitat quality improved from, say, 35 percent to 45 percent of optimal condition. The functional relationships were only used to guide professional judgment in estimating potential survival increases. They were not developed to estimate "absolute" survival rates.

3. IDENTIFICATION OF FUNCTIONAL RELATIONSHIPS

Not knowing if the "shape" of the relationship between habitat quality (as a percent of optimal condition) and survival was linear or non-linear, the Habitat Workgroup began by exploring existing lifecycle models in search of common relationships that could be used to guide professional judgment. Examination of relationships in EDT was difficult, because of the complexities of the model. The workgroup found no simple functions in EDT that could be used to guide professional judgment. On the other hand, the Shiraz model (Scheuerell et al. 2006) and work by McHugh et al. (2004) were more transparent and provided analytical relationships between habitat attributes and survival. These models included relationships for temperature, fine sediment (embeddedness), flows, and cover (cobbles and wood) for different juvenile life stages and for pre-spawning adults. Listed below are relationships between survival and habitat attributes for different life stages.

3.1 LIFESTAGE HABITAT/SURVIVAL RELATIONSHIP

3.1.1 Incubation

Scheuerell et al. (2006) described the following hockey-stick relationship between temperature and egg-fry survival based on data in Tappel and Bjornn (1983):

$$p_{1,2} = \begin{cases} 0.95 & \text{if } f < 0.268 \\ -3.32f + 1.81 & \text{if } 0.268 \le f < 0.544 \\ 0.06 & \text{if } f \ge 0.544 \end{cases}$$

This function relates survival ($p_{1,2}$) to the percentage of fine sediment ($f < 6.35$ mm) within spawning and incubation habitat. If fines less than 1.7 mm are used, the following relationship applies:

$$p_{1,2} = \begin{cases} 0.93 & \text{if } f < 0.116 \\ -5.21f + 1.54 & \text{if } 0.116 \le f < 0.283 \\ 0.06 & \text{if } f \ge 0.283 \end{cases}$$

[4] In contrast, controlling factors include variables that do not directly kill fish but can affect their abundance and distribution (e.g., number of pools, off-channel habitat, woody debris, etc.). These variables were averaged to estimate overall habitat quality.

McHugh et al. (2006) provided an alternative survival function based on data in Stowell et al. (1983) and Tappel and Bjornn (1983).

$$p_{1,2} = [92.95 / (1 + e^{-3.994+0.1067*fines})]/100$$

This relationship is based on fine sediments in spawning gravels less than 6.35 mm in diameter. Scheuerell et al. (2006) described the following relationship between water temperature (T_{inc}) and egg-fry survival ($p_{1,2}$):

$$p_{2,1} = \begin{cases} 0.273T_{inc} - 0.342 & \text{if } 1.3 \le T_{inc} < 4.7 \\ 0.94 & \text{if } 4.7 \le T_{inc} < 14.3 \\ -0.245T_{inc} + 4.44 & \text{if } 14.3 \le T_{inc} < 18.1 \\ 0.01 & \text{if } T_{inc} \ge 18.1 \end{cases}$$

McHugh et al. (2004) described an alternative survival rate function for egg-fry survival.

$$p_{1,2} = -0.26 + 0.27(T_{inc}) - 0.02(T_{inc})^2$$

Scheuerell et al. (2006) described the following relationship between normalized flow (Q*) and egg-fry survival ($p_{1,2}$):

$$p_{2,2} = \begin{cases} 0.58 - 0.844Q^* & \text{if } Q^* < 0.675 \\ 0.01 & \text{if } Q^* \ge 0.675 \end{cases}$$

3.1.2 Summer Rearing

McHugh et al. (2006) provided the following functional relationship using a polynomial function reported in Stowell et al. (1983) based on the work of Bjornn et al. (1977).

$$S = [100 - 1.79(\text{Emb}) + 0.0081(\text{Emb})^2]/100$$

The function relates percentage summer stream capacity to the degree (percent) that cobbles are embedded in riffle/run habitat.

McHugh et al. (2004) described the following relationship between water temperature and survival of Chinook salmon parr during summer rearing:

$$S = \exp\left\{-\left[\left(\frac{sumT}{27.0271}\right)^{10.74}\right]\right\}$$

This function was computed using a Weibull function that related daily survival (S) to mean daily stream temperature ($sumT$) for any given day of the summer rearing period. Using this function, the daily survival rate decreases whenever the average daily temperature exceeds an upper temperature threshold of 17.8 °C.

3.1.3 Winter Rearing

McHugh et al. (2006) provided the following relationship using a function reported in Stowell et al. (1983) based on the work of Bjornn et al. (1977).

$$S = 1.001e^{-0.013(\mathrm{Emb})}$$

This exponential function relates overwinter capacity for Chinook salmon parr to percent pool embeddedness (Emb).

Cramer (2001) described the following relationship between percentage of cobbles and wood in pools (<15 percent) and overwinter survival of Chinook salmon parr:

$$S = 20 + [80(\mathrm{Cob})/15]/100$$

3.1.4 Pre-Spawning Adult

Cramer (2001) provided the following relationship for pre-spawner adult Chinook salmon:

$$p_1 = \begin{cases} 1 & \text{if } T_{pre} < 16 \\ 1 - 0.15(T_{pre} - 16) & \text{if } 16 \le T_{pre} < 22.6 \\ 0.01 & \text{if } T_{pre} \ge 22.6 \end{cases}$$

This function relates adult survival (p_1) to mean maximum temperatures (T_{pre}) during migration and pre-spawning.

These functions describe relationships between specific habitat attributes (e.g., temperature, fine sediment, etc.) and survival. However, local biologists provided habitat quality data scaled from 0 percent to 100 percent of optimal condition. Therefore, it was necessary to transform the habitat attributes into a common habitat quality index that ranged from 0-100 percent; where 0 percent habitat quality represented the worst habitat condition (lethal sediment levels and temperatures) and 100 percent habitat quality represented the best habitat condition (optimal temperature and sediment levels). These habitat quality ratings of 0-100 percent equated to survival indices that ranged from 0.0 to 1.0, respectively. In this case the survival index has no connection with "absolute" survival rate. That is, one cannot determine the absolute egg-smolt survival rate from these relationships. In contrast, the functions can be used to estimate possible survival increases associated with habitat actions if the ratio of the survival index under improved habitat conditions (potential survival index; S_{rp}) to the survival index under current conditions (S_{rc}) equals the ratio of potential absolute survival (S_{ap}) to current absolute survival (S_{ac}).

$$S_{rp} / S_{rc} \approx S_{ap} / S_{ac}$$

Thus, an estimated survival index ratio of 1.2, calculated as the ratio of the potential survival index of 0.30 to the current survival index of 0.25, implies that the absolute survival rate would increase approximately 20 percent if habitat restoration actions were implemented. If the current absolute survival rate is 0.08[5], the expected potential survival rate would increase about 20 percent to 0.10. In this exercise the workgroup is more concerned with the ratio than with the absolute survival values.

The workgroup plotted the relationships in an effort to find a common "shape" among the functions (Figure 3). It was clear that no "common" functional relationship existed within or among life stages. Therefore, the workgroup tried to combine relationships in an attempt to find a shape of central tendency.[6] The workgroup explored several different approaches: (1) average across all survival functions, (2) average survival functions within a life stage and multiply the mean functions across life stages, (3) multiply across all survival functions, and (4) use a simple linear function. These relationships are shown in Figure 4.

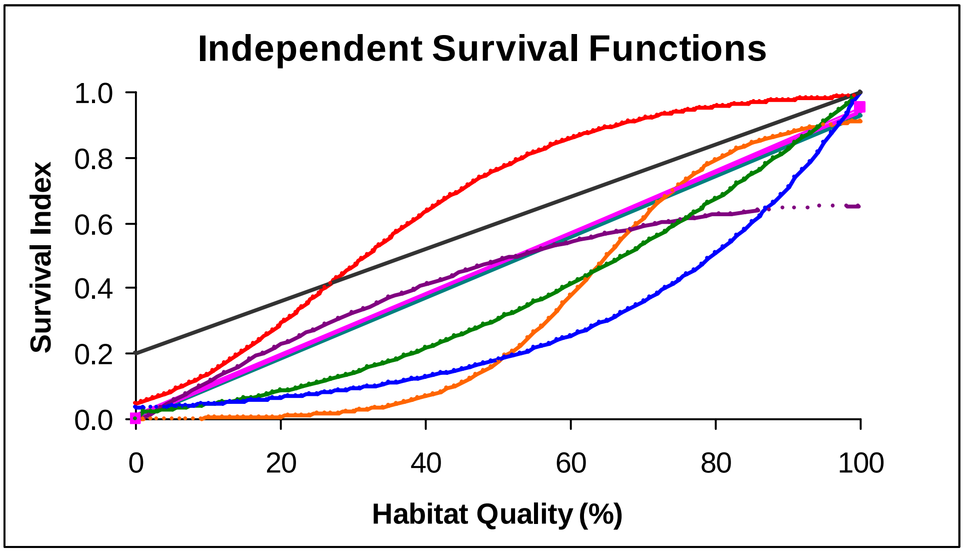


Figure 3. Various Shapes of Functional Relationships between Habitat Quality and Survival Index

[5] For many populations, absolute survival rates for juvenile Chinook salmon are unknown. Calculating ratios of survival indices appears to be a useful alternative in the absence of absolute survival rates. This is based on the assumption that ratios of survival indices represent ratios of absolute survival rates.

[6] It is important to note that there are several problems with generating functions of central tendency. For example, absolute survival rates cannot be estimated, information is lost by converting habitat attributes into habitat quality ratings, and combining functions provides false precision and accuracy. However, the intent was simply to identify a functional shape that would guide professional judgment. The function was not developed to estimate absolute survival rates.

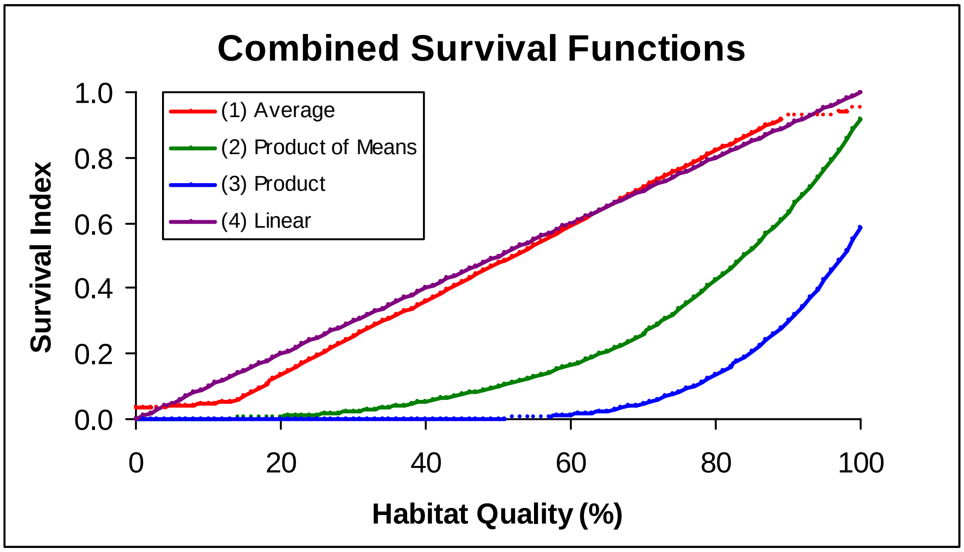


Figure 4. Comparison of Shapes of Functions Generated by Seeking Relationships of Central Tendency

Each of the "combined" functions was then evaluated by calculating potential survival gains associated with habitat quality data provided by local biologists. Where possible, estimated survival increases were compared with EDT results, historic redd counts, and/or survival benefits identified in the Human Impacts Report (from the Framework Workgroup). Both the linear function and the average function (based on median scores) provided estimates closest to EDT results and estimates contained in the Human Impacts Report. The exponential functions grossly overestimated survival benefits (in some cases they estimated well over 10,000 fold increases in juvenile survival).

The workgroup found no biological reason why the average function was the most appropriate relationship. There is no justification why there would be little survival increase associated with habitat quality increases from 0-10 percent and 90-100 percent. The workgroup collectively agreed, given the current data, that the linear function was the most realistic and should be used to guide professional judgment. This relationship also fits well with published literature that indicates that more intensive and extensive restoration actions result in greater survival benefits (e.g., see Paulsen and Fisher 2001).

To avoid the misconception that juvenile survival could be near 100 percent (survival index of 1.0) at high habitat quality, the Habitat Workgroup converted the survival indices into survival rates that represented actual juvenile and adult survivals measured in natural environments. The workgroup then developed different linear functions for Chinook salmon, steelhead, and chum salmon based on these actual survival rates. The goal was to identify what egg-smolt survivals for naturally produced Chinook salmon and steelhead and egg-fry survivals of chum salmon corresponded to optimal habitat conditions (100 percent habitat quality under natural conditions). The following is a brief summary of egg-smolt and egg-fry survival estimates that were readily available.

3.2 SPECIFIC HABITAT/SURVIVAL RELATIONSHIPS

3.2.1 Chinook Salmon

Some of the highest Chinook salmon survival rates were reported by Bugert and Seidel (1988) in the Tucannon River. Using a migrant trap on the lower Tucannon River, Bugert and Seidel (1988) estimated an egg-smolt survival that ranged from 13-22 percent between 1985 and 1987. In the Yakima River, Major and Mighell (1969) estimated that 5.4-16.4 percent of the potential spring Chinook salmon egg deposition survived to migrate as yearling smolts. Later work by Fast et al. (1989) indicated that, on average, 4.94 percent (range, 4.2-6.5 percent) of the eggs survived to migrate as smolts in the Yakima River. In the John Day River, egg-smolt survivals of spring Chinook salmon were estimated as 3.6-8.6 percent (Knox et al. 1984), while Lindsay et al. (1989) reported spring Chinook salmon survivals of 2.1-8.7 percent in the Deschutes River.

In the Methow, Wenatchee, and Entiat systems, Mullan et al. (1992) estimated egg-smolt survivals of 1.35-2.15 percent, 1.55-2.35 percent, and 2.90-6.65 percent, respectively, for spring Chinook salmon. Mullan et al. (1992) calculated these survivals by extrapolating rearing densities for the total basin rearing areas by habitat quality index ranking with an assumed 40 percent overwinter survival. In the Chiwawa Basin, the Washington Department of Fish and Wildlife (WDFW) (unpublished data) has estimated egg-smolt survivals for spring Chinook salmon brood years 1991-2003. WDFW estimated an average egg-smolt survival of 8.6 percent (range, 3.7-16.9 percent). Quinn (2005) recently reviewed published and unpublished estimates for wild or naturally produced Chinook salmon populations and reported a mean egg-smolt survival of 10.4 percent.

3.2.2 Steelhead

Ward and Slaney (1993) conducted a thorough study of steelhead egg-smolt survival for seven years in the Keogh River, B.C. and estimated a mean survival of 0.51 percent (range, 0.28-1.30 percent). Bley and Moring (1988) described a study that was conducted by the Washington Department of Wildlife (WDW – now WDFW) Snow Creek Research Station in Washington. Using winter steelhead, WDW estimated an egg-smolt survival of 1.6 percent. Bjornn (1978) reported that survival of steelhead from egg-smolt in the Lemhi River ranged from 0.16-3.61 percent. WDF et al. (1990) estimated an egg-smolt survival of 1.7 percent for steelhead in the Wenatchee River. In contrast, Peven (1992) reported a survival of 0.4 percent. Peven's estimate included the entire mid-Columbia Basin.

Thurow (1987) reviewed egg-smolt survival rates for wild steelhead. He found that rates ranged from 0.5-2.5 percent. Most of the work reported for seven river systems indicated survivals from 1-2 percent (Bjornn 1978; Phillips et al. 1981; Washington Department of Game [WDG] 1983). Thurow (1987) assumed survival of 1 percent under poor spawning conditions (e.g., poor quality spawning habitat, abnormal flows, abnormal temperature regimes, and redd superimposition), 1.5 percent under average conditions, and 2 percent under optimal conditions in the South Fork Salmon River. Quinn's (2005) review of published and unpublished estimates for wild or naturally produced steelhead populations indicated a mean egg-smolt survival of 1.4 percent.

3.2.3 Chum Salmon

Salo (1991) summarized egg-fry survival rates of chum salmon in his Tables 10 and 11. His summary indicates that egg-fry survivals of naturally produced chum salmon in natural environments can range from 0.1 to 85.9 percent. The latter is an estimate of survival of chum in the Iski River (tributary to the Amur River in Russia). This estimate appears to be an outlier when compared to estimates from other systems. Most survival estimates were less than 35 percent. Quinn's (2005) review indicated a mean egg-fry survival of 12.9 percent for chum salmon.

Based on this review of readily available literature, the following egg-smolt and egg-fry survival estimates appear reasonable if one assumes optimal (100 percent habitat quality) spawning and rearing conditions:

Chinook Salmon:	18 percent egg-smolt survival
Steelhead:	4 percent egg-smolt survival

Chum Salmon: 35 percent egg-fry survival

These estimates represent the highest survivals that could be achieved under optimal habitat conditions. The workgroup also assumed that the maximum pre-spawning adult survival would be 100 percent at optimal conditions. It is important to note that some systems may never achieve these life-stage survivals, because the systems are naturally unable to establish conditions that would be "optimal," even if all anthropogenic effects could be removed.

Applying these maximum survival rates to optimal habitat conditions resulted in linear functions with different slopes (rates of change) for each species and life stage (Figure 5). The Habitat Workgroup used the following linear functions to guide professional judgment in estimating survival improvements associated with habitat quality improvements:

Chinook salmon egg-smolt survival = 0.0018*(Habitat Quality)
Steelhead egg-smolt survival = 0.0004*(Habitat Quality)
Chum salmon egg-fry survival = 0.0035*(Habitat Quality)
Adult pre-spawning survival = 1.0*(Habitat Quality)

These functions provided a conservative approach to estimating survival gains and resulted in estimates that were generally less than those calculated with the Ecosystem Diagnosis and Treatment (EDT) model.

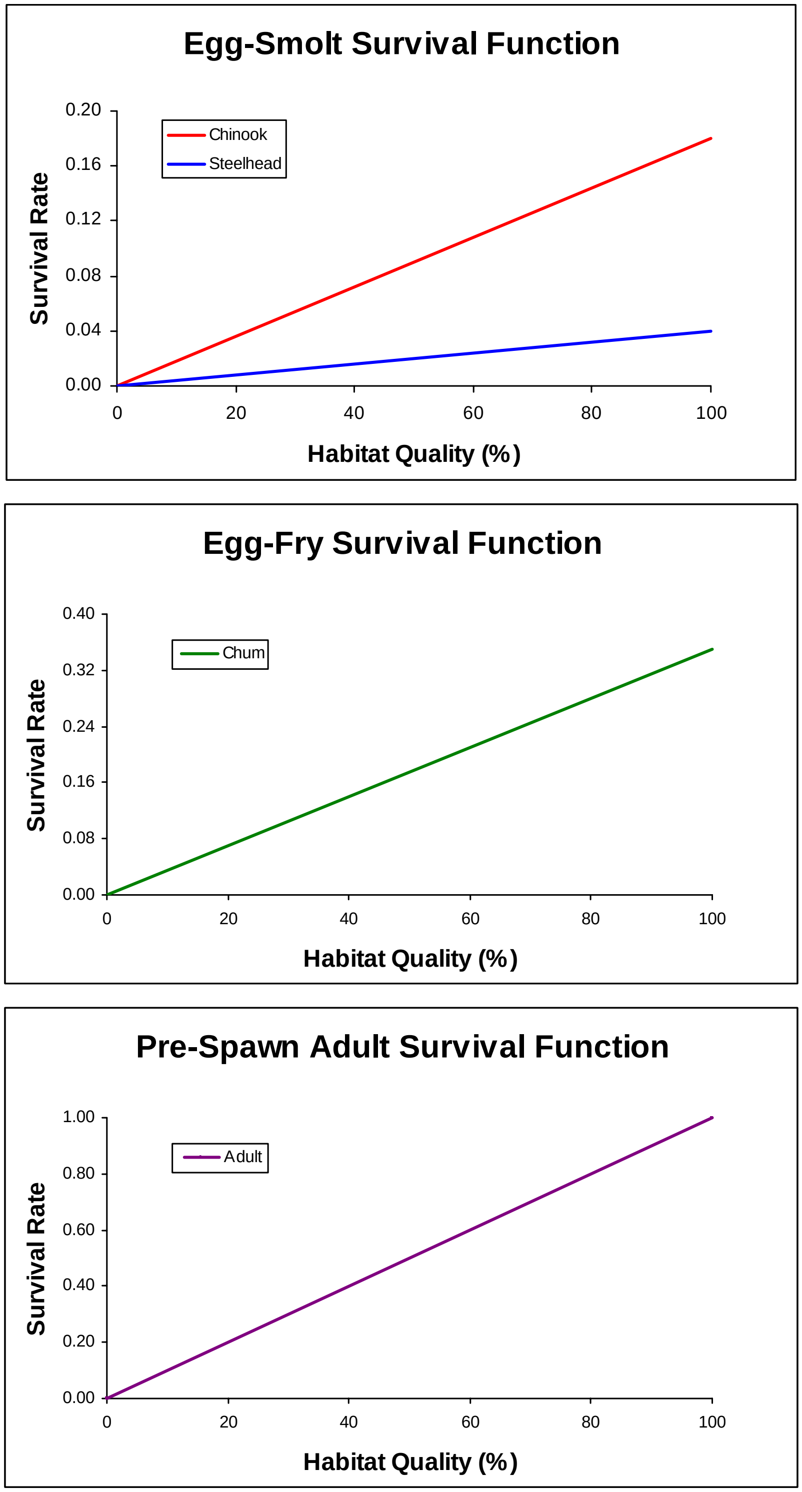


Figure 5. Linear Functions for Egg-smolt, Egg-fry, and Pre-spawning Adult Survival of Chinook Salmon, Chum Salmon, and Steelhead

4. ESTIMATING SURVIVAL CHANGES WITHIN ASSESSMENT UNITS

Local biologists have subdivided the geographic areas of some populations into smaller assessment units or watersheds. Within these smaller units, they described current habitat conditions (as a percent of optimal conditions), identified primary limiting factors, proposed restoration actions that would address limiting factors, and estimated the potential habitat condition (as a percent of optimal condition) that would result if restoration actions were implemented. These habitat conditions within assessment units were translated into relative survival estimates using the linear relationships described above. Current and potential survival rates were estimated based on current and potential habitat conditions. Potential survival rates were based on habitat conditions that could be achieved if actions were implemented within each assessment unit.

Because different assessment units within a population have different capacities and/or production potentials, survival estimates for those assessment units were weighted according to their capacities or production potentials. Weightings were based on the fraction of the population that spawns within each assessment unit or on the fraction of the total geographic area of the population that was contained in each assessment unit. For example, if a given population had three assessment units and one unit supported 65 percent of the spawners, another supported 10 percent, and the last supported 25 percent of the spawners, then Assessment Unit 1 was given a weight of 0.65, 2 a weight of 0.10, and Assessment Unit 3 a weight of 0.25. Survival estimates for each assessment unit were then multiplied by their respective weights to estimate a weighted survival rate. These weighted rates were added together to estimate the overall survival rate for the juvenile (tributary) life-stage of the population.

Overall current and potential survival estimates for the population were calculated separately. That is, current and potential survival estimates for each assessment unit were multiplied by their respective weights and summed independently of each other. Once the workgroup had calculated the current and potential survival estimates for the population, the survival increase associated with habitat restoration actions was calculated simply as the ratio of the potential survival estimate for the population (S_p) to the current survival estimate for the population (S_c). That is,

$$S = Sp/Sc$$

The Habitat Workgroup reported these ratios as the survival improvements associated with habitat restoration actions.

REFERENCES

Bjornn, T. C. 1978. Survival, production, and yield of trout and Chinook salmon in the Lemhi River, Idaho. University of Idaho, Forest, Wildlife, and Range Experiment Station Bulletin 27, Moscow, Idaho.

Bjornn, T. C., M. A Brusven, M. P. Molnau, R. A. Klamt, E. Chacho, and C. Schaye. 1977. Transport of granitic sediment in streams and its effects on aquatic life. University of Idaho, Forest, Wildlife, and Range Experiment Station Bulletin 17, Moscow, Idaho.

Bley, P. W. and J. R. Moring. 1988. Freshwater and ocean survival of Atlantic salmon and steelhead: a synopsis. U.S. Fish and Wildlife Service Biological Report 88(9).

Bugert, R. and P. Seidel. 1988. Production and survival of juvenile spring Chinook salmon in a southeast Washington stream. Pages 156-164 *in*: B. G. Shepard, ed. Proceedings of the Chinook/coho workshop. North Pacific International Chapter, American Fisheries Society.

Cramer, S. P. 2001. The relationship of stream habitat features to potential for production of four salmonid species. Final report to the Oregon Building Industry Association. S. P. Cramer and Associates, Gresham, Oregon.

Fast, D., J. Hubble, and B. Watson. 1989. Yakima River spring Chinook—the decline and recovery of a mid-Columbia natural spawning stock. Pages 18-26 *in*: B. G. Shephard, ed. Proceedings of the 1988 Northeast Pacific Chinook salmon and coho salmon workshop. North Pacific International Chapter, American Fisheries Society.

Knox, W. J., M. W. Flesher, R. B. Lindsay, and L. S. Lutz. 1984. Spring Chinook studies in the John Day River, John Day salmon studies. Oregon Department of Fish and Wildlife, Research Division, Annual Report, FY 1984. Prepared for Bonneville Power Administration, Division of Fish and Wildlife, Project No. 79-4, Contract No. DE-AC79-84BP39796, Portland, Oregon.

Knudsen, E. E., C. R. Steward, D. D. MacDonald, J. E. Williams, and D. W. Reiser. 2000. Sustainable fisheries management: Pacific salmon. Lewis Publishers, New York, New York.

Lichatowich, J. A. 1999. Salmon without rivers. Island Press, New York, New York.

Lindsay, R. B., B. C. Jonasson, R. K. Schroeder, and B. C. Cates. 1989. Spring Chinook salmon in the Deschutes River, Oregon. Oregon Fish and Wildlife Information Report No. 89-4, Portland, Oregon.

Lynch, K. D., M. L. Jones, and W. W. Taylor, editors. 2002. Sustaining North American Salmon: perspectives across regions and disciplines. American Fisheries Society, Bethesda, Maryland.

Major, R. L. and J. L. Mighell. 1969. Egg-to-migrant survival of spring Chinook salmon (*Oncorhynchus tshawytscha*) in the Yakima River, Washington. Fisheries Bulletin 67:347-359.

McHugh, P., P. Budy, and H. Schaller. 2004. A model-based assessment of the potential response of Snake River spring-summer Chinook salmon to habitat improvements. Transactions of the American Fisheries Society 133:622-638.

Montgomery, D. R., S. Bolton, D. B. Booth, and L. Wall, editors. 2003. Restoration of Puget Sound rivers. University of Washington Press, Seattle, Washington.

Mullan, J. W., K. R. Williams, G. Rhodus, T. W. Hillman, and J. D. McIntyre. 1992. Production and habitat of salmonids in mid-Columbia River tributary streams. U.S. Fish and Wildlife Service Monograph I, Leavenworth, Washington.

NMFS (National Marine Fisheries Service). 1996. Making Endangered Species Act determinations of effect for individual or grouped actions at the watershed scale. The National Marine Fisheries Service, Environmental Technical Services Division, Habitat Conservation Branch, Seattle, Washington.

NRC (National Research Council). 1996. Upstream: salmon and society in the Pacific Northwest. National Academy Press, Washington, D.C.

Paulsen, C. M. and T. R. Fisher. 2001. Statistical relationship between parr-to-smolt survival of Snake River spring-summer Chinook salmon and indices of land use. Transactions of the American Fisheries Society 130:347-358.

Peven, C. M. 1992. Population status of selected stocks of salmonids from the mid-Columbia River Basin. Chelan County Public Utility District, Wenatchee, Washington.

Phillips, C. R. Cooper, and T. Quinn. 1981. Skagit River salmonid studies. Washington Department of Game and U.S. Fish and Wildlife Service, Olympia, Washington.

Quinn, T. P. 2005. The behavior and ecology of Pacific salmon and trout. University of Washington Press, Seattle, Washington.

Salo, E. O. 1991. Life history of chum salmon (*Oncorhynchus keta*). Pages 231-310 *in*: C. Groot and L. Margolis, eds. Pacific salmon life histories. UBC Press, Vancouver, Canada.

Scheurerell, M. D., R. Hilborn, M. H. Ruckelshaus, K. K. Bartz, K. M. Lagueux, A. D. H. Aas, and K. Rawson. 2006. The Shiraz model: a tool for incorporating anthropogenic effects and fish-habitat relationships in conservation planning. *Canadian Journal of Fisheries and Aquatic Sciences* 63:1596-1607.

Stouder, D. J., P. A. Bisson, and R. J. Naiman, editors. 1997. Pacific salmon and their ecosystems; status and future options. Chapman and Hall, New York, New York.

Stowell, R., A. Espinosa, T. C. Bjornn, W. S. Platts, D. C. Burns, and J. S. Irving. 1983. Guide for predicting salmonid response to sediment yields in Idaho batholith watersheds. U.S. Forest Service, Missoula, Montana.

Tappel, P. D. and T. C. Bjornn. 1983. A new method of relating size of spawning gravel to salmonid embryo survival. *North American Journal of Fisheries Management* 3:123-135.

Thurow, R. 1987. Evaluation of the South Fork Salmon River steelhead trout fishery restoration program. Completion Report. Idaho Department of Fish and Game, U.S. Fish and Wildlife Service Contract 14-16-0001-86505, Boise, Idaho.

Ward, B. R. and P. A. Slaney. 1993. Egg-to-smolt survival and fry-to-smolt density dependence of Keogh River steelhead trout. Pages 209-217 *in*: R. J. Gibson and R. E. Cutting, eds. Production of juvenile Atlantic salmon, *Salmo salar,* in natural waters. Canadian Special Publication of Fisheries and Aquatic Sciences 118.

WDFW (Washington Department of Fish and Wildlife), Confederated Tribes and Bands of the Yakima Indian Nation, Confederated Tribes of the Colville Reservation, and Washington Department of Wildlife. 1990. Columbia basin system planning salmon and steelhead production, Wenatchee River Subbasin. Northwest Power Planning Council, Portland, Oregon.

WDG (Washington Department of Game). 1983. Memorandum to all treaty tribes and other concerned parties re: 1983-84 winter run steelhead harvest management. Washington Department of Game, Olympia, Washington.

Wissmar, R. C. and P. A. Bisson. 2003. Strategies for restoring river ecosystems: sources of variability and uncertainty in natural and managed systems. American Fisheries Society, Bethesda, Maryland.

ANNEX 3

UNDERSTANDING THE HABITAT WORKGROUP APPROACH TO ESTIMATING HABITAT QUALITY AND FRESHWATER SURVIVAL BENEFITS

The Remand Habitat Workgroup (RHW) developed a simple approach for estimating overall habitat quality and freshwater (egg-to-smolt) survival benefits. The approach relied primarily on the professional judgment of local biologists, who had the most knowledge about local watershed processes, habitat conditions, and fish populations within their respective areas. Information from the local biologists provided the raw materials used by the RHW and Action Agencies to estimate overall habitat quality and population survival benefits. This paper describes how the information provided by the local biologists was used to derive overall habitat quality and survival benefits.

Logic Path and Assumptions

In the absence of life-cycle models (because of a lack of time, resources, and data to populate and run the models), the RHW developed the following general logic path for estimating overall habitat quality and freshwater survival benefits.

Habitat Action → Limiting Factors (Habitat Variables) → Local Habitat Conditions → Overall Habitat Quality (at the population scale) → Freshwater Survival

In words, the implementation of habitat actions should reduce the detrimental effects of factors currently limiting the productivity of a population or portion of a population. Thus, these habitat actions directly affect specific habitat variables (flow, temperature, fine sediments, woody debris, pools, etc.) that are thought to limit the freshwater survival or productivity of the population. As the negative effects of the limiting factors are reduced (the quality of habitat variables beneficial to fish survival increase), local habitat conditions should improve. These local conditions represent the amalgamation of habitat variables that affect the freshwater survival of fish in specific locations (e.g., in streams or watersheds). Because limiting factors and habitat conditions vary across the distribution of the population, improvements in local habitat conditions across the distribution of the population should improve the overall habitat quality for the population.[7] That is, the combination of improvements in local habitat conditions should result in population-level habitat quality improvements. Finally, improvement to population-level habitat quality correlates to a change in population survival for the egg-to-smolt life history stage.

There are several assumptions associated with this logic path:

1. Limiting factors are known for each population.
2. Habitat actions directly affect habitat variables that limit the population.
3. Habitat variables can be combined to describe local habitat conditions.
4. Local habitat conditions can be combined to describe overall habitat quality for the entire population.
5. Changes in overall habitat quality are directly linked to changes in freshwater survival.

[7] The difference between "local habitat condition" and "overall habitat quality" is based on spatial scale. Although both represent composite habitat scores, "local habitat condition" refers to the composite score at a scale smaller than the distribution of the population (i.e., at the assessment unit or watershed scale). The "overall habitat quality" score refers to the composite score at the scale of the population, which may consist of several assessment units or watersheds. Therefore, the overall habitat quality score can be estimated as the composite (weighted average) of local habitat condition scores.

Local Biologist Input

The RHW relied on local biologists to provide the following:

1. A list of primary limiting factors for each population or assessment unit[8].
2. The current status of each limiting habitat variables.
3. Habitat actions that would address the primary limiting factors or habitat variables.[9]
4. An estimate of the potential status of limiting habitat variables if those variables were treated with the habitat actions.

Local biologists described the "status" of limiting factors (habitat variables) as a percent of optimal condition. As a guide, local biologists used the definition of properly functioning condition (PFC) developed by NMFS to estimate the status of habitat variables.[10]

For those populations that local biologists divided into assessment units, they also provide weights for each assessment unit. The weights were needed because different watersheds or assessment units within a population have different habitat capacities and productivities.

Assessment units were assigned weights according to the proportion of the total population area that each assessment unit made up. For example, if a given population consisted of three assessment units and one unit made up 65 percent of the total area, another made up 10 percent, and the last made up 25 percent of the total area, then Unit 1 was given a weight of 0.65, Unit 2 a weight of 0.10, and Unit 3 a weight of 0.25. The weights were scaled from 0.00-1.00 and their sums equaled 1.00. These weights represented the importance of each assessment unit in contributing to overall habitat quality for the population.

Some biologists also provided weights for each habitat variable. These weights indicated the importance of each habitat variable to the freshwater survival or productivity of fish. For example, if a given assessment unit or population was limited by three primary factors, high levels of fine sediments, lack of woody debris, and a lack of off-channel habitat, the biologist weighted each habitat variable by its relative importance to fish survival. In this case, the biologist may weight fine sediment the highest, because it has a relatively larger effect on fish survival than the other two factors. The resulting weights may be 0.75 for fine sediment, 0.15 for off-channel habitat, and 0.10 for woody debris. These weights were scaled from 0.00-1.00 and their sums equaled 1.00. The idea was to make sure that some factors or habitat variables (those that had a relatively greater detrimental effect on fish survival or productivity) had a greater influence on overall local habitat condition.

Not all biologists assigned weights to each habitat variable that limited freshwater fish production. Biologists in Washington, for example, assumed equal weights among habitat variables, unless the concentration or level of a given factor was considered lethal to fish (< 20 percent of optimal condition). In this case, the lethal factor was assigned a weight of 1.00 and all other limiting variables were assigned a weight of 0.00. Once the lethal factor is addressed through habitat actions, the remaining, non-lethal factors would be assigned equal weights.

Derivation of Local Habitat Conditions

With information from local biologists on limiting factors, current and potential status of habitat variables, habitat actions, and weightings, the RHW and Action Agencies estimated local habitat

[8] Some biologists divided the spatial distribution of populations into smaller streams or watersheds. These smaller areas were referred to as "assessment units." Thus, a population may consist of one or more assessment units.

[9] Biologists relied on draft recovery plans and subbasin plans to identify primary limiting factors and tributary habitat actions.

[10] PFC was used to help standardize optimal conditions across the Columbia River Basin.

conditions for each assessment unit (e.g., see Table 1 in this annex, below). The first step was to estimate the weighted status for each limiting habitat variable. This was calculated as the status of the habitat variable (as a percent of optimal condition) times its associated weight (relative weight of the variable on fish survival). In Table 1, the weighted current and potential status of habitat variables are shown in columns F and K, respectively.

The second step was to combine the weighted status scores into a composite local habitat condition score for each assessment unit. This was accomplished by simply adding together the weighted habitat status scores. For example, for the O'Hara Creek assessment unit in Table 1, the current weighted status scores of 35 percent for fine sediment and 18 percent for temperature/riparian vegetation were added together to estimate a current local habitat condition score of 53 percent (column G in Table 1). This score represents the current average habitat condition for the O'Hara Creek assessment unit. If the negative effects of the limiting factors are reduced with the implementation of the proposed actions (identified in column I in Table 1), the average habitat condition for the assessment unit should increase to 67 percent. This represents a 1.26 fold (67 percent ÷ 53 percent = 1.26, or 26 percent) increase in average habitat condition for the assessment unit.

In those cases where biologists assumed equal weights among limiting factors, the local habitat condition score for an assessment unit was estimated as the arithmetic mean of the status of habitat variables. In Table 1, for example, if the biologists had assumed equal weights for the two limiting factors (fine sediment and temperature/riparian habitat) in the O'Hara Creek assessment unit, the current local habitat condition would have been 55 percent (mean of the current status of habitat variables in column E; (50 percent + 60 percent)/2 = 55 percent)) rather than 53 percent, which was based on unequal weightings.

Table 1. Example of Limiting Habitat Variables (factors), Habitat Weights, Current and Potential Status of Habitat Variables, Current and Potential Local Habitat Condition, and Overall Habitat Quality Scores for the Selway Steelhead Population within the Clearwater MPG of the Snake River Steelhead DPS[1/2/]

				Current Conditions				Resulting Potential Conditions				
[A] Assessment unit	**[B] AU weight (proportion of population area)**	**[C] Limiting habitat variables**	**[D] Relative weight of variable on survival**	**[E] Current status of habitat variable (% of optimum)**	**[F] Current weighted status of habitat variable (D x E)**	**[G] Current local habitat condition (sum of F)**	**[H] Current overall habitat quality score (sum of G x B)**	**[I] Proposed habitat actions**	**[J] Potential status of habitat variable (% of optimum)**	**[K] Potential weighted status of habitat variable (J x D)**	**[L] Potential local habitat condition (sum of K)**	**[M] Potential overall habitat quality score (sum of L x B)**
O’Hara Creek	0.015	Fine sediment	0.70	50	35.0	53%	83%	Road decommission and improvements	65	45.5	67%	86%
		Temperature and riparian vegetation	0.30	60	18.0			Riparian restoration and woody debris treatments	70	21.0		
Lower Selway River	0.035	Fine sediment	0.70	55	38.5	61%		Riparian restoration and sediment filters	65	45.5	73%	
		Connectivity	0.30	75	22.5			Culvert replacement	90	27.0		
Meadow Creek	0.165	Fine sediment	1.00	78	78.0	78%		Trail improvements	80	80.0	80%	
Wilderness Area	0.785	Fine sediment	1.00	85	85.0	85%		Trail improvements	88	88.0	88%	

Notes:
1/ Data are from the Nez Perce Tribe DFRM Watershed Division
2/ The numbers in black were provided by the local biologists; numbers in red are derived values.

Derivation of Overall Habitat Quality

With the estimation of local habitat condition scores for each assessment unit within a population, one can calculate overall habitat quality scores for the entire population.[11] This is accomplished by multiplying the local habitat condition scores for each assessment unit by their respective assessment unit weights. These products (weighted habitat condition scores) are then added together to estimate the overall habitat quality score for the population. For example, in Table 1, the current local habitat condition score of 53 percent in column G) for the O'Hara Creek assessment unit is multiplied by its assessment unit weight of 0.015 (in column B). This results in a weighted local habitat condition score of 0.79. The sum of these weighted local habitat condition scores results in a current overall habitat quality score of 83 percent (column H in Table 1), which represents the current average habitat quality for the Selway steelhead population.

The same approach is used to estimate the potential overall habitat quality score that would result if the proposed actions were implemented. In the example above, the resulting overall habitat quality score is 86 percent (column M in Table 1). Thus, the implementation of actions identified in Table 1 would result in a 1.04 fold (86 percent ÷ 83 percent = 1.04, or 4 percent) increase in overall average habitat quality for the Selway steelhead population. Note that the 1.26 fold increase in local habitat condition in the O'Hara Creek assessment unit had little effect on the overall habitat quality score for the population. This is because the O'Hara Creek assessment unit made up a very small portion (1.5 percent) of the overall spatial distribution of the population.

The largest assessment unit was in wilderness and its projected improvement in local habitat condition was relatively small (wilderness areas have relatively high quality habitat and little room for improvement). Therefore, the increase in overall habitat quality for the population was low because of the influence of the higher quality habitat in the larger assessment units.

Derivation of Survival Benefits

The RHW spent a large amount of time trying to identify common relationships between habitat quality and freshwater survival (see Annex 2 - *Approach to Estimating Survival Benefits of Habitat Actions* for a complete discussion). After considerable discussion, the RHW decided that a simple linear relationship between habitat quality and egg-smolt survival was the most appropriate relationship and should be used to guide professional judgment. For each species, survival was scaled from 0.00 to the maximum egg-smolt survival reported in the literature. Habitat quality was scaled from 0 to 100 percent of optimal condition. This resulted in the following linear functions:

Chinook salmon egg-smolt survival = 0.0018 x (habitat quality score)

Steelhead egg-smolt survival = 0.0004 x (habitat quality score)

Chum salmon egg-fry survival = 0.0035 x (habitat quality score)

There are several assumptions associated with this approach.

1. Egg-smolt survival is the lowest when habitat quality is the lowest and survival is the highest when habitat quality is the highest.

[11] Although overall habitat quality for the entire population can be calculated with the information provided by the local biologists, the RHW and Action Agencies did not calculate these scores for all populations. This is because survival changes, which were the focus of the RHW and Action Agencies at the time proposed RPA were being identified, can be estimated using local habitat condition scores (see later section). Recently, however, overall habitat quality was identified as a performance metric that needs to be identified in the RPA.

2. Egg-smolt survival is directly proportional to habitat quality.
3. Density dependence is not considered.[12]
4. Any effect of hatchery programs on egg-smolt survival of naturally produced fish is not considered.

Although some of these assumptions are extremely generalized considering natural biological variability, the overall approach is useful in describing potential changes in survival associated with habitat quality improvements.

It is important to note that the estimated egg-smolt survival for a given habitat quality is less important than the change in survival that is expected to occur with habitat quality improvements. That is, for the purposes of the BiOp, it is more appropriate to report that a 25 percent increase in juvenile steelhead survival is expected from increasing habitat quality from 53 percent to 66 percent than it is to report absolute survivals of 0.0212 and 0.0264 for the respective habitat quality scores. The absolute survival values are not precise estimates, even though they appear precise.[13]

The RHW and Action Agencies used the habitat information provided by the local biologists to translate habitat quality changes into egg-smolt survival benefits. The process began by converting the local habitat condition scores for each assessment unit into survival estimates. This was done by multiplying the local habitat condition score by their respective assessment unit weights. This product was then multiplied by the appropriate habitat/survival function (0.0018 for Chinook, 0.0004 for steelhead, and 0.0035 for chum; from the above linear equations). The result was a fish survival estimate for each assessment unit. The survival estimates for each assessment unit were then added together to derive an overall survival estimate for the population.

An example of this approach is shown in Table 2 for the Selway steelhead population. The current and potential local habitat conditions for each assessment unit shown in Table 2 were carried over from columns G and L in Table 1. These local habitat conditions were multiplied by their respective assessment unit weights (column B in Table 2) to estimate the weighted local habitat conditions (shown in columns E and I in Table 2). These scores were then multiplied by 0.0004, the steelhead habitat/survival function, which resulted in weighted survival scores for each assessment unit. Adding these survival scores together resulted in a current steelhead survival value of 0.0330 (column G) and a potential survival value of 0.0343 (column K). The ratio of the potential survival to current survival indicates that steelhead egg-smolt survival could increase 4 percent (0.0343 ÷ 0.0330 = 1.04 or 4 percent) if the habitat actions proposed in Table 1 increase overall habitat quality from 83 percent to 86 percent.

[12] This means that survival is not regulated by mechanisms controlled by the size of the population.
[13] The appearance of precision is shown in the number of decimal places. The more decimal places, the more precise an estimate appears to be.

Table 2. Example of Limiting Habitat Variables, Current and Potential Local Habitat Conditions, and Current and Potential Egg-Smolt Survivals for the Selway Steelhead Population within the Clearwater MPG of the Snake River Steelhead DPS[1/]

			Current Condition				**Resulting Potential Condition**			
[A] Assessment unit	**[B]** AU weight (proportion of population area)	**[C]** Limiting habitat variables	**[D]** Current local habitat condition (from column G in Table 1)	**[E]** Current weighted local habitat condition (D x B)	**[F]** Current survival estimate for each AU (E x 0.0004)	**[G]** Current survival estimate for entire population (sum of F)	**[H]** Potential local habitat condition (from column L in Table 1)	**[I]** Potential weighted local habitat condition (H x B)	**[J]** Potential survival estimate for each AU (I x 0.0004)	**[K]** Potential survival estimate for entire population (sum of J)
O'Hara Creek	0.015	Fine sediment	53%	0.795	0.00032	0.0330	67%	1.005	0.00040	0.0343
		Temperature and riparian vegetation								
Lower Selway River	0.035	Fine sediment	61%	2.135	0.00085		73%	2.555	0.00102	
		Connectivity								
Meadow Creek	0.165	Fine sediment	78%	12.870	0.00515		80%	13.200	0.00528	
Wilderness Area	0.785	Fine sediment	85%	66.725	0.02669		88%	69.080	0.02763	

Note:
1/ Data from the Nez Perce Tribe DFRM Watershed Division

Notice that one could translate the overall habitat quality scores into survival values by simply multiplying 83 percent and 86 percent (from Table 1, columns H and M) by 0.0004 to obtain the same survival estimates obtained in Table 2, columns G and K (ignoring rounding errors). Thus, both ways of estimating survival values result in the same survival estimates.

Because the method used to estimate survival benefits assumes that survival change is directly proportional to habitat quality change, the change in survival equals the change in overall habitat quality. That is, the ratio of potential survival to current survival equals the ratio of potential overall habitat quality to current overall habitat quality. In the Selway steelhead example, the 1.04 fold increase in overall habitat quality (86 percent ÷ 83 percent = 1.04) equals the 1.04 fold increase in egg-smolt survival (0.0343 ÷ 0.0330 = 1.04). This equality only applies to the ratios. Differences in overall habitat quality scores and survival values are not equal (i.e., 86 percent - 83 percent ≠ 0.0343 – 0.0330) and differences in habitat quality scores are not equal to the ratio of the survival estimates (86 percent - 83 percent ≠ 0.0343 ÷ 0.0330).

Estimating Benefits from Non-Specific Proposed Actions

For some populations, the Action Agencies were unable to identify specific habitat actions for the period 2010-2017. This is because recovery plan implementation teams and local biologists have not had a chance to work with local landowners to determine the feasibility of implementing specific habitat actions in the long term. Therefore, the Action Agencies proposed identifying specific habitat projects in 3-year cycles from 2010-2017 and identified suites of actions that could be implemented, projecting a linear increase in habitat quality and survival improvement from 2007-2009 to 2010-2017 (not to exceed the potential habitat quality status) to obtain a target value for change in fish survival and overall habitat quality. For example, the Action Agencies identified different suites of habitat actions that should result in a 1.04 fold increase in overall habitat quality and juvenile steelhead survival in the Wenatchee Basin for the period 2010 to 2017.[15] Each suite of actions proposed by the Action Agencies addresses the primary limiting factors with different intensities of implementation but yielding the same projected overall habitat quality improvement.

As specific actions are identified but before those actions are implemented during the 2010-2017 period, the projected change in overall habitat quality will be determined for priority populations by using the analytical approach described earlier for estimating overall habitat quality. This means that local biologist will have to estimate the resulting status of limiting habitat variables, which are then weighted according to their influence on fish survival. The sum of the weighted habitat variables will then be multiplied by the weight of the assessment unit in which the action was implemented. This product, which represents the local habitat condition for a given assessment unit, will be added to the other assessment unit habitat condition scores to estimate the overall habitat quality for the population. This score will be compared to the target value to determine how much the proposed actions closed the gap between current overall habitat quality and the overall habitat quality target. This process is important to properly represent the effects of habitat actions in attaining the habitat quality target because the same magnitude of a given action implemented within different assessment units will have different effects on local habitat conditions and overall habitat quality scores.

[15] Because changes in survival are directly proportional to changes in overall habitat quality, the target of a 4 percent (or 1.04 fold) change in survival also means a 4 percent change in overall habitat quality for the Wenatchee steelhead population. This is useful because local biologists are better able to estimate a 4 percent change in habitat than a 4 percent change in egg-smolt survival.