Columbia River Instream Atlas

December 2016

2016 Columbia River Basin Water Supply & Demand Forecast

Ecology Publication Number
16-12-006

DEPARTMENT OF ECOLOGY
State of Washington

Cover photo: Sockeye salmon spawning in the Cle Elum River, October 2016.

COLUMBIA RIVER BASIN 2016 WATER SUPPLY & DEMAND FORECAST

Columbia River Instream Atlas (CRIA)

Interagency Agreement (IAA) No. C1600079

between The State of Washington Department of Ecology and

The State of Washington Department of Fish & Wildlife

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November 9, 2016

<u>Suggested Document Citation:</u>

Scott, T., J. Kohr, R. Granger, A. Marshall, D. Gombert, M. Winkowski, E. Bosman Clark and S. Vigg. 2016. Columbia River Instream Atlas (CRIA), FY2016. A component of the Columbia River Basin 2016 Water Supply & Demand Forecast. November 9, 2016. Funded by Washington Office of the Columbia River, Department of Ecology. 98 Pages

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Several WDFW staff contributed to technical analyses in previous years that were incorporated to some extent in this document, e.g., the coauthors of the FY2011 CRIA document (Ecology Publication Number 11-12-015, September 2011). In addition, Andy Weiss and Gabe Madel made direct contributions to the FY2016 CRIA project during part of the performance period. Allison Hart (WDFW) assisted with developing public outreach materials, and Sonia Hall and Georgine Grace Yorgey (WSU) set up several Long-term Supply and Demand Forecast public outreach meetings that included WDFW's participation regarding the CRIA Project. Budget development and monitoring was provided by Eleanor Bosman-Clark; and supervisory oversight was provided by Amy Windrope, Michael Garrity, Neala Kendall, and Brodie Cox. The following WDFW regional staff and external partners contributed to the CRIA scoring workshops and/or technical reviews:

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Executive Summary

The purpose of the Columbia River Instream Atlas (CRIA) Project is to determine instream flow restoration needs and priorities by stream reach in 12 selected Water Resource Inventory Areas (WRIAs) within the Columbia River Basin (Figure 1). We updated the evaluation of eight WRIAs that was done in 2011 (WDFW 2011; http://wdfw.wa.gov/publications/01498/) and evaluated an additional four WRIAs, one of which (WRIA 29) was divided into two sub-basins (Figure 1; Table 1). We used existing published and publically available information to collect data for all 313 stream reaches (2,674.29 stream miles; Table 1). We also used collaborative site-specific workshops to compile best professional knowledge of regional biologists and CRIA staff using an interactive discussion and review of existing data, especially for fish species distribution. CRIA stream reach priorities were evaluated using three basic data types, 'Fish, Habitat, Flow', and a variety of data for each type were analyzed to produce a simple composite prioritization score (low-medium-high) for each reach. To help users interpret reach-specific results, we have provided a visualization of the three-factor scoring using a color-coded matrix or cube. All prioritization scores per reach are included as data layers in the GIS-based CRIA web map tool, which is the primary product of this project. When viewing the 2016 CRIA web map, various data for each reach can be selected for display, including data or information that supported fish, habitat and flow scoring. CRIA reach-specific scoring is intended to assist Department of Ecology's Office of Columbia River (OCR) in evaluating and prioritizing instream flow enhancement projects in conjunction with other information from various planning processes.

Every five years, OCR develops a long-term water supply and demand forecast for the State Legislature. This forecast incorporates CRIA instream flow scores with modeling of out-of-stream demands (e.g., agricultural, municipal and hydropower) to provide a basin-wide assessment of how trends in environmental and economic conditions are likely to change water supply and demand into the future. Understanding where additional water flow is most critically needed for fish habitat versus out-of-stream uses will help OCR work with WDFW to make informed investments that enhance water supply for in- and out-of-stream flow in key locations in the Columbia Basin.

Instream demand is focused on basins supporting salmon and steelhead, per chapter 90.90 RCW. Our CRIA stream reach scoring for fish utilization was based on anadromous salmon species, steelhead, and bull trout.

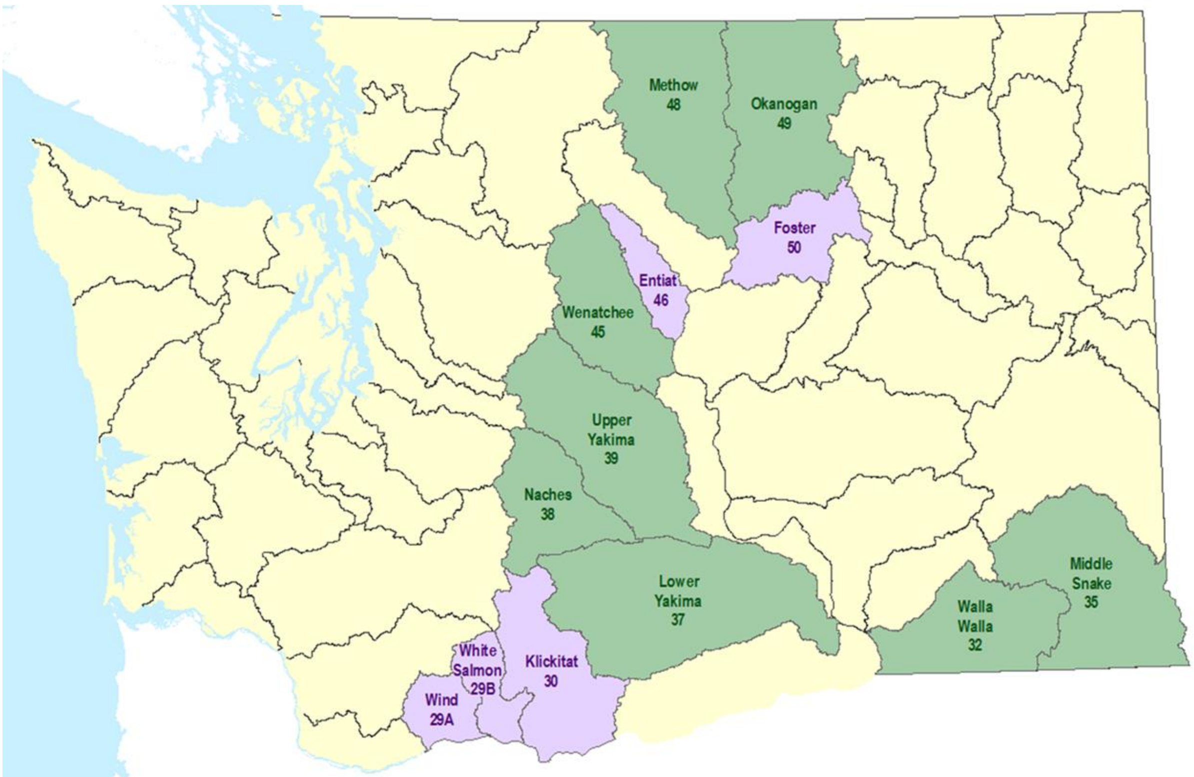

Figure 1. Map illustrating eight WRIAs initiated in the CRIA (2011) study (green) and four additional WRIAs (lavender) added during the FY 2016 CRIA project.

Table 1. Water Resource Inventory Areas (WRIAs) in the Columbia River Instream Atlas project area FY 2016.

Subbasin	CRIA WRIA	Stream Miles	Number of Reaches
Wind River	29A	74.60	25
White Salmon	29B	74.72	17
Klickitat	30	360.30	46
Walla Walla	32	337.20	36
Middle Snake	35	430.16	32
Lower Yakima	37	233.31	11
Naches	38	119.49	9
Upper Yakima	39	309.71	36
Wenatchee	45	172.00	30
Entiat	46	36.10	7
Methow	48	173.69	35
Okanogan	49	293.63	25
Foster	50	59.38	4
Total		**2,674.29**	**313**

Introduction

This report describes the products for each data component comprising the Columbia River Instream Atlas (CRIA) Project deliverables, and the detailed methods used to develop the CRIA scores and deliverables. The methodology description includes specific metrics, algorithms and protocols used to calculate the scores and specific deliverables.

The objective of the CRIA project is to recommend flow restoration priorities by stream reach within each selected Water Resource Inventory Area (WRIA). We established reach-specific priorities by developing CRIA scores for three components: (1) fish population composition and seasonal life history use, (2) habitat conditions, and (3) flow metrics and limitations with respect to fish habitat. We used collaborative workshops to compile current best professional knowledge of regional biologists and CRIA staff and to review existing data. We conducted workshops at five locations during 2015 and 2016 to collect information for all WRIAs. We especially used these workshops to review CRIA-designated stream reaches, and to update fish species geographical and life history-based distributions that existed within WDFW's SalmonScape mapping tool (http://apps.wdfw.wa.gov/salmonscape/). New fish population distributional data were subsequently input into SalmonScape data layers, which are viewable through the CRIA interactive web map. Stream reach habitat conditions were discussed at workshops, and instructions for subsequent scoring of reach-specific habitat characteristics by regional biologists were provided.

Development of Stream Reach Network for each WRIA

Collaborative workshops are used to develop a stream reach network for each WRIA based on detailed knowledge of regional biologists and CRIA staff that have conducted stream surveys on the specific reaches. The overall stream reach network provides the framework for presenting the CRIA scores (refer to Appendix 1).

Fish Component

The CRIA project is focused on salmon, steelhead and bull trout that are present in the specific WRIAs being evaluated (Chapter 90.90 RCW). ESA-listed and non-listed anadromous salmonid species that occur in the 12 WRIAs evaluated in the CRIA project are listed in Table 2. We included several recently reintroduced populations or groups (e.g., Yakima sockeye, Snake/Clearwater Coho), which have not been considered for ESA status. The 'Upper Columbia' coho group (Table 2) includes coho that are present in Wenatchee, Entiat and Methow basins due to reintroduction or colonization by coho reintroduced elsewhere. All 12

WRIAs are within the geographic area designated by NOAA Fisheries as the "Interior Columbia Domain", except for WRIA 29, which is within NOAA's Lower Columbia /Willamette Domain. Bull trout are ESA-listed as "threatened" throughout the Columbia Basin and the contiguous United States, and are under the jurisdiction of USFWS.

Table 2. Salmonid fishes listed under the Endangered Species Act[1] in Washington's Columbia River Basin (including proposed but not warranted)that inhabit 12 WRIAs and were included in the Columbia River Instream Atlas project.

ESU, DPS (ESA listing unit) or other species group by region	ESA-listing Status	WRIAs inhabited by each unit
Lower Columbia River	**Lower Columbia / Willamette Domain**	**29A/29B**
Columbia River Chum	Threatened	All of above
Lower Columbia River Chinook	Threatened	All of above
Lower Columbia River Coho	Threatened	All of above
Lower Columbia River Steelhead	Threatened	All of above
Bull Trout	Threatened	29B (migration only)
Mid-Columbia River	**Interior Columbia Domain**	**29B, 30, 32, 37, 38, 39**
Mid-Columbia River Spring Run Chinook	Not Warranted	30, 37, 38, 39
Middle Columbia Steelhead	Threatened	29B, 30, 32, 37, 38, 39
Columbia River Chum	Threatened	30 (migration only)
Bull Trout	Threatened	30, 32, 37, 38, 39
Klickitat Coho	Not ESA-listed	30
Yakima Sockeye	Not ESA-listed	37, 38, 39
Yakima Coho	Not Warranted	37, 38, 39
Snake Basin	**Interior Columbia Domain**	**35 (WA portion mid-Snake)**
Snake River Sockeye	Endangered	35 (migration only)
Snake River Basin Steelhead	Threatened	35
Snake River Fall Run Chinook	Threatened	35
Snake River Spring and Summer Run Chinook	Threatened	35
Bull Trout	Threatened	35
Snake/Clearwater Coho	Not ESA-listed	35
Upper Columbia River	**Interior Columbia Domain**	**45, 46, 48, 49, 50**
Upper Columbia River Spring Run Chinook	Endangered	All of above
Upper Columbia River Summer and Fall Run Chinook	Not Warranted	All of above

[1] The technical terms for "ESA species" are Evolutionarily Significant Unit (ESU) for salmon under the jurisdiction of NOAA Fisheries, or Distinct Population Segment (DPS) for steelhead and other fishes under the jurisdiction of US Fish & Wildlife Service (USFWS and NMFS 1996). These ESA-listed species are generally geographically and reproductively isolated units of a biological species.

ESU, DPS (ESA listing unit) or other species group by region	ESA-listing Status	WRIAs inhabited by each unit
Upper Columbia Steelhead	Threatened	All of above
Lake Wenatchee Sockeye	Not Warranted	45
Okanogan Sockeye	Not Warranted	49
Bull Trout	Threatened	45, 46, 48, 49
'Upper Columbia' Coho	Not ESA-listed	45, 46, 48

WRIA Key:

Subbasin	WRIA
Wind River, Little White Salmon	29A
White Salmon	29B
Klickitat	30
Walla Walla	32
Middle Snake	35
Lower Yakima	37
Naches	38
Upper Yakima	39
Wenatchee	45
Entiat	46
Methow	48
Okanogan	49
Foster	50

Fish, Habitat and Flow Scoring Methodology

Fish component

Fish populations

We used anadromous salmonid and bull trout populations present in each WRIAs included in the 2016 CRIA project to prioritize reaches by fish utilization. Generally, populations were those recognized and described by National Oceanic and Atmospheric Administration (NOAA) Fisheries, U.S. Fish and Wildlife Service (USFWS), or as defined in WDFW's Salmonid Stock Inventory (SaSI). The USFWS has designated bull trout "core areas", which they described as the closest approximation of a biologically functioning unit for bull trout and that may contain a number of local populations (USFWS 2002). We used bull trout core areas described for Washington (e.g., Yakima River core area bull trout) as the equivalent to NOAA-designated populations for ESA-listed anadromous salmonids. In a few cases, formal population designations were not available for anadromous salmonids that have been colonizing drainages or are becoming established through direct re-introduction programs. For CRIA purposes, these species groups were named for the drainage inhabited (e.g., 'Yakima sockeye'), or for their likely source (e.g., 'Upper Columbia summer Chinook' for summer Chinook present in Entiat River).

The use of these population designations is an update relative to 2011 CRIA project in which populations evaluated were those as described in SaSI. At that time, SaSI-designated populations may have differed from official population designations for ESA-listed species. Also, Washington bull trout were incompletely described throughout the state in terms of population designation in SaSI, and we deemed the USFWS core area designations the best fit for CRIA needs.

Information sources for fish presence and utilization by life history phase in CRIA reaches

We used a variety of sources to determine each population's physical distribution within each WRIA and their life history phase usage of CRIA reaches. The primary ones were WDFW's SalmonScape mapping utility (http://apps.wdfw.wa.gov/salmonscape/), consultations with local biologists, and publically available technical reports, such as those produced by state, federal and tribal agencies. Local biologists included staff with WDFW, USFWS, tribal nations (e.g., Yakama Nation; Colville Confederated Tribes), USFS, USGS, BPA, state and county natural resource agencies, regional salmon recovery boards, and private consulting companies. We endeavored to obtain the most up-to-date information on salmonid population usage because distribution has changed since the 2011 CRIA due to fish passage barrier removals, habitat restoration, re-introductions, natural processes and other factors. Uncertainty about fish presence and usage for some reaches still occurred and in most cases if no documentation (including biologists' personal observations) of presence was available, we assumed a reach currently did not support the population in question. Rarely, a population's presence in a reach had not been documented, but circumstances suggested a high likelihood that presence did occur and we chose to score the reach as supporting the population. We noted these instances in the WRIA fish utilization scoring spreadsheet files.

Prioritizing populations by ESA status and risk status

We characterized populations by their ESA-listing status and a risk status rating. For risk status, we either calculated it based on analyses of annual abundance estimates (see below), or obtained it from NOAA Fisheries 5-year risk assessments (Ford (ed.) 2011) or USFWS's 2008 bull trout 5-year status review (USFWS 2008). In some cases, such as re-introduced populations (e.g., Yakima coho) or spawning aggregations within a WRIA that appeared to be established by straying, in which a putative population did not have appropriate abundance data and no federal risk rating, we rated risk as low because source populations were either non-local or were at low risk.

We used the two status metrics as weighting factors for fish usage of CRIA reaches, and used a simple point system for weighting values. ESA-listed populations got one point, and all populations got a risk status rating (described below) of 1, 2 or 3 points, which correspond to low, moderate, or high risk. Points were summed for a total population weight value, and values ranged from 1 to 4. Reach-specific scores for monthly stream usage by life history phase per population (described below) were multiplied by the population's total weight value to obtain a total weighted score. In this process, reaches that are inhabited by or support ESA-listed populations with high risk ratings will receive relatively high fish utilization scores. We intended this weighting scheme to yield relatively high prioritization scores for reaches within a WRIA that were utilized by ESA-listed populations and/or non-ESA-listed populations that were nonetheless currently at relatively high risk for decline.

Rating population risk status

The 2011 CRIA project used WDFW's SaSI status ratings for populations (where available) for stream reach prioritization purposes, but SaSI status ratings are no longer available. We used the following method to rate population risk status for populations that had data series of annual spawner abundance or adult escapement estimates. In most cases, these data series were available in WDFW's SaSI database (https://fortress.wa.gov/dfw/score/score/species/species.jsp). This method was adopted from the WDFW Steelhead at Risk Report (WDFW 2016 unpublished) and incorporated five variables that characterize adult abundance over varying timeframes. These were: 1) adult abundance trends since 1980 or later, depending on available data; 2) instantaneous rates of change in the last 12 years (a population growth rate estimator); 3) percentage of years in last 10 years that a population met its recovery or escapement goal; 4) the probability of a population's abundance reaching a quasi-extinction threshold (QET) over the next 20 years; and 5) for ESA-listed populations, the 2010 NOAA Status Review risk rating, which was based on assessment of abundance, productivity, spatial structure, and diversity risks, or the 2008 USFWS bull trout core area risk ranking.

Adult abundance trends since 1980 were estimated by calculating a linear model from averages of the first five and last five years of available data and calculating the percent change. We established a risk criterion of greater than 55% decline through breakpoint analysis that considered each population's percent change in abundance. For each population, we calculated the instantaneous rate of change in the last 12 years and the probability of a population reaching a QET of 50 over the next 20 years using population viability analysis (PVA) methods of Dennis et al. (1991) and Staples et al. (2004). Significance for the instantaneous rate of change was calculated using a t-test with α less than 0.1, and a significant rate of change was the risk criterion. The QET for each population was set as 50 based on the Interior Columbia Basin Technical Recovery Team viability criteria (Cooney et al. 2007), and we chose a risk criterion of greater than 20% probability of reaching the QET. We established a risk criterion that population abundance had to meet or exceed a recovery or escapement goal at least seven of the last ten years. For ESA-listed anadromous salmonids, we chose a NOAA 2010 Status Review (Ford (ed.) 2011) risk rating of 'high' to be the risk criterion. A summary of risk rating variables and their risk ranking criteria is presented in Table 3.

We determined a population's risk level (low, moderate, high) based on the number of criteria met. If no criteria were met we rated risk as low, if one or two of the criteria were met, risk was moderate, and if at least three criteria were met, risk was high. For ESA-listed populations with insufficient adult abundance data for calculating the above risk variables, we used 2010 NOAA Status Review risk ratings for anadromous salmonids (Ford (ed.) 2011) or 2008 risk ratings for bull trout (USFWS 2008). Population risk rating results were used as inputs to WRIA-specific fish utilization scoring spreadsheet files.

Table 3. Variables used to evaluate risk, and risk rating criteria.

Variable	Adult abundance trend since 1980	Instantaneous rate of change in last 12 years	Over last 10 years % of years abundance > goal	Probability of reaching QET at least once in 20 years	2010 NOAA Status Review risk rating
Risk Criterion	>55% decline	Significantly negative	< 70%	>20%	High

Fish utilization scoring methodology

We constructed spreadsheet files for each WRIA that included fish utilization scoring worksheets for each CRIA-designated reach. All populations determined to be present in a WRIA were scored for their utilization of each reach. In each reach worksheet, we scored each population for annual monthly fish usage during three life history phases: 1) spawning and incubation; 2) juvenile rearing and smolt migration; 3) adult migration. For bull trout, scoring for the juvenile phase included sub-adult usage for foraging and migrating, and for the adult migration phase included usage for over-wintering. We applied scores of 1 or 0 to months with or without, respectively, usage by any of the three life history phases. All monthly per life history phase scores were summed, and the total was multiplied by the population's weight factor (see above) to get a weighted or 'prioritized' total. An example of scoring a population's usage of a reach in the worksheets is shown in Figure 2. We summed prioritized totals for each population to produce a reach's grand total fish utilization score.

For each WRIA, we categorized reaches' grand total scores into priority 'bins' classified as high (3), medium (2), and low (1), to produce final reach-specific fish utilization ratings. We divided each reach total score by the highest reach total score to calculate the percentage of the highest score that each reach's score represented. Each reach's resulting percentage received a bin score using the following bin divisions. Bin 3 contained percentage scores greater than 66% of high score; bin 2 contained percentage scores greater than 34% and less than or equal to 66% of high score; and bin 1 contained percentage scores less than or equal to 34% of high score. For example, for a WRIA with 200 as the highest reach-specific total score, another reach's total score of 120 was 60% of the high score, and that reach received a bin score of 2. These WRIA-specific bin scores of 1, 2, or 3 are intended to be used with similarly simplified prioritized habitat and flow scores to guide flow improvement choices. Reach-specific fish utilization grand total scores and associated bin scores were the products designed to be incorporated into the CRIA interactive web map. It is important to remember that reach-specific total scores and associated bin scores are WRIA-specific and not comparable among WRIAs because they are based on different assortments of populations.

Weight Factor	Fish use characterization for stream reach	January	February	March	April	May	June	July	August	September	October	November	December	Subtotal	Total
3	Is the reach used for Spawning and Incubation? (no=0, yes=1)	1	1	1	1	0	0	0	0	1	1	1	1	8	57
	Is the reach used for Rearing and/or Smolt Migration? (no=0, yes=1)	0	1	1	1	1	1	1	1	0	0	0	0	7	
	Is the reach an adult migration corridor? (no=0, yes=1)	0	0	0	0	0	0	1	1	1	1	0	0	4	
	Weighted Monthly Total	3	6	6	6	3	3	6	6	6	6	3	3	57	

Figure 2. Excerpt from a CRIA reach's fish utilization worksheet that shows example of scoring a fish population's annual monthly life history phase utilization of that reach, including the application of a weight factor that aids in prioritizing scores.

We provided draft fish utilization scoring files for each WRIA to biologists for review. We requested reviews from biologists that were knowledgeable about the distribution and life history of the populations included. Biologists we contacted included those that had attended our regional CRIA information gathering meetings. We also provided the fish utilization periodicity charts for each WRIA (see below) for their review at the same time. We incorporated all corrections, additions and comments received from reviewers into final products.

Updating fish utilization periodicity charts

For 2011 CRIA, charts were produced that displayed monthly fish utilization for five life history stages for all populations within each WRIA. We updated these charts for population information and monthly fish life phase usage, and produced charts for WRIAs added for 2016. These charts provide an overview of monthly fish utilization for each population present at five life history phases. Charts provide more detail on monthly fish utilization than the reach-specific fish-use scoring files. For example, charts show information on periods for juvenile rearing and out-migration separately. Charts show the widest temporal range of life history phase utilization expected within a WRIA. Note that reach-specific monthly fish utilization scoring may differ from that shown in charts. Monthly reach-specific utilization could differ due variation among reaches within a WRIA for factors such as migration distance between river mouth to spawning grounds, water temperature, or passage blockages caused by seasonal water flows.

Habitat Component

CRIA "Habitat" scores are determined from the condition of each stream reach for six attributes contributing to healthy fish habitat: 1) off-channel habitat, 2) floodplain connectivity, 3) riparian conditions, 4) spawning suitability, 5) rearing suitability, and 6) passage conditions. Additional habitat data will be investigated for inclusion in mapping, and perhaps scoring (e.g., reach drainage area, water quality, land cover types).

Each of these six habitat parameters are rated from 1 to 4 (1=Poor, 2=Fair, 3=Good, 4=Excellent) condition for each stream reach based on criteria specified in Appendix 2.

The scores for the new CRIA stream reaches are based on three tiers of review: 1) scoring from local biologists using their best professional knowledge (BPK) of the streams and respective reaches, 2) actual on-the-ground site evaluations of stream reaches by CRIA team biologists, and 3) the use of map-based habitat metrics to create quantified results.

1. Habitat CRIA team members met and communicated with local biologists to explain how the scoring mechanism worked. Several local biologists scored the reaches and entered their experience of each stream. The experience scores are not considered part of the overall scoring but gave an understanding of how significant those scores would be. In cases with low experience, we obtained more robust scores via the second and third tiers of review.
2. In a number of stream reaches, there was little to no knowledge of the entire reach. CRIA Habitat team assessed and scored those reaches by conducting site reviews and scored based on their knowledge and expertise of habitat conditions for the six parameters. For some site visits, there was very little or no access and a third tier of evaluations was necessary.
3. The third tier consisted of using mapping tools such as the National Fish Habitat Action Plan (NFHAP) scoring. These scores are based on reach length and are used for specific scoring such as % canopy cover for riparian conditions. Habitat metric reviews via mapping consist of six different values: (a) the % of human modified area within a 500 and 50 meter zone along the stream for scoring Off-Channel Habitat, (b) the NFHAP scores for Riparian Condition, (c) the % of mean canopy cover within a 500 and 50 meter zone for Riparian Condition, (d) the % mean impervious surface within 500 and 50 meter zone for Floodplain Connectivity, (e) the % of valley bottom that is human modified for Floodplain Connectivity, and (f) the % of the active channel that is human modified for Floodplain Connectivity. After in-depth review of these six scoring conditions, the NFHAP scores and the % canopy cover within a 50 meter zone are used for riparian conditions. Other components of the mapping exercise gave low correlation to biologist on-ground scores or consisted of incomplete data sets.

Two of the stream reaches scored for habitat had inaccessible roads and are scored using nearby accessible reach scores, habitat metrics (tier 3), and mapping reviews. A total of twenty of the 293 stream reaches were not completed for habitat scores at all. A number of reasons occurred that prevented the output of a robust score for each habitat parameter. In these streams, there were no area biologist scores given, no access, and heavy canopy cover (making it difficult to score via mapping). Some streams have good data for canopy cover and floodplain connectivity, but need ground-truthing for spawning and rearing conditions. In these streams with limited data, the habitat score is not used.

Only streams with anadromous access were scored, and all present salmonid species are taken into consideration for the habitat scoring. Where anadromous species are naturally blocked, the reach was not scored upstream of that point. The six habitat attributes' scores were summed to get an overall score for each reach. Therefore the lowest possible score is 6 (all rated as poor) and the highest is 24 (all rated excellent). For each WRIA, reaches were then binned using their total habitat score.

Binning of the habitat scores is determined using a range of the lowest and highest scores within each WRIA stratified into thirds, i.e., 3 bins. The combined score for the 6 habitat metrics has a possible range of 6 to 24 -- for ease of binning we scale it to a range of 1 to 18. Therefore, the lowest possible score for the reach is 1 and the highest possible score is 18. All the reach scores within a given WRIA are divided evenly from affixed low score of 1 to whatever is the highest score within that WRIA. The lowest 1/3 of the scores for a given WRIA are assigned a rating of "1= Poor"; the middle 1/3 of the scores are assigned a rating of "2= Fair", and the highest 1/3 of the scores for the WRIA are assigned a rating of "3= Good". The individual reach score (of 1 to 18) is then assigned a rank of 1, 2 or 3 depending on which bin for that WRIA it falls into. Therefore, all the reaches are scored consistently within each WRIA.

Flow Component

"Flow" data were derived from: (a) basic hydrographs for gauged stream reaches; (b) estimates of mean annual flow and mean August flow for stream reaches without gauges. We collected and compiled data for 113 gauges; forty-one from USGS, fourteen from Reclamation, and fifty-eight from Ecology (Table 4). We later replaced data from twelve of the Ecology gauges with National Hydrography Dataset Plus (NHDPlus)-generated data. There were 215 non-gauged reaches for which NHDPlus-generated data were used (Table 4).

Table 4. Number of reaches by WRIA, by gauge owner, subtotals, and proportion of reaches that are non-gauged

WRIA	Total Reaches	ECY Gauges Used	Reclam-ation	USGS	Gauged Reaches	Non-gauged (Used NHDPlus)	Ppn non-gauged	ECY Gauges Not Used
29	45	4		1	5	40	0.89	3
30	46	1		3	4	42	0.91	
32	36	12		4	16	20	0.56	3
35	32	10		3	13	19	0.59	
37	11		2	6	8	3	0.27	
38	9	2	5		7	2	0.22	1
39	36	4	7	2	13	23	0.64	1
45	30	6		5	11	19	0.63	1
46	7	1		2	3	4	0.57	1
48	35			9	9	26	0.74	
49	25	6		6	12	13	0.52	2
50	4					4	1.00	
Total	316	46	14	41	101	215	0.68	12

Appendix 3 Table 2 provides a summary of gauges used for each CRIA reach, and the year-range from which the daily or monthly mean is calculated.

2016 flow scoring approach

Flow scoring for CRIA 2016 started with a review of the literature relating to stream reach prioritization for flow restoration. The 2015 drought in Washington provided a preview of conditions predicted to occur more regularly later in the twenty-first century. This changed our perspective on flow restoration from a “restore the worst reaches” emphasis to one more considering of future predicted flows and hydrographs. Also, recent scientific literature includes development of concepts and methods for evaluating stream segments. The CRIA team considered and discussed stream types (hydrographs, ecosystems), limiting factors (temperature, flow diversions), levels of vulnerability for each of those types (predicted climate effects), and how to provide thoughtful scoring metrics to contribute to decisions about the types of management actions that should be directed at those vulnerabilities.

Considered but not used

One metric we considered to help score vulnerability is water temperature. Water temperature turned out to be our “Achilles Heel” during the 2015 drought response. State biologists were caught off-guard by the rapid increases in water temperature and consequent environmental effects. Thus we were sensitized to the way this element can directly impact fish when stream flows are low. Also, water temperature predictions have been the subject of climate modeling, and 2040 and 2080 projections of stream temperature are now available as geo-referenced information at a fine enough scale for use in the CRIA analysis. In the end, we did not have the time needed to adequately understand those modeling results and adapt them for CRIA use. So although this will be a fruitful factor to investigate for future CRIA analyses, the difficulty matching up geographic references led us to drop this line of inquiry for 2016.

Frequency is an important hydrologic attribute not adequately measured using the CRIA 2016 scoring approach. We would need to determine flow levels comprising "drought" (or "flood") conditions for each reach, then measure how often those conditions were reached during the period of record. Another approach would be to examine frequency of curtailment of junior water right holders in order to meet instream flow rules. For the CRIA basins (other than the Yakima and Walla Walla), this frequency matches the frequency that "drought" is declared, which is about 10-to-15 years for CRIA basins. The limitations of such an analysis include the possibility that instream flow rules are not good indicators for low-flow impacts and that drought frequency is likely to increase at an unknown rate. For CRIA 2016, the assumption is that low flows will be an issue more often for almost every reach being scored, so the work to find an adequate metric would not be justified in providing further clarity to reach scoring.

Climate streamflow modeling predictions (Hamlet et al. 2010) were examined to determine whether predicted flows or stream temperature changes over time could be used as a measure of risk of low flow impacts. We encountered the same inability to match up geographic scales for this analysis, however, and elected not to proceed to develop this idea.

Overall, existing and future hydrologic and climate modeling work should be more deeply evaluated for their potential contributions to evaluating flow conditions.

2016 flow scoring metrics

Poff et al. (2010), Reidy Liermann et al. (2011), and many others have identified key variables necessary for analyses of hydrologic classification. Stream segments can be distinguished by measuring the frequency, duration, magnitude, timing, and rate of change of streamflows, and that information, in turn, can help us understand vulnerabilities and potential flow management strategies. With an eye toward these key attributes, metrics (Table 5) and scoring components (Table 6) were identified for each stream reach. For CRIA, we are examining low flows and not flood flows, though both are important to determining fish value.

Table 5. CRIA 2016 flow scoring metrics and why they are important.

METRIC	WHAT IT MEANS	REMARKS
Mean monthly flow	Mean of the daily flow values for each month in each year of the period of record. (Daily values are themselves averaged from the 15-minute values recorded at the gauge)	Foundation for scoring

METRIC	WHAT IT MEANS	REMARKS
"Mean annual flow"	The average of the mean monthly flows	Gives a frame of reference for "flow volume class"
Maximum of mean monthly flow	Maximum of the mean monthly flows	Tells us when the hydrograph peaks
Minimum of mean monthly flow	Minimum of the mean monthly flows.	Gives us an idea how bad flow can be, on average.
MAX month and MIN month	The months in which the max and min values occurred	Helps us further distinguish reaches by generalized hydrograph types (snow, rain, combo) to help us understand the risk of future impairment.
Mean August flow	August flow value	Intended to represent the flow during the highest diversion month. We use August as the peak month for irrigation demand and August is sometimes the lowest flow month. Most Washington streams are actually lower in September or October, but this is the best we can do for 2016.
Hydrograph classification	Text code for classification after Reidy Liermann et al. (2011)	Hydrographs were charted and grouped into like-shaped hydrograph sets, then assigned to a hydrograph classification.
Number of records (water rights) in the reach	From the "ECYPOD" spreadsheet	See spreadsheet documentation (reference Teresa Scott, WDFW)
Sum of diversions (Qi) for the reach	From the "ECYPOD" spreadsheet	See spreadsheet documentation (reference Teresa Scott, WDFW)

Those flow metrics listed in Table 5 were used alone or in combination to provide the following CRIA scoring components (Table 6).

Table 6. CRIA 2016 Flow Scoring Components.

ITEM/ FOOTNOTE	COMPONENT	HOW IT'S CALCULATED	WHAT WE THINK IT MEANS
A	Magnitude difference between mean and August (minimum) flows	August flow / mean flow	Measures distance between the mean and minimum flows. How bad are low flows in this reach?
B	Duration of flows less than the mean	Counts the number of months the mean monthly flow is below the mean annual flow.	The concept behind this score is the assumption that more months spent below the mean annual flow can indicate vulnerability or flashiness.[B]
C	Flow volume class	Scores assigned based on relative discharge.	Assumption is that reaches with lower flows are at more risk from low flows that higher-flow reaches.
D	Hydrologic vulnerability	Scores based on "shape" of hydrograph (as representation of hydrologic classification)	Hamlet et al. (2010), Reidy Liermann et al. (2011), and others have posited that climate vulnerability can be predicted based on hydrologic classification.[D]
E	Deviation in mean monthly flows	Standard Deviation of monthly mean flows / average of monthly mean flows	Helps us understand the amount of variability in flows through the year.[E]
F	Scaling the risk of human-caused low flows: Diversions in proportion to mean August flows	Sum of water right diversion quantities / mean August flow (cfs)	We assume that a high proportion of diverted flow is bad.[F]

ITEM/ FOOTNOTE	COMPONENT	HOW IT'S CALCULATED	WHAT WE THINK IT MEANS
G	Count of diversions	Count of water right records in the WRTS database for a reach	Assesses risk that high diversions impact fish.[G]
B	Finer-scale analyses (e.g., Julian day) might provide better distinction between the reaches (Reidy Liermann et al. 2011). We are assuming for this metric that more low flow months are riskier for fish.		
D	There are many schemes for determining hydrologic classification; CRIA attempts to conflate these complex ideas and analytical results into an easily score-able scheme. Scores are based on hydrologic classifications after Reidy Liermann et al., (2011) and general understanding of vulnerability based on Elsner (2010), Littell (2014), Mantua (2010), Steward (2004), Tohver (2014), and Vano (2015). CRIA scoring was based on the assumptions that snow-driven or ultra-snow have high risk, snow and rain driven have medium high risk, rain and snow driven have medium risk, rain driven has medium low risk and groundwater or groundwater/rain mixes have low risk. Classes were assigned independently of relative volume (i.e. based on shape of hydrograph alone) so no penalty points are given for low volume. These assignments and assumptions are for this analysis only, probably don't adequately reflect the broad range of science on this topic, over-simplify the huge complexity of these problems, and may not hold up under evolving science. Also note an assumption that flow estimates (on which the hydrographs are based) are independently derived, which is clearly untrue for the NHDPlus-generated values. This is the best we can do for this analysis, and hope users agree that it adds value to the scoring system.		
E	In the quest to provide low scores for reaches with a lot of variation between monthly flows, we also impose an assumption that less dynamic streams are better for salmonids, which we know to be incorrect		
F	High diversion volumes compared to the existing August flow (or a negative number showing more is diverted on paper than exists instream) signifies greater risk of critically-low flows impacting fish regularly. Note that potential for missed or miss-assigned diversions is high. If diversions were more than twice the August flow in WRTS, then risk is high that actual diversions are impairing August flows. This analysis doesn't need a "nice" distribution across reaches, because more than twice the existing (mean August flow) is the same as more than 20 times for this analysis.		
G	We were being cautious, and possibly redundant, using our available data. Because WRTS does not necessarily provide an accurate depiction of total diversions, we assume that a larger number of records ("water rights") means that more water is diverted than we actually evaluated in the previous metric. One or		

ITEM/ FOOTNOTE	COMPONENT	HOW IT'S CALCULATED	WHAT WE THINK IT MEANS
	the other of these metrics might be sufficient for future analyses – we were keeping both for CRIA 2016 "just to make sure" we captured the differences in diversion risk between reaches.		

Every potential scoring rubric was tested to ensure that scoring results would distribute broadly (if not statistically evenly) across all CRIA reaches, ensuring that the scoring metric would be useful in distinguishing among reaches. We did not perform statistical analyses of the distributions of scores.

Scoring metrics using WRTS water rights data

In 2016, we retrieved about 11,000 water rights data records from Water Rights Tracking System WRTS, which included all records (having geographic identification information) located in any of the CRIA basins. Records were screened based on several criteria. Records that did not represent certified or permitted water rights were excluded from further analysis, as were records for non-consumptive uses, new applications, change applications, groundwater (in spite of many groundwater records being locations affecting surface flows), see Appendix 3 for a more detailed description of the methodology employed in the CRIA analysis.

We assigned the filtered records to adjacent CRIA reaches using a crosswalk generated by the CRIA team translating HUC12 to CRIA reach. Some records did not match CRIA reaches. After all that was accomplished, we summed the reach-specific diversion quantity (Qi) for scoring purposes. A water rights spreadsheet (T. Scott and J. Kohr) shows the process and records that were used for CRIA scoring.

Flow scoring for hydrologic vulnerability

Hydrographs can help us classify stream reaches, which in turn can aid in determining relative vulnerability to flow-related changes through climate change. Elsner et al. (2010) classified Pacific Northwest watersheds into rain-dominated, transitional, and snow-dominated based on the ratio of peak snow water equivalent (SWE) to accumulated winter (October to March) precipitation (P). Reidy Liermann et al. (2011) analyzed stream segments across Washington State to determine stream classifications based on their dominant flow source, and evaluated them for vulnerability. Reidy Liermann et al. (2011) determined stream segments fit into one of several hydrographic classifications: Groundwater; rainfall; rain-snow; snow-rain; snowmelt; and "ultra-snowmelt" are the ones we use for CRIA. Groundwater controlled reaches are characterized by relatively uniform mean monthly discharge. We classified as "Odd" the reaches that are likely groundwater-controlled, or otherwise don't fit into the other classifications. Our determination that "Odd" reaches are low-vulnerability" is based on the "groundwater" classification.

Of the types Reidy Liermann et al. (2011) found in eastern Washington basins, Table 7 shows distinguishing characteristics for each that were important in developing the CRIA score.

Table 7. Hydrologic classifications as used for CRIA scoring.

Type	Month of maximum flow	Variability
Groundwater or "Odd"	Multiple peaks	Low monthly variability
Rainfall	Peak winter flows (December, January)	High variability
Rain-snow	Often bimodal; Higher winter, another lower peak in spring	Medium variability
Snow-rain	Often bimodal; Higher spring; 2nd peak winter rainfall	Medium variability
Snowmelt	Peak spring flows	Less winter rainfall influence; higher variability
Ultra snowmelt	Later spring	Even less winter rainfall influence; highest variability

Refer to Appendix 3 Table 8 for the number of CRIA reaches that were classified under each hydrologic class.

2016 Binning

Binning was done for reach scores within a WRIA. Simplicity in presentation of results led us to employ three "bins" as in 2011, with one bin containing all the "best" scoring reaches, another the worst. Binning for flow scores was done based on percentiles, with the worst (most flow impaired) 33% of scores binning as "1" and the best (67th percentile; least flow impaired) binning as "3."

A reach score binned as "1" for flow in one watershed will not necessarily be of the same overall priority as a reach binned as "1" in another watershed; several other factors, including fish status/utilization, habitat condition, and feasibility must be considered before priorities across WRIAs can be made. Reaches binned as "1" however are the highest priority for flow restoration - based on flow condition alone – within a particular watershed.

Composite CRIA Scores

For each stream reach within each WRIA, the CRIA Composite Score is categorized using: low, medium or high condition scores of three elements: 1) fish utilization and status; 2) habitat condition; and 3) flow condition. These scores can be visualized within a geographic information systems framework using a two dimensional color-code scheme for fish versus habitat conditions and a thickness of stream segment visual for flow condition (Figure 3).

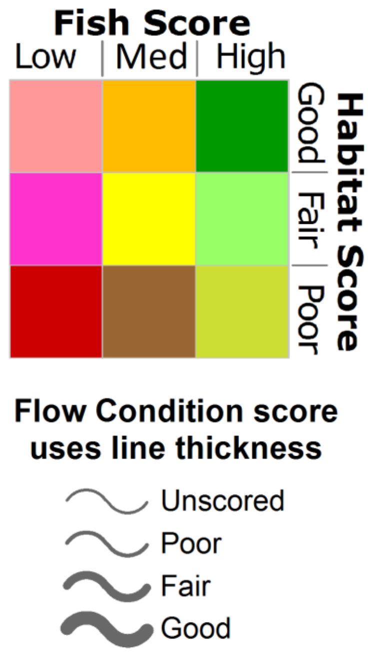

Figure 3. Scheme for illustrating the CRIA composite score incorporating ordinal scores – low, medium and high – for the three scoring components: fish, habitat and flow conditions.

Results

Public and Stakeholder Outreach

We planned and facilitated three stakeholder outreach workshop meetings to get input from regional biologists and external partners regarding the CRIA scoring procedures and available data for fish, habitat, flow and the GIS Web Map stream reach system for the four WRIAs added in 2016:

1. December 11, 2015 at the Columbia River USGS Research Station, Willard – to discuss and review two WRIAs (one was subdivided): Wind (29A), White Salmon (29B) and Klickitat (30). Twelve professionals representing three entities participated in this meeting.
2. March 17, 2016 at the Department of Ecology/WDFW Offices, Wenatchee – to discuss and review two WRIAs: Entiat (46) and Foster (50). Twelve professionals representing three entities participated in this meeting.
3. On April 7, 2016, we planned and facilitated a meeting with the Klickitat County Natural Resources Department and interested public regarding the CRIA project methods and results to date on the GIS-based Web Map tool. This meeting was advertised in three

local newspapers and held at the Goldendale Public Library; it was attended by six participants representing two agencies. Allison Hart (WDFW Public Affairs) assisted with developing CRIA materials and brochures for the Goldendale meeting and subsequent public outreach meetings.

Sonia Hall and Georgine Grace Yorgey from Washington State University (WSU) facilitated four Long-term Supply and Demand Forecast public outreach meetings that included WDFW's participation regarding the CRIA Project:

1. June 21, 2016 Tri-Cities at Washington State University, Richland
2. June 22, 2016 Wenatchee, WSU Agricultural Extension Center
3. June 23, 2016 Spokane Enduris Training Center at the Airport
4. August 4, 2016 Ellensburg, Eastern Washington University

At each of these meetings, the CRIA Project Manager made a power point presentation and questions were answered by CRIA staff, as well as a demonstration of the CRIA Web Map tool. All of these WSU-lead outreach meetings were publicized in local newspapers and well attended by participating agencies and the public. The public that attended these meeting was primarily interested in the effects of future water supplies and demand on agricultural interests; however, several questions were directed for the CRIA project, and review comments were generally favorable regarding the CRIA project in terms of evaluation approach and potential utility.

<u>Deliverables:</u> The CRIA Project Manager coordinated public and stakeholder outreach workshops to develop and review the CRIA products with CRIA staff, the WDFW Public Affairs Department, Washington State University and the Ecology Project Manager.

CRIA Stream Reach Network by WRIA

The 2011 CRIA included the analysis of 189 reaches in 8 WRIAs. We added or redefined some reaches within the 2011 WRIAs and the WRIAs added for 2016 analysis included 99 reaches. The total count of CRIA 2016 stream reaches was 313 (Table 1; Appendix 1).

<u>Deliverables:</u> The detailed stream reach network Arc GIS data layers used for the CRIA web map have been submitted to Ecology.

Fish Component Results

Fish utilization of CRIA reaches

Fish utilization scoring spreadsheet files

All results for reach-specific utilization by fish populations present in each WRIA are included in scoring spreadsheet files that we provided to Department of Ecology, Office of Columbia River staff. Each spreadsheet file has a summarization worksheet that shows: 1) reach names and their CRIA identification number; 2) populations present and their CRIA risk rating; 3) total prioritization score and monthly prioritization scores per reach; 4) prioritization bin scores per reach. The reach-specific worksheets in each WRIA spreadsheet file contain the monthly and total fish utilization results per life history phase for each population present, the population's ESA status, and the grand total (all populations) reach score. These worksheets also include information on populations' life history and utilization of reaches in the form of text notes, which are intended to support and substantiate the scoring results. These notes may include citations of reports, journal papers or personal communications, and if so, a reference list is included in a separate worksheet.

We provided all reach-specific fish utilization prioritization total scores and their relative bin scores as input for the CRIA interactive web map. On the web map, when a user selects (clicks on) a CRIA reach a pop-up window will show the fish prioritization score and bin score values.

Fish utilization scores within and among WRIAs

Within WRIAs, reaches that supported the most populations for most life history phases over a large number of months had the highest total scores. These reaches were typically mainstem reaches of the primary river or its major tributaries. The most upstream and typically higher elevation reaches tended to support fewer populations and usually had relatively lower total fish-use scores. However, even though these upstream reaches may have received lower scores relative to other reaches in a WRIA, in many WRIAs these reaches supported ESA-listed steelhead and bull trout. Thus, we suggest that prioritization decisions regarding flow improvements consider this contrast between mainstem reaches (generally high fish utilization scores) and upstream tributary reaches (often supportive of a few, relatively high risk populations). It's possible that opportunities to improve flows in some upper tributary reaches could be relatively more beneficial to fish populations in a WRIA than a reach's numerical or binned prioritization scores might suggest.

Proportions of reaches with high (3), medium (2), and low (1) fish utilization bin scores varied widely among WRIAs (Table 8). For example, 50% or greater of the reaches in three WRIAs (Lower Yakima, Entiat and Okanogan) had high bin scores, while 50% or greater of the reaches in three other WRIAs had low bin scores (Klickitat, Middle Snake and Foster; Table 8). The high proportions of low bin scores for Klickitat and Middle Snake is likely due to relatively large numbers of CRIA-designated reaches occurring in tributary creeks. When evaluating prioritization results, it is important to remember that the binning process was done for each WRIA separately and thus results are WRIA-specific.

Table 8. Number of CRIA reaches and proportions (percent) of reaches that received high, medium and low prioritization "bin" scores for fish utilization within each WRIA.

			Fish Bin Scores (percent by category)		
Subbasin Name	WRIA Number	Number of Reaches	3 (High)	2 (Medium)	1 (Low)
Wind River	29A	25	12.0%	40.0%	48.0%
White Salmon	29B	17	35.3%	23.5%	41.2%
Klickitat	30	46	6.5%	10.9%	82.6%
Walla Walla	32	36	36.1%	36.1%	27.8%
Middle Snake	35	32	12.5%	21.9%	65.6%
Lower Yakima	37	11	54.5%	27.3%	18.2%
Naches	38	9	44.4%	44.4%	11.1%
Upper Yakima	39	36	22.2%	38.9%	38.9%
Wenatchee	45	30	36.7%	23.3%	40.0%
Entiat	46	7	71.4%	14.3%	14.3%
Methow	48	35	31.4%	25.7%	42.9%
Okanogan	49	25	52.0%	8.0%	40.0%
Foster	50	4	25.0%	0.0%	75.0%

Fish utilization periodicity charts

We provided electronic files for all WRIA-specific charts depicting monthly life history phase utilization by fish populations to Department of Ecology, Office of Columbia River (images of charts are in Appendix 4). For some populations we found that not all life history phases occurred in CRIA-designated reaches within a WRIA. In these cases, we did not show monthly periodicity for those life history phases in a WRIA's chart. An example of a periodicity chart is provided in Figure 4. The chart depicted is for WRIA 49, Okanogan and because Okanogan Sockeye salmon do not spawn or rear in CRIA-designated reaches, monthly utilization for those life history phases is not shown (Figure 4).

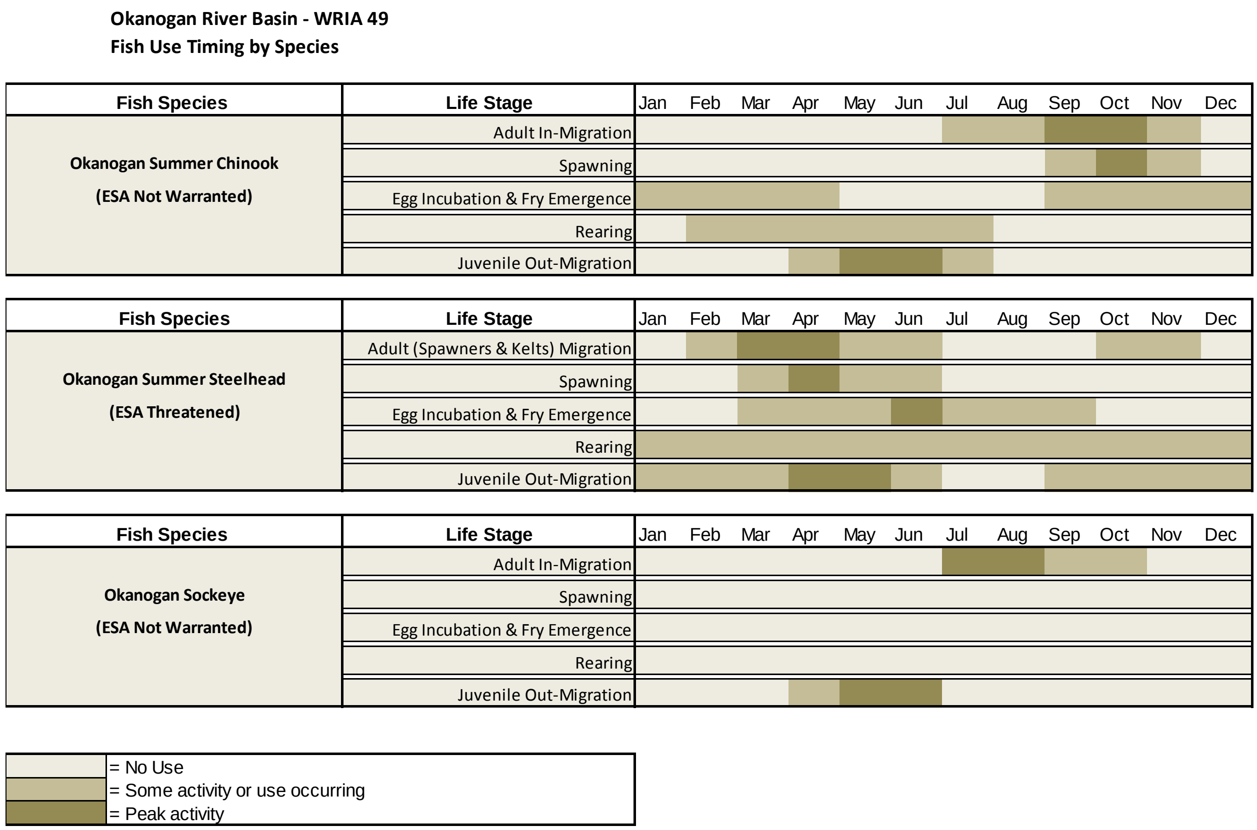

Figure 4. Example of a fish utilization periodicity chart, WRIA 49.

<u>Deliverables:</u> "Fish" data deliverables include: (a) GIS data layers showing geographic distributions for each species of fish in each sub-basin and stream reach; and (b) Charts depicting fish species life history periodicity by month in each sub-basin are presented in Appendix 4.

Habitat Data

Proportions of reaches with high (3), medium (2), and low (1) habitat condition bin scores varied greatly among WRIAs (Table 9). The White Salmon basin had the highest proportion – 87.5 percent – of reaches in the highest habitat category (bin 3). The second tier – 50 to 40 percent of reaches in bin 3 – was exhibited by four additional WRIAs: Foster, Naches, Wind and Klickitat. The WRIAs with the lowest proportion of reaches in bin 3 (17 to 10%) were Upper Yakima, Middle Snake, Methow, and Wenatchee. High proportions of reaches having low bin scores (1) occurred in four WRIAs (Table 9): Walla Walla (58%), Wenatchee (53%), Methow (51%) and Upper Yakima (47%). A cautionary note for interpretation: the habitat binning process was done for each WRIA independently and thus results are not directly comparable across WRIAs. The

WRIAs that exhibited numerous reaches with high habitat (bin 3) scores did not generally correspond to the WRIAs with high proportions of bin 3 scores for fish (refer to Table 8).

Table 9. Number of CRIA reaches and proportions (percent) of reaches that received high, medium and low prioritization "bin" scores for habitat condition within each WRIA.

			Habitat Bin Scores (percent by category)		
Subbasin Name	**WRIA Number**	**Number of Reaches**	**3 (High)**	**2 (Medium)**	**1 (Low)**
Wind River	29A	25	44.00%	44.00%	12.00%
White Salmon	29B	16	87.50%	6.25%	6.25%
Klickitat	30	39	41.03%	41.03%	17.95%
Walla Walla	32	31	22.58%	19.35%	58.06%
Middle Snake	35	29	13.79%	48.28%	37.93%
Lower Yakima	37	11	36.36%	54.55%	9.09%
Naches	38	9	44.44%	44.44%	11.11%
Upper Yakima	39	36	16.67%	36.11%	47.22%
Wenatchee	45	30	10.00%	36.67%	53.33%
Entiat	46	7	28.57%	57.14%	14.29%
Methow	48	35	11.43%	37.14%	51.43%
Okanogan	49	25	24.00%	52.00%	24.00%
Foster	50	4	50.00%	25.00%	25.00%

Deliverables: Habitat condition scores WRIA and stream reach are summarized in Appendix 1, and have been submitted to Ecology as Arc GIS data layers.

Flow Data

In the 2016 flow analysis, we did not use instream flow rules as a metric, therefore we did not create estimates of flow deficits by stream reach. However, the Web Map tool provides a means for the user to look at current hydrographs of specific reaches on the GIS-based map. Also, we provided Ecology with the flow databases WDFW compiled for the CRIA analysis that includes the mean flow values by month and the individual flow attribute scores for each reach. The Web Map provides these monthly mean and by-attribute flows as info boxes for every mapped reach.

Compared to habitat and fish bin scores, the proportions of reaches with high (3), medium (2), and low (1) flow condition bin scores was less variable across WRIAs (Table 10). High proportions of reaches having high bin scores (3) for flow occurred in three WRIAs (Table 10): Wenatchee (33%), Okanogan (32%) and Middle Snake (31%). At the other end of the bin scale, high proportions of reaches having low bin scores (1) occurred in seven WRIAs (Table 10): Okanogan (52%), White Salmon (47%), Wenatchee (43%), Middle Snake (40%), Methow (40%), Walla Walla (39%), and Klickitat (37%). The flow binning process was done for each WRIA separately and thus results are not directly comparable across WRIAs.

Table 10. Number of CRIA reaches and proportions (percent) of reaches that received high, medium and low prioritization "bin" scores for flow condition within each WRIA (Yakima Basin excluded from bin scores for flow).

			Flow Bin Scores (percent by category)		
Subbasin Name	WRIA Number	Number of Reaches	3 (High)	2 (Medium)	1 (Low)
Wind River	29A	25	28.00%	56.00%	16.00%
White Salmon	29B	17	17.65%	35.29%	47.06%
Klickitat	30	46	23.91%	39.13%	36.96%
Walla Walla	32	36	25.00%	36.11%	38.89%
Middle Snake	35	32	31.25%	28.13%	40.63%
Wenatchee	45	30	33.33%	23.33%	43.33%
Entiat	46	7	28.57%	42.86%	28.57%
Methow	48	35	17.14%	42.86%	40.00%
Okanogan	49	25	32.00%	16.00%	52.00%
Foster	50	4	25.00%	50.00%	25.00%

Deliverables: Flow condition scores by WRIA and stream reach are summarized in Appendix 1, and have been submitted to Ecology as Arc GIS data layers.

Web Map Tool

The CRIA scores for each data element (Fish, Flow, and Habitat) are evaluated within each WRIA, and the scores are binned into three categories. Each stream reach is colored on maps or the web map per the categories as red for low/poor, yellow for medium, and green for high/ good. These three scores will be displayed simultaneously using a more complicated color scheme as shown in the section on Composite Scores.

Results of Composite Data – Web Map Output

A bin score of “1” indicates poor flow conditions (lower third of reaches in each WRIA) and therefore identifies reaches where instream flow enhancement may be beneficial for fish. Of the 313 stream reaches evaluated by the CRIA team in 2016 ninety-nine had were categorized as bin 1 for flow; of these about 59.6 percent of fish scores and 46.6 percent of habitat scores were also rated in the lowest-third category (Table 11). We generally consider across-the-board low (bin 1) scores as lower priority candidates for flow enhancement. However, about 18.2% of reaches with low flow scores had high fish scores and 15.9% had high habitat scores (Table 11, bin 3).

Table 11. The number and percent of CRIA stream reaches with a low flow score (bin 1) that fall into the three categories of scores (bin 1, 2 or 3) for fish and habitat scores.

Bin Score	Fish Scores		Habitat Scores	
	Number	Percent	Number	Percent
1 (low)	59	59.60%	41	46.59%
2 (medium)	22	22.22%	33	37.50%
3 (high)	18	18.18%	14	15.91%
Total	**99**	100.00%	**88**	100.00%

One approach to select stream reaches with good potential for flow enhancement is (a) to filter out all stream reaches with poor flow conditions (bin 1) and then (b) filter this subset for the high combined habitat and/or fish bin scores of 5 or 6. Eighteen of the 313 CRIA stream reaches evaluated in 2016 met these composite score criteria (Table 12). The 18 stream reaches identified occur in the following WRIAs (number of reaches in parentheses): White Salmon (3), Klickitat (1), Wenatchee (4), Entiat (1), Methow (3), and Okanogan (6).

Table 12. Stream reaches (n=18) with poor flow conditions (bin 1) where fish and/or habitat scores are high, i.e., combined bin score of 5 or 6.

CRIA ID Number	**Reach Name**	**Fish Metric Score**	**Fish Bin Score**	**Habitat Metric Score**	**Habitat Bin Score**	**Flow Metric Score**	**Sum of Fish & Habitat Scores**
2931	**Mill Creek**	270	2	15.9	3	10	5
2933	**Spring Creek**	298	3	15.2	3	8	6
2936	**Indian Creek**	242	2	16.5	3	10	5
3018	**Bowman Creek**	132	2	16.5	3	10	5
4502	**Wenatchee River (Reach 2)**	338	3	14.2	2	14	5
4503	**Wenatchee River (Reach 3)**	338	3	14.7	2	13	5
4517	**Chiwawa River**	282	3	21.0	3	14	6
4519	**Icicle Creek (Reach 2)**	287	3	16.0	2	14	5
4601	**Entiat River (Reach 1)**	287	3	16.6	2	9	5
4801	**Methow River (Reach 1)**	284	3	11.8	2	9	5
4821	**Poorman Creek**	219	3	12.6	2	9	5
4830	**Wolf Creek**	295	3	15.2	3	7	6
4902	**Okanogan River (Reach 2)**	129	3	9.6	2	7	5
4906	**Loup Loup Creek**	96	3	11.7	3	6	6
4907	**Ninemile Creek**	98	3	10.2	2	7	5
4912	**Antoine Creek**	92	3	9.6	2	8	5
4917	**Salmon Creek (Reach 2)**	92	3	14.9	3	8	6
4923	**Similkameen River (Reach 1)**	121	3	13.4	3	8	6

The GIS (Web Map) summary of bin scores for fish, habitat and flow for the Wind River Basin are presented in Figure 5.

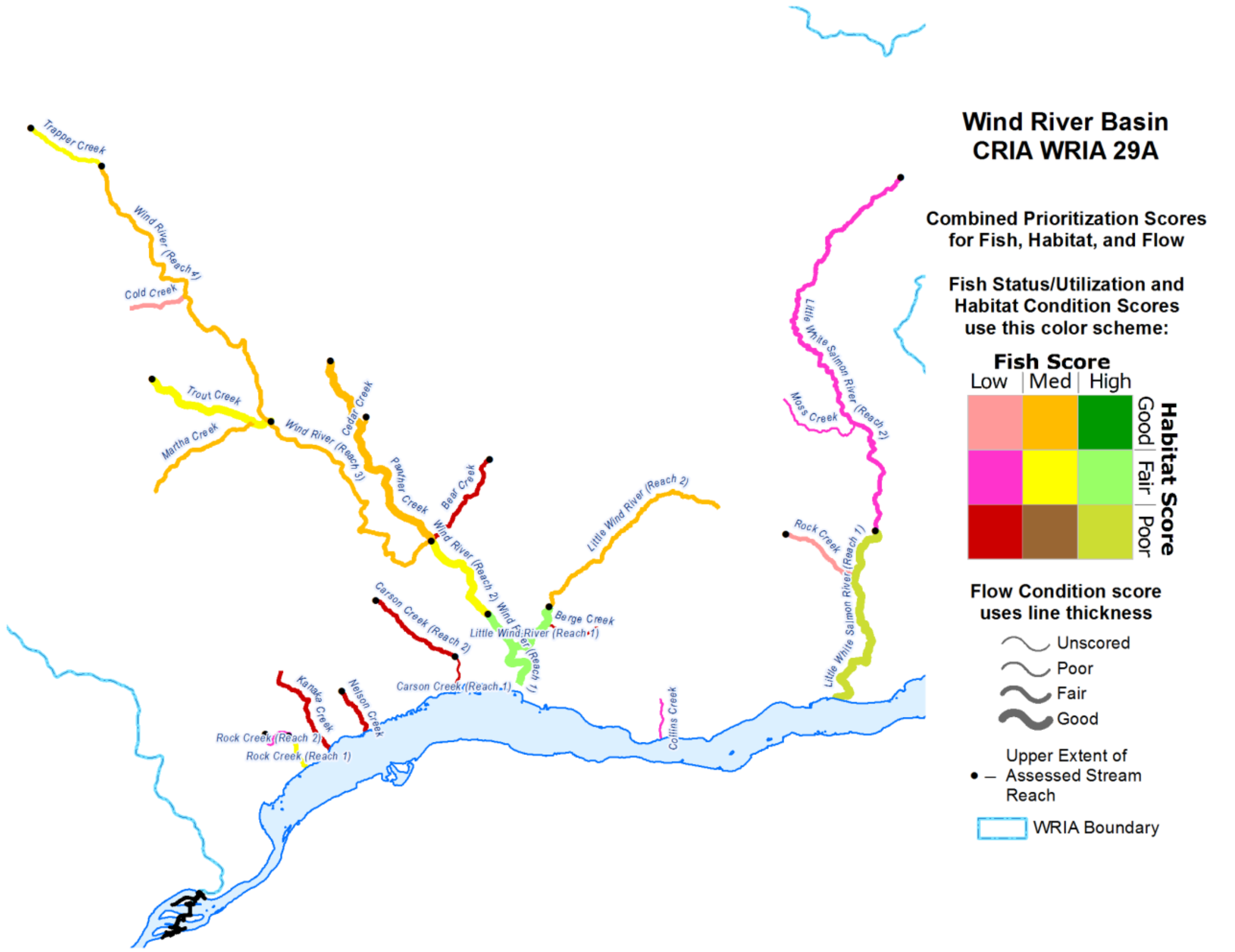

Figure 5. Combined prioritization (bin) scores for fish, habitat and flow – WRIA 29A, Wind River Basin.

The GIS (Web Map) summary of bin scores for fish, habitat and flow for the White Salmon River Basin are presented in Figure 6. Three streams in this basin meet the criteria in Table 12: Mill Creek, Spring Creek and Indian Creek.

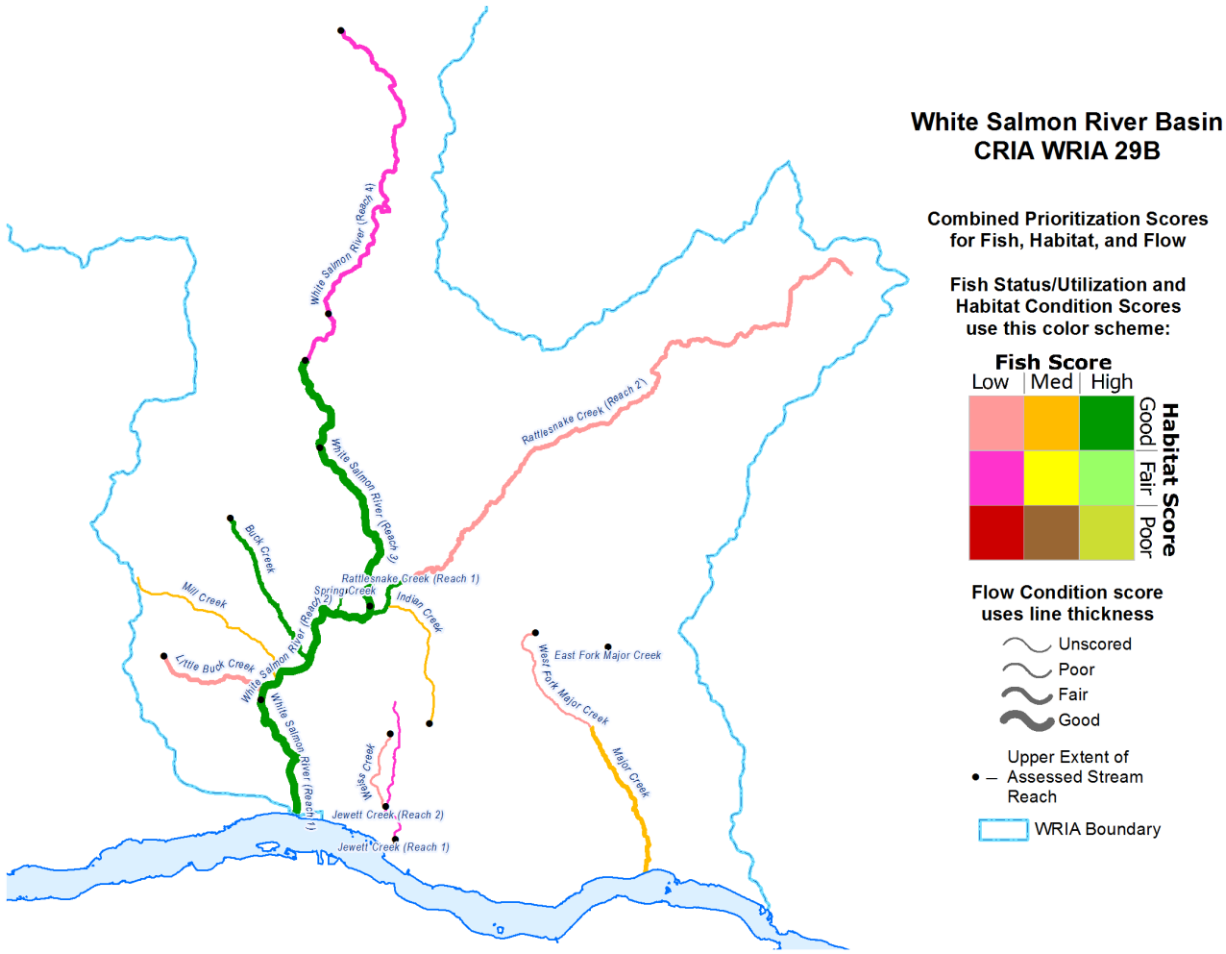

Figure 6. Combined prioritization (bin) scores for fish, habitat and flow – WRIA 29b, White Salmon River Basin.

The GIS (Web Map) summary of bin scores for fish, habitat and flow for the Klickitat River Basin are presented in Figure 7. One stream in the Klickitat River, Bowman Creek, met the criteria used in Table 12.

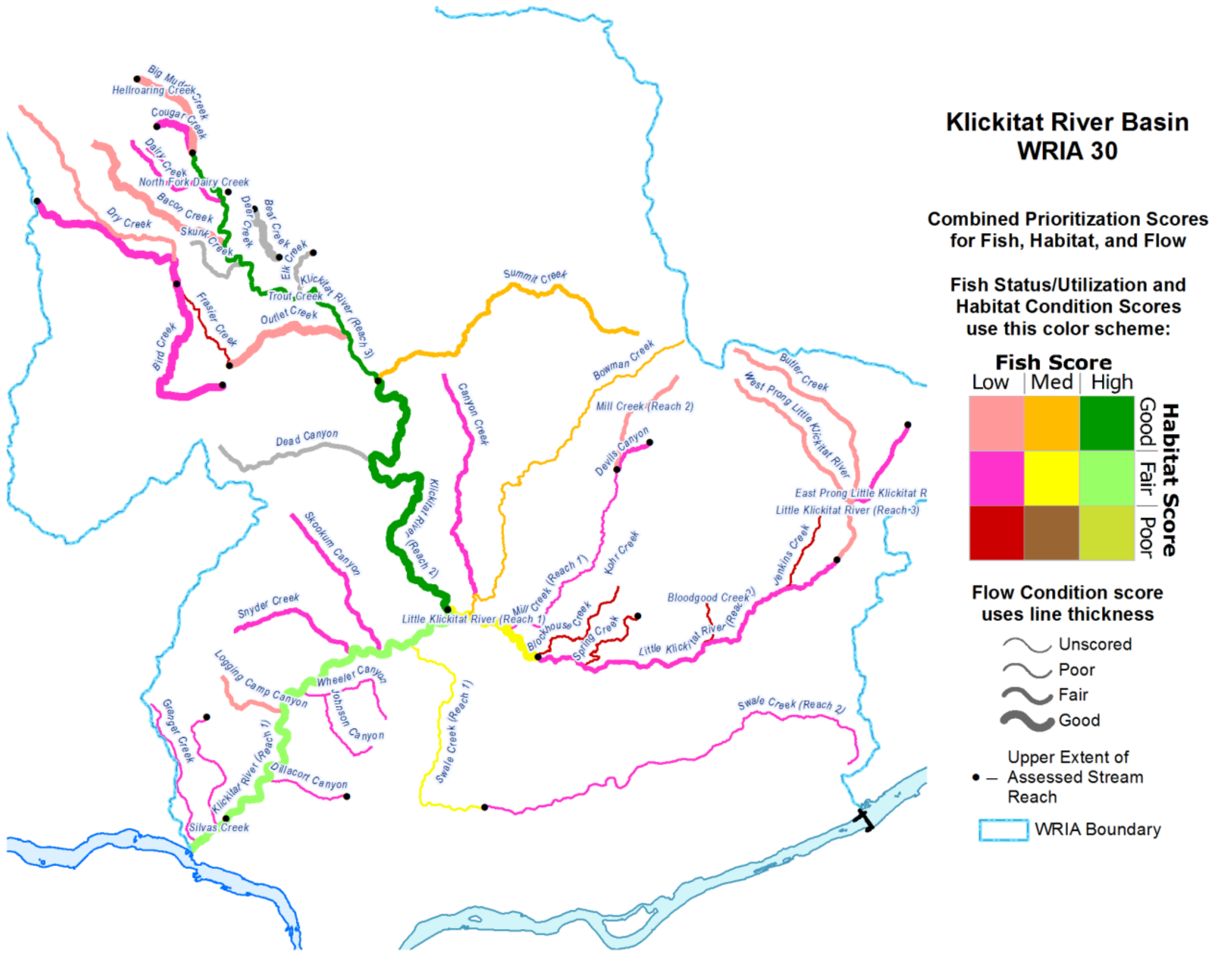

Figure 7. Combined prioritization (bin) scores for fish, habitat and flow – WRIA 30, Klickitat River Basin.

The GIS (Web Map) summary of bin scores for fish, habitat and flow for the Walla Walla River Basin are presented in Figure 8.

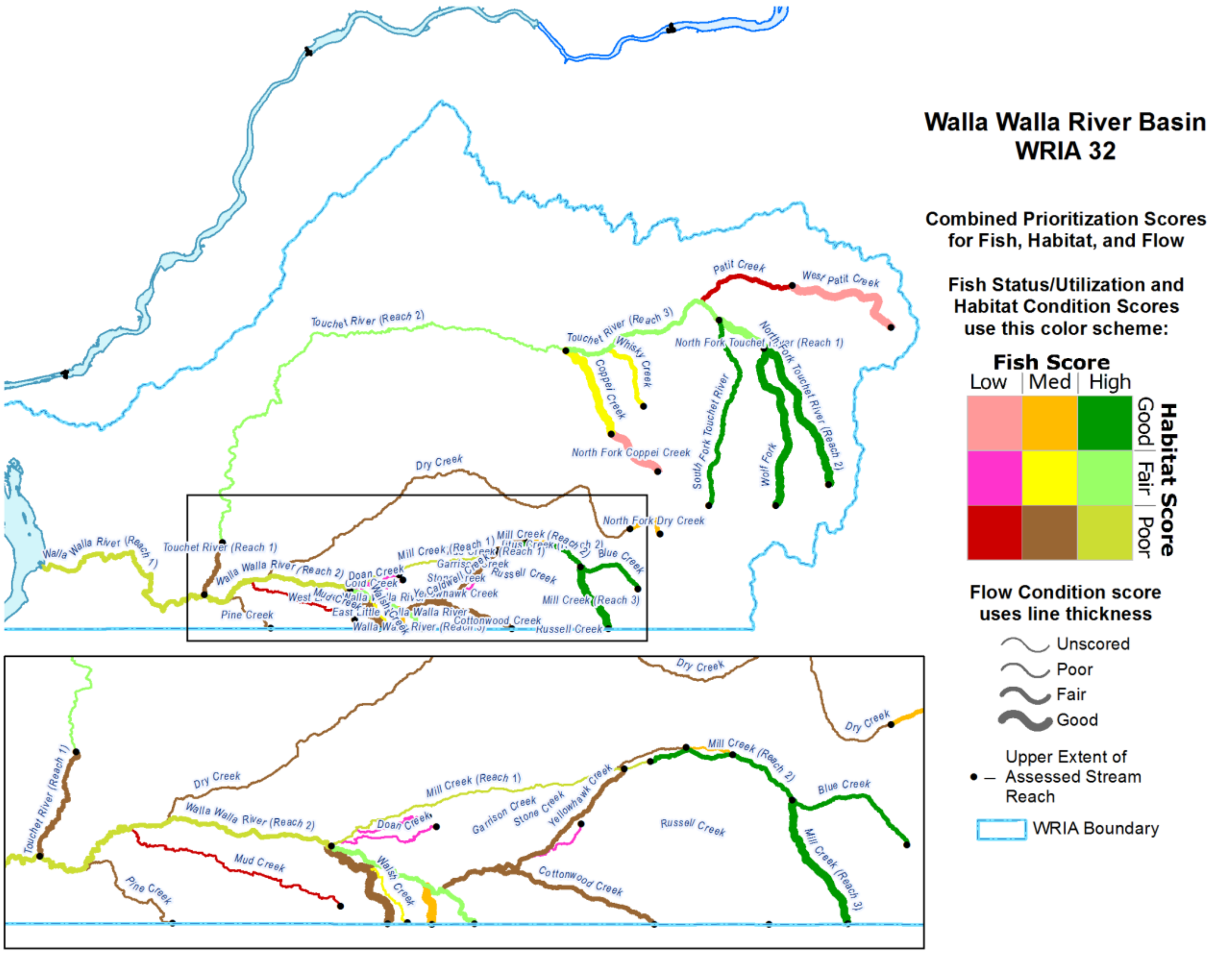

Figure 8. Combined prioritization (bin) scores for fish, habitat and flow – WRIA 32, Walla Walla River Basin.

The GIS (Web Map) summary of bin scores for fish, habitat and flow for the Middle Snake River Basin are presented in Figure 9.

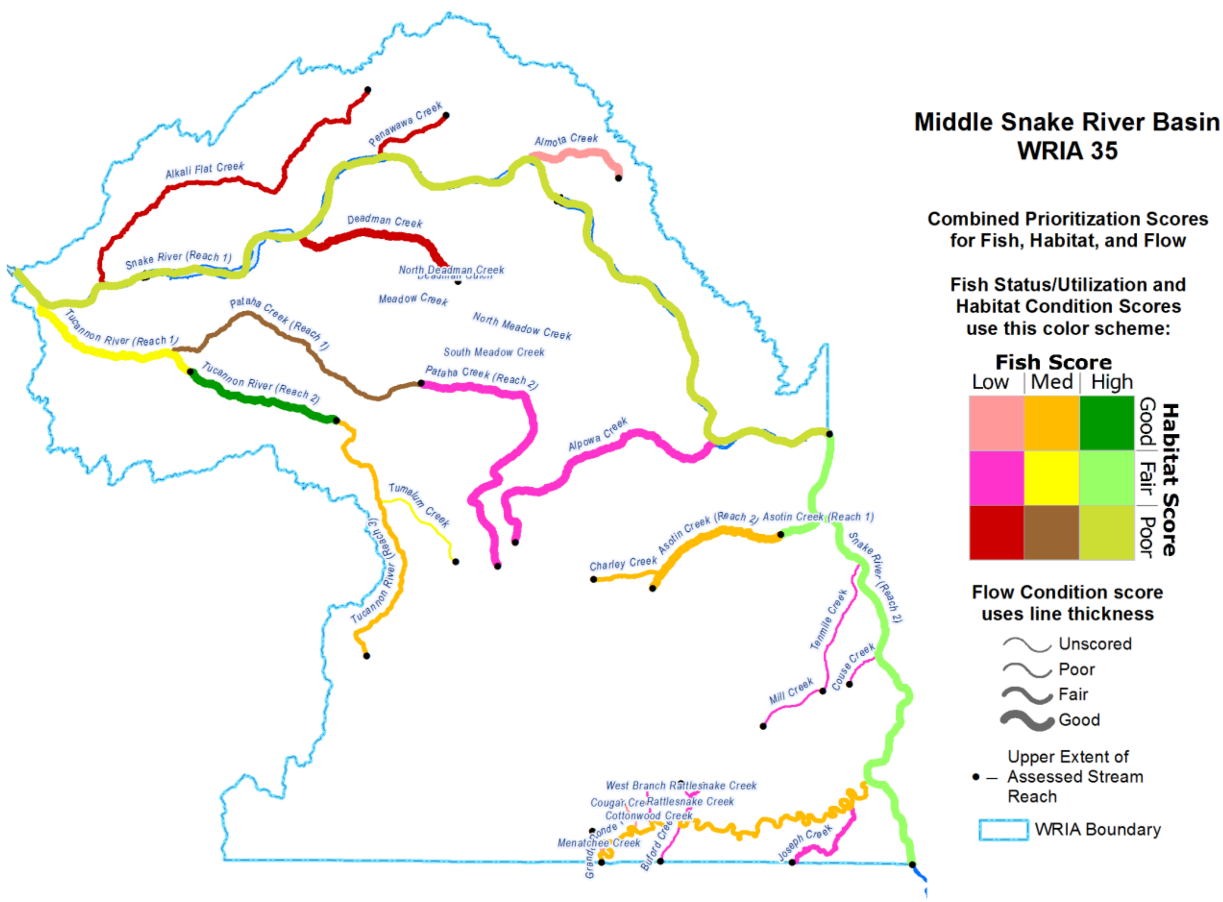

Figure 9. Combined prioritization (bin) scores for fish, habitat and flow – WRIA 35, Middle Snake River Basin.

The GIS (Web Map) summary of bin scores for fish and habitat for the Lower Yakima River are presented in Figure 10. CRIA flow scores were not calculated for Yakima Basin tributaries because more comprehensive flow analyses have been conducted under other programs.

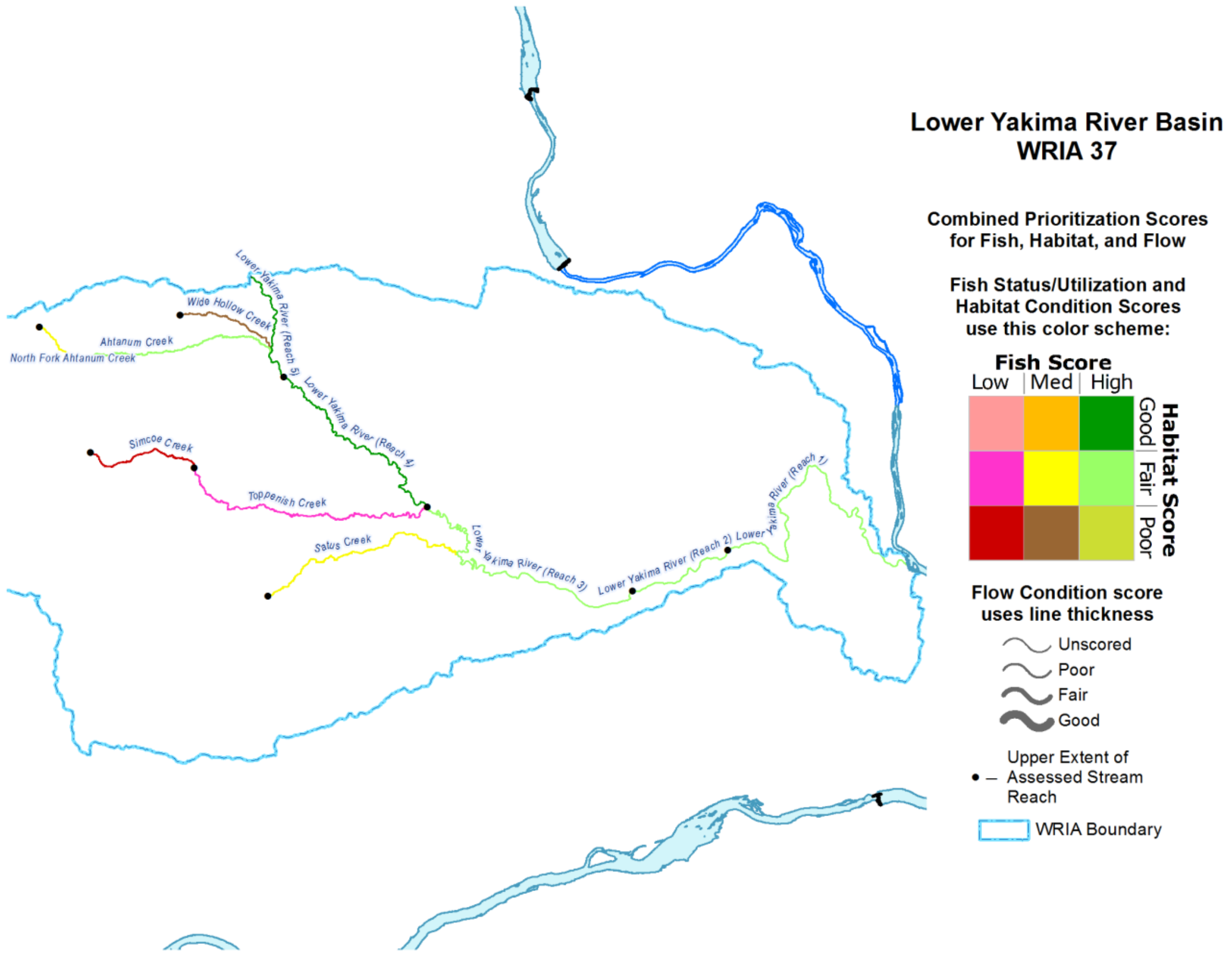

Figure 10. Combined prioritization (bin) scores for fish, habitat and flow – WRIA 37, Lower Yakima River Basin.

The GIS (Web Map) summary of bin scores for fish and habitat for the Naches River are presented in Figure 11. CRIA flow scores were not calculated for Yakima Basin tributaries because more comprehensive flow analyses have been conducted under other programs.

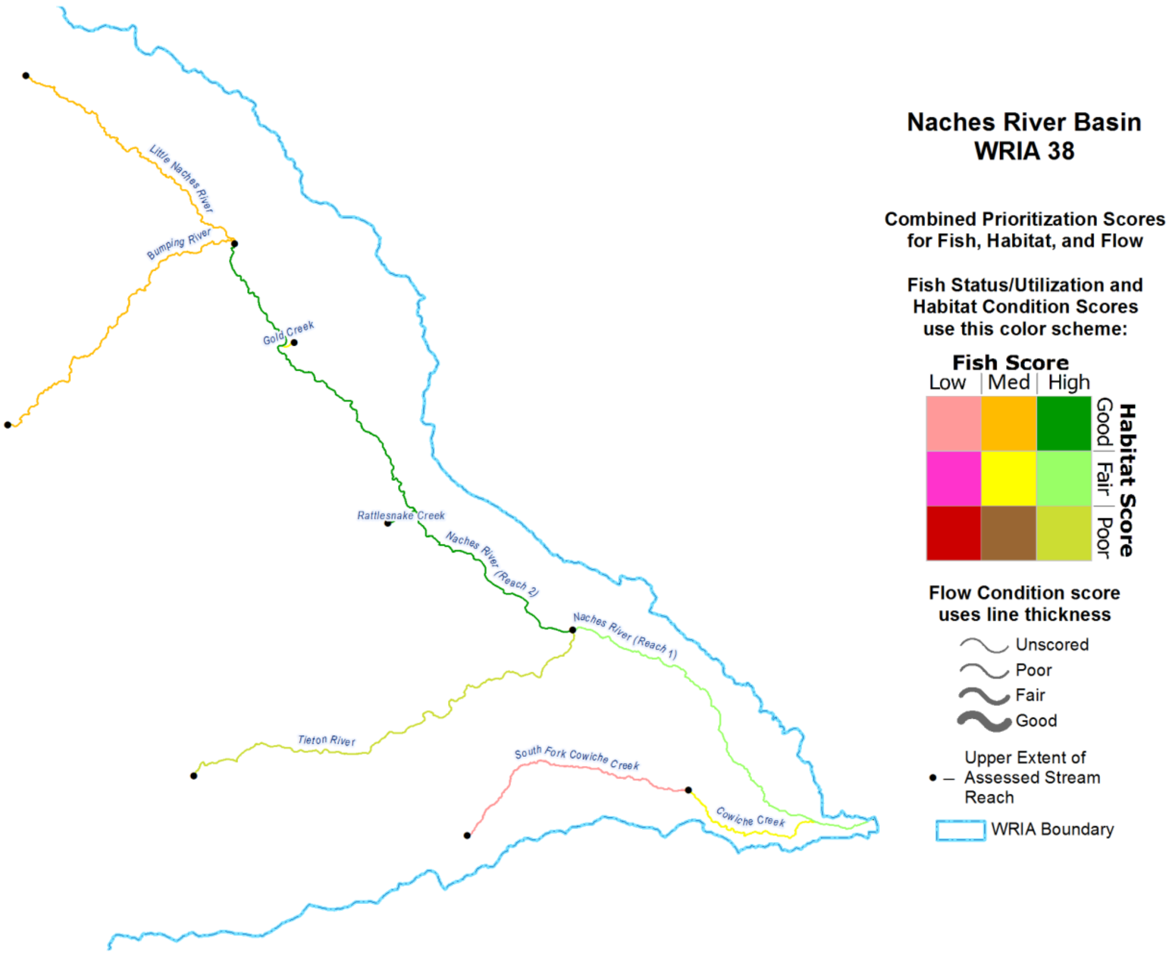

Figure 11. Combined prioritization (bin) scores for fish, habitat and flow – WRIA 38, Naches River Basin.

The GIS (Web Map) summary of bin scores for fish and habitat for the Upper Yakama River are presented in Figure 12. CRIA flow scores were not calculated for Yakima Basin tributaries because more comprehensive flow analyses have been conducted under other programs.

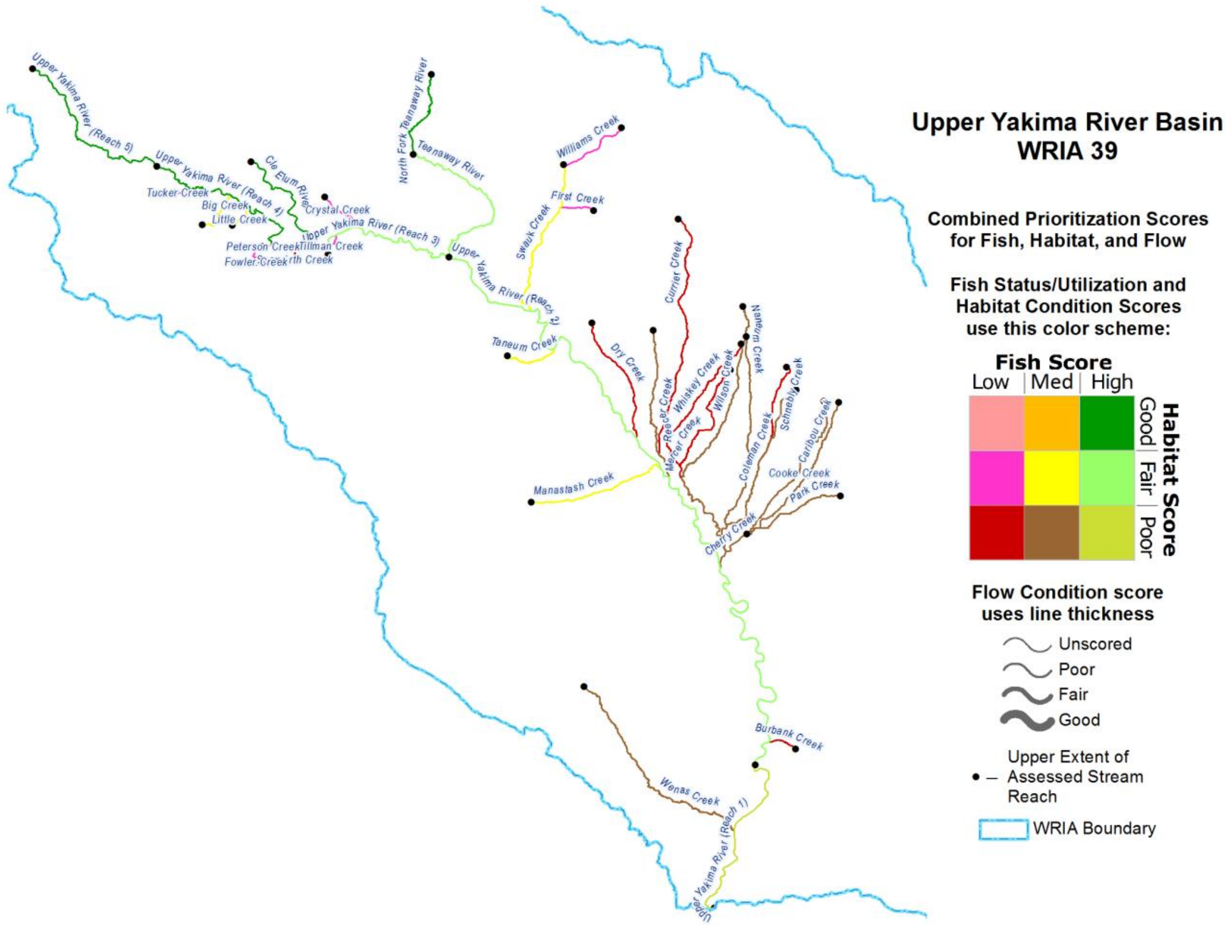

Figure 12. Combined prioritization (bin) scores for fish, habitat and flow – WRIA 39, Upper Yakima River Basin.

The GIS (Web Map) summary of bin scores for fish, habitat and flow for the Wenatchee River Basin are presented in Figure 13. Four reaches in this river basin meet the criteria in Table 12, (i.e., poor flow conditions combined with good fish status and habitat conditions): Wenatchee River (Reach 2), Wenatchee River (Reach 3), Chiwawa River and Icicle Creek (Reach 2).

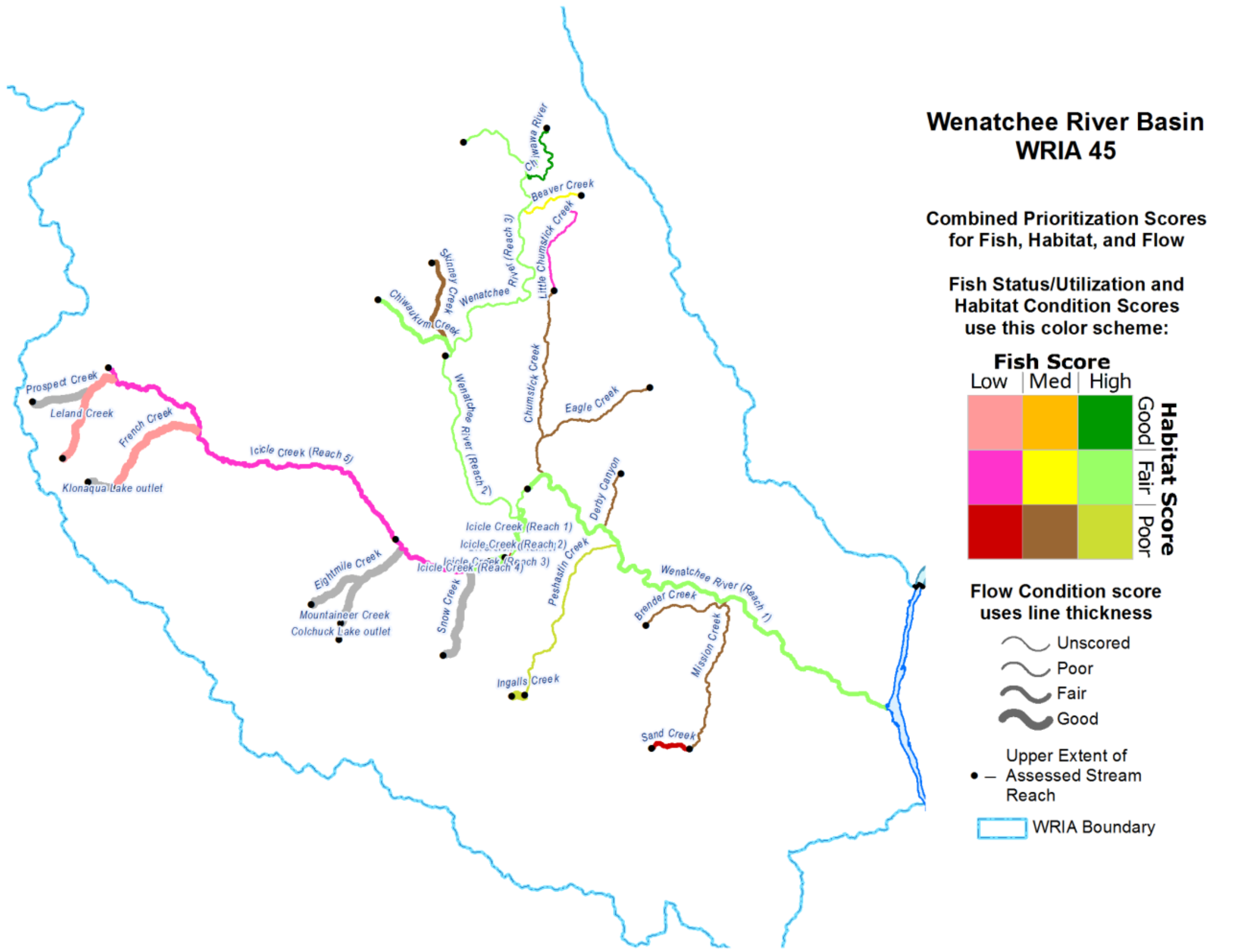

Figure 13. Combined prioritization (bin) scores for fish, habitat and flow – WRIA 45, Wenatchee River Basin.

The GIS (Web Map) summary of bin scores for fish, habitat and flow for the Entiat River Basin are presented in Figure 14. One stream reach in this basin – Entiat River (Reach 1) -- met the criteria used in Table 12, i.e., for good ratings for fish and habitat combined with poor ratings for flow.

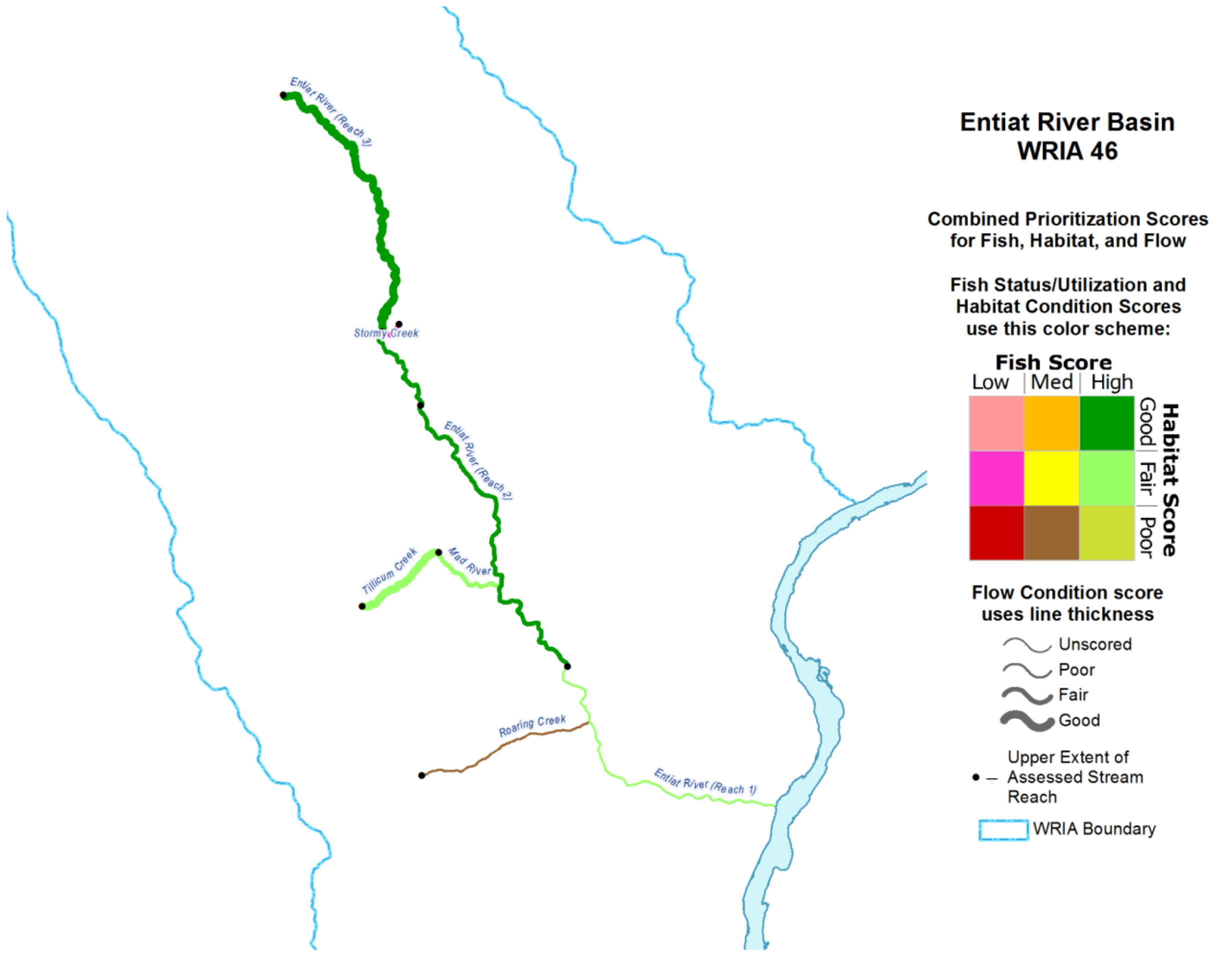

Figure 14. Combined prioritization (bin) scores for fish, habitat and flow – WRIA 46, Entiat River Basin.

The GIS (Web Map) summary of bin scores for fish, habitat and flow for the Methow River Basin are presented in Figure 15. Three reaches in the Methow River basin meet the criteria in Table 12 (i.e., poor flow conditions combined with good fish status and habitat conditions): Methow River (Reach 1), Poorman Creek, Wolf Creek.

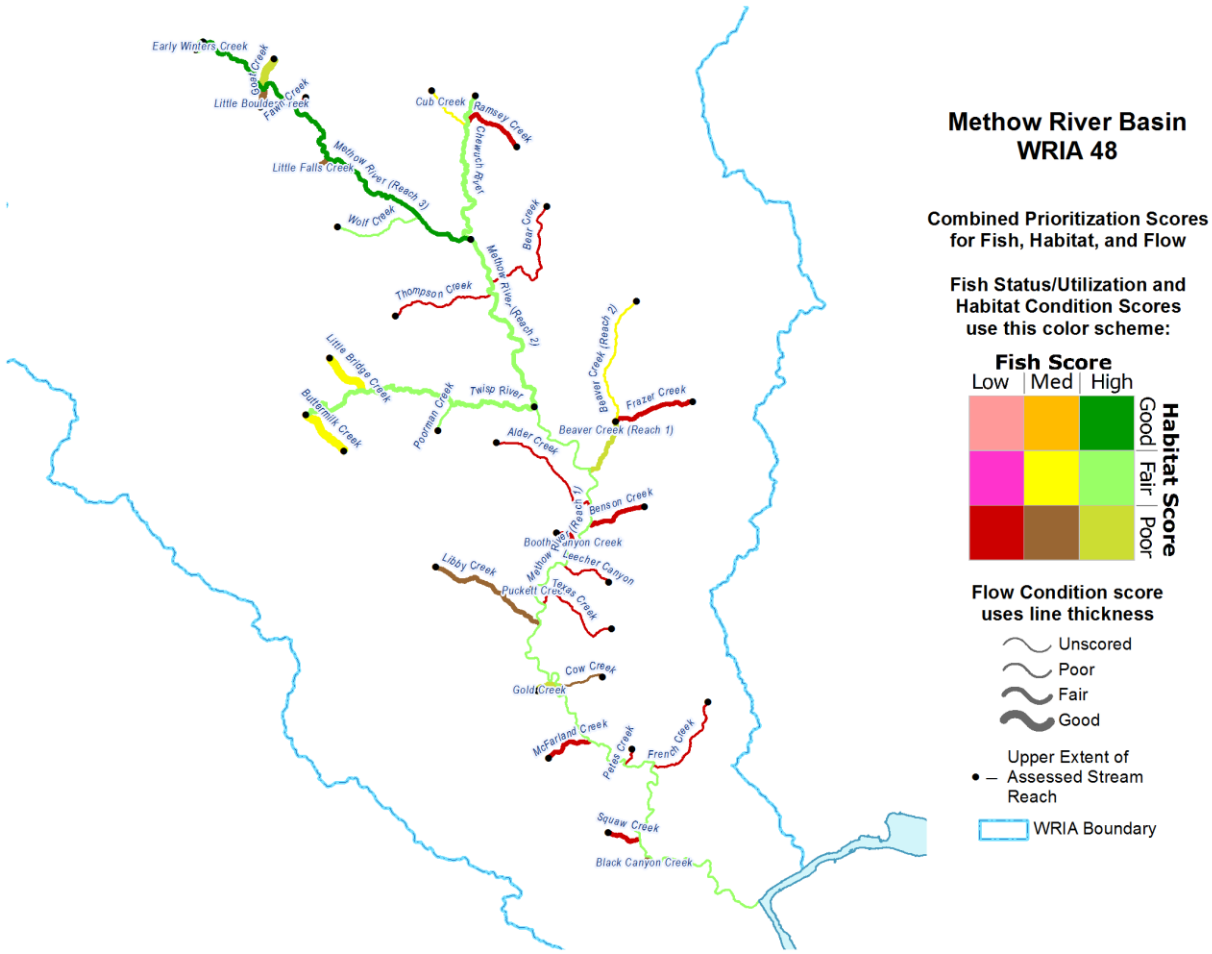

Figure 15. Combined prioritization (bin) scores for fish, habitat and flow – WRIA 48, Methow River Basin.

The GIS (Web Map) summary of bin scores for fish, habitat and flow for the Okanogan River Basin are presented in Figure 16. Six reaches in this river basin meet the criteria in Table 12: Okanogan River (Reach 2), Loup Loup Creek, Ninemile Creek, Antoine Creek, Salmon Creek (Reach 2), Similkameen River (Reach 1). Thus these reaches exhibited good ratings for fish and habitat combined with poor ratings for flow.

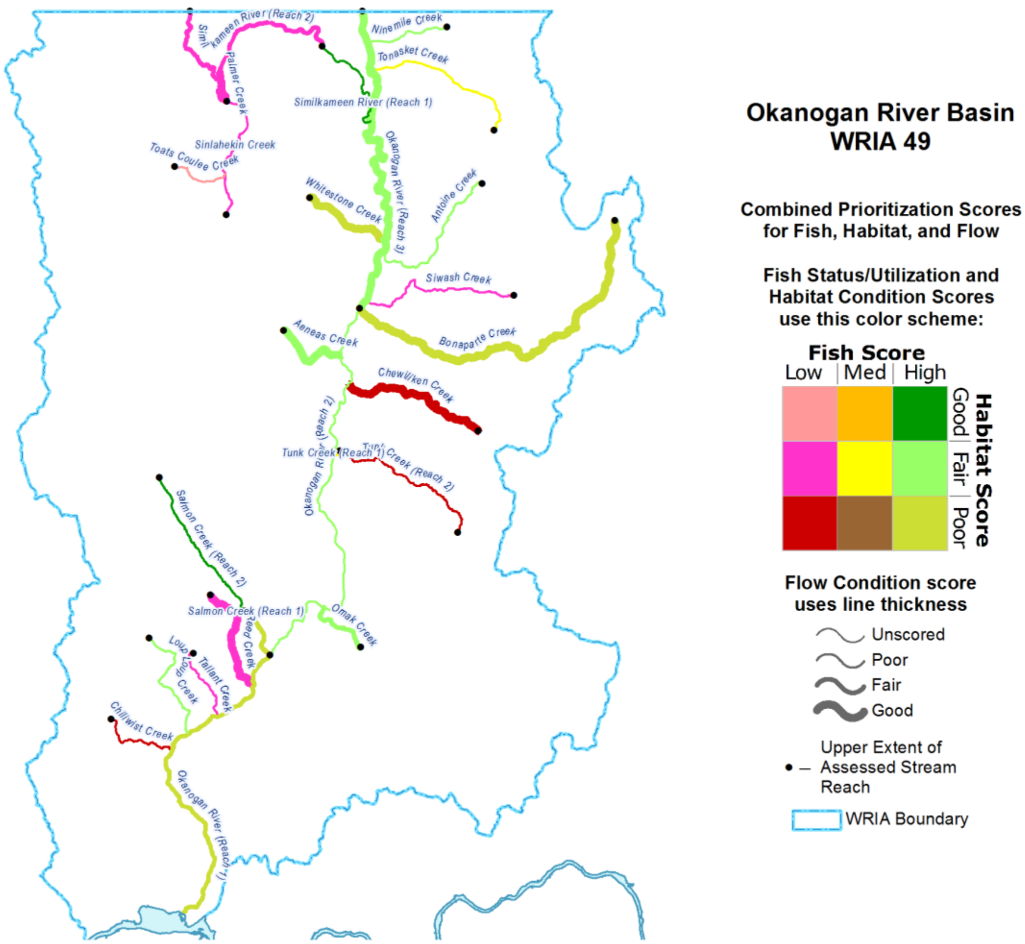

Figure 16. Combined prioritization (bin) scores for fish, habitat and flow – WRIA 49, Okanogan River Basin.

The GIS (Web Map) summary of bin scores for fish, habitat and flow for the Foster River Basin are presented in Figure 17.

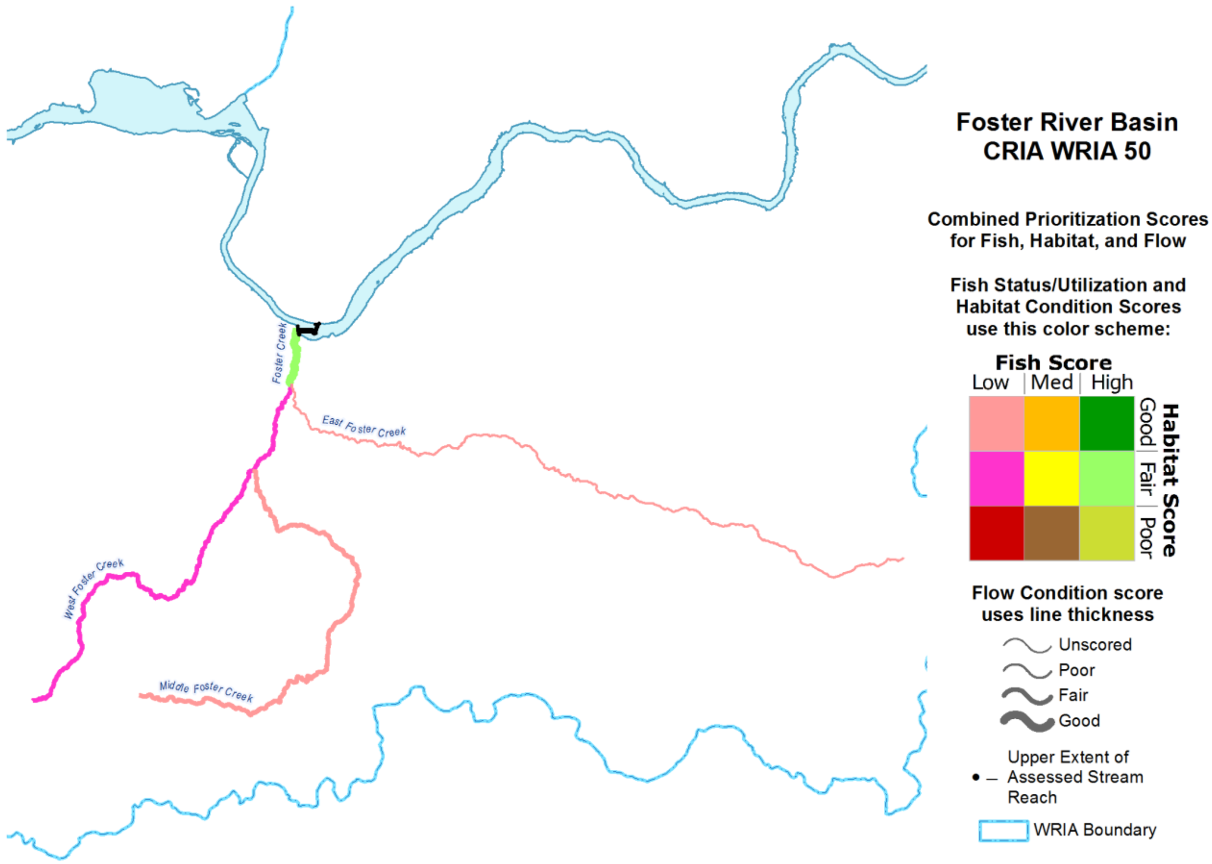

Figure 17. Combined prioritization (bin) scores for fish, habitat and flow – WRIA 50, Foster River Basin.

Deliverables: The fish, habitat, flow and composite CRIA scores by WRIA and stream reach are summarized in Appendix 1, and have been submitted to Ecology as Arc GIS data layers.

Conclusions

FY 2011 Conclusions:

While combined ranks of fish status, fish utilization, and instream flow varied across stream reaches (see Ecology Publication 11-12-015), WDFW concluded that great opportunity to improve salmonid production exists by pursuing water acquisition in smaller, lower elevation streams with good to excellent habitat. In addition, streams with good to excellent habitat in

higher elevations or less populous areas were likely to benefit from flow augmentation, as were lower mainstems through which most fish species must migrate. Any flow augmentation could be helpful in salmonid restoration efforts, especially in smaller systems that have limited flow, in over-appropriated basins, or in combination with other recovery measures.
Prioritization of stream reaches for flow restoration in each WRIA are summarized in Appendix 1, and have been submitted to Ecology as Arc GIS data layers.

2016 Conclusions – Flow Component

Flow Scoring Approach

In 2011, the CRIA team was attempting to identify stream reaches with the highest flow impairment. In 2016, we approached the problem from a more positive perspective and cast a broader net to develop metrics for each of the basic hydrologic attributes: magnitude, timing, frequency, duration, and rate of change. Mean monthly flows and minimum monthly flows were examined for 2011; in 2016 we again evaluated both mean and minimum flow metrics. Ultimately we used only mean monthly and mean annual flows for CRIA 2016 scoring. Scoring emphasis for 2016 also incorporated examination of the shape of each reach's hydrograph in a primitive attempt to classify reaches into types. CRIA 2011 used a flow volume metric to adjust score for other attributes; CRIA 2016 still discounts reaches having high flow volumes, but not as directly as in 2011.

Flow targets

The 2011 CRIA employed flow targets as a scoring metric, and used instream flows set in administrative rule as those targets for scoring. This severely limited the number of reaches that were scored using the "flow target" metric in 2011 (Table 4). Scores are missing for this metric for 91% of 2011 reaches, which could have biased those results.

In 2016, the CRIA team determined that instream flow rules or other targets did not provide enough insight into current or future risk of flow impairment in comparison to the low number of reaches benefitting from that scoring metric. Therefore, no scoring metric was devised in 2016 to measure achievement of instream flow rules.

Yakima Basin prioritization scoring

After the 2011 product was made available, it was determined that the CRIA scores did not add value to the body of knowledge for the Yakima Basin. This is primarily because descriptions of limiting factors for each reach had already been developed and, in many cases, actions to remedy those limiting factors were already planned and prioritized. Also, flows within Yakima mainstem reaches, and many tributaries, are regulated by Reclamation at quantities determined using a federal decision-making process. This is a mixed blessing in the Yakima: Federal flow control means that there are both more opportunities to manage flows for fish (by manipulating stored water) and fewer opportunities (because of irrigation delivery obligations). Those decisions are independent from state agency decision-making processes, so there is no audience for the CRIA blended score in the Yakima. For 2016, the CRIA team presented the fish, habitat, and most flow condition metrics, but did not combine them to provide overall prioritization scores for the Yakima Basin. Because of this, some detailed analyses, such as compilation of water right information, were not conducted for the Yakima Basin.

Water Rights

In 2011, the CRIA team summed the quantified water rights data (diversion flows) as one scoring metric and employed the number of water right "claims" in each reach as a metric indicating risk that diversions are actually greater than the values gleaned from the water rights data. Ecology has warned users of the Water Rights Tracking System (WRTS) that water rights diversion values potentially do not accurately reflect the actual water use. Many team members liked the concept of scoring number of claims as a way to capture risk, but the flow scoring lead was very uncomfortable with this metric (Teresa Scott, Personal Correspondence, November 2016). In 2016, the CRIA team agreed not to use a count of the number of claims per CRIA reach.

Updating the Products for the Next Forecast

The 2011 CRIA product mentioned several planned improvements in scoring for the next forecast round. Persisting data limitations mean that flow condition scoring metrics developed in 2016 have not varied significantly from the 2011 CRIA, nor have the results changed dramatically for reaches evaluated for the 2011 product. Improvements were achieved through better access to the full complement of Ecology historic gauge data; use of data from a broader suite of U.S. Geographic Survey (USGS) and U.S. Bureau of Reclamation (Reclamation) streamflow gauges (including some that are no longer active); and the availability of mean monthly flows generated for all CRIA reaches from NHDPlus. Especially, the availability of monthly means from NHDPlus data provide a better basis to determine whether spotty gauge data or NHDPlus data would be the better source for scoring flow condition for a particular reach, and monthly means could be incorporated into more than one scoring metric.

The results of the 2016 Columbia River Water Supply and Demand Forecast suggested that overall seasonal shifts in timing of water supply and demand will require area specific management and adaptation strategies in the future (Washington State University 2016). The CRIA instream component should incorporate additional metrics related to water temperature and seasonal changes in stream flow that will help to evaluate anticipated future changes in the climate of the Pacific Northwest that would impact environmental factors such as air temperature, snow pack, precipitation, drought cycles, etc. – which in turn effect seasonal dynamics of in-stream water quality and quantity.

Water temperature impairment under climate change was examined for potential use in determining future vulnerability of stream flows. Datasets predicting streamflows under future climate scenarios were also investigated as a potential vulnerability scoring metric. All of these data components were viewed from several angles to develop the scoring mechanism that seems to yield the best results in context with the other scored elements (Habitat and Fish) and planned applications of the CRIA product.

Also, during the interim between 2011 and 2016, climate modelers have developed and evaluated projected flow and water temperature impairment at a finer scale than the original regional-scale results. More literature is available postulating the effects of climate change to stream inhabitants, and more insights have been gained about the distribution of impairments. This has been very helpful when screening potential datasets for scoring the 2016 CRIA.

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Appendices

Appendix 1. CRIA stream reach system for 12 WRIAs and CRIA 2016 scores for fish, habitat and flow (Source Dale Gombert, November 2016).

CRIA_ID	Reach Name	Fish Metric Score	Fish Bin Score	Habitat Metric Score	Habitat Bin Score	Flow Metric Score	Flow Bin Score
2901	**Wind River (Reach 1)**	304	3	11.5	2	19	3
2902	**Wind River (Reach 2)**	165	2	13.4	3	20	3
2903	**Wind River (Reach 3)**	165	2	15.7	3	16	2
2904	**Wind River (Reach 4)**	165	2	14.3	3	16	2
2905	**Little Wind River (Reach 1)**	304	3	12.2	2	17	3
2906	**Little Wind River (Reach 2)**	118	2	15.8	3	13	2
2907	**Berge Creek**	0	1	5	1	10	1
2908	**Panther Creek**	141	2	16.8	3	17	3
2909	**Bear Creek**	0	1	10.5	2	13	2
2910	**Cedar Creek**	141	2	15.9	3	13	2
2911	**Trout Creek**	141	2	13.5	3	19	3
2912	**Martha Creek**	105	2	15.7	3	12	2
2913	**Cold Creek**	66	1	16	3	11	2
2914	**Trapper Creek**	135	2	14.5	3	16	2
2915	**Rock Creek (Reach 1)**	148	2	9.1	2	16	2
2916	**Rock Creek (Reach 2)**	0	1	9.7	2	17	3
2917	**Kanaka Creek**	24	1	5.5	1	11	2
2918	**Nelson Creek**	24	1	8.7	2	11	2
2919	**Carson Creek (Reach 1)**	96	1	7.2	1	10	1
2920	**Carson Creek (Reach 2)**	0	1	8.3	2	13	2
2921	**Little White Salmon River (Reach 1)**	295	3	8.8	2	19	3
2922	**Little White Salmon River (Reach 2)**	0	1	12.7	2	16	2
2923	**Rock Creek**	0	1	15.7	3	16	2
2924	**Moss Creek**	0	1	11.8	2	9	1
2925	**Collins Creek**	12	1	12	2	5	1
2926	**White Salmon River (Reach 1)**	420	3	14.1	3	21	3
2927	**White Salmon River (Reach 2)**	408	3	14.4	3	17	3
2928	**White Salmon River (Reach 3)**	320	3	15.8	3	19	3
2929	**White Salmon River (Reach 4)**	120	1	12.1	2	16	2

CRIA_ID	Reach Name	Fish Metric Score	Fish Bin Score	Habitat Metric Score	Habitat Bin Score	Flow Metric Score	Flow Bin Score
2930	**Little Buck Creek**	0	1	15.2	3	14	2
2931	**Mill Creek**	270	2	15.9	3	10	1
2932	**Buck Creek**	298	3	16.5	3	14	2
2933	**Spring Creek**	298	3	15.2	3	8	1
2934	**Rattlesnake Creek (Reach 1)**	298	3	16.6	3	16	2
2935	**Rattlesnake Creek (Reach 2)**	112	1	15.7	3	11	2
2936	**Indian Creek**	242	2	16.5	3	10	1
2940	**Jewett Creek (Reach 1)**	224	2	4.7	1	10	1
2941	**Jewett Creek (Reach 2)**	0	1	13.3	3	9	1
2942	**Weiss Creek**	0	1	13.5	3	9	1
2943	**Major Creek**	224	2	14.7	3	11	2
2944	**West Fork Major Creek**	96	1	16	3	8	1
2945	**East Fork Major Creek**	96	1			10	1
3001	**Klickitat River (Reach 1)**	240	3	11.3	2	19	3
3002	**Klickitat River (Reach 2)**	258	3	17.7	3	21	3
3003	**Klickitat River (Reach 3)**	258	3	17.8	3	13	2
3004	**Granger Creek**	25	1	12.5	2	9	1
3005	**Silvas Creek**	25	1	11.7	2	9	1
3006	**Dillacort Canyon**	79	1	13.8	2	7	1
3007	**Logging Camp Canyon**	79	1	19.5	3	11	2
3008	**Wheeler Canyon**	79	1	12	2	10	1
3009	**Johnson Canyon**	54	1	10	2	8	1
3010	**Snyder Creek**	79	1	14.3	2	12	2
3011	**Skookum Canyon**	24	1	10.6	2	11	2
3012	**Swale Creek (Reach 1)**	134	2	8	1	9	1
3013	**Swale Creek (Reach 2)**	56	1	8.2	1	7	1
3014	**Little Klickitat River (Reach 1)**	148	2	12.3	2	18	3
3015	**Little Klickitat River (Reach 2)**	56	1	10.3	2	11	2
3016	**Little Klickitat River (Reach 3)**	56	1	16.7	3	12	2
3017	**Canyon Creek**	56	1	14.7	2	14	2
3018	**Bowman Creek**	132	2	16.5	3	10	1
3019	**Mill Creek (Reach 1)**	44	1	13	2	10	1
3020	**Mill Creek (Reach 2)**	0	1	18.9	3	13	2
3021	**Devils Canyon**	0	1	11.4	2	13	2
3022	**Blockhouse Creek**	44	1	5	1	6	1
3023	**Kohr Creek**	0	1			6	1
3024	**Spring Creek**	44	1	5	1	8	1
3025	**Bloodgood Creek**	56	1	8	1	7	1
3026	**Jenkins Creek**	56	1	8.7	1	8	1
3027	**West Prong Little Klickitat**	56	1	16.5	3	13	2

CRIA_ID	Reach Name	Fish Metric Score	Fish Bin Score	Habitat Metric Score	Habitat Bin Score	Flow Metric Score	Flow Bin Score
	River						
3028	East Prong Little Klickitat River	56	1	15.6	3	13	2
3029	Butler Creek	56	1	17.6	3	14	2
3030	Dead Canyon	80	1			13	2
3031	Summit Creek	149	2	16.7	3	14	2
3032	Outlet Creek	48	1	15.6	3	16	3
3033	Frasier Creek	0	1	5.1	1	7	1
3034	Bird Creek	0	1	10.9	2	16	3
3035	Dry Creek	0	1	17.7	3	14	2
3036	Elk Creek	0	1			14	2
3037	Trout Creek	121	2			15	3
3038	Bear Creek	48	1			15	3
3039	Deer Creek	0	1			10	1
3040	Skunk Creek	0	1			12	2
3041	Bacon Creek	0	1	18.8	3	16	3
3042	Dairy Creek	0	1	15.4	2	11	2
3043	North Fork Dairy Creek	0	1	15.3	2	9	1
3044	Big Muddy Creek	0	1	18	3	24	3
3045	Cougar Creek	0	1	16.8	3	15	3
3046	Hellroaring Creek	0	1	18	3	22	3
3201	Walla Walla River (Reach 1)	188	3	4	1	12	2
3202	Walla Walla River (Reach 2)	186	3	5	1	14	2
3203	Walla Walla River (Reach 3)	170	3	7	1	13	2
3205	Touchet River (Reach 1)	122	2	3	1	14	2
3206	Touchet River (Reach 2)	134	3	6	1	11	1
3207	Touchet River (Reach 3)	142	3	10.3	2	14	2
3208	Coppei Creek	68	2	6	1	15	3
3209	North Fork Coppei Creek	56	1	15	3	15	3
3210	South Fork Touchet River	152	3	14.5	3	12	2
3211	North Fork Touchet River (Reach 1)	136	3	11.1	2	16	3
3212	North Fork Touchet River (Reach 2)	166	3	17	3	16	3
3213	Pine Creek	96	2			10	1
3214	Mud Creek	48	1			11	1
3215	Dry Creek	96	2	5.2	1	8	1
3216	North Fork Dry Creek	84	2	15.7	3	13	2
3217	West Little Walla Walla River	96	2	5	1	15	3
3218	Mill Creek (Reach 1)	164	3	3.2	1	11	1

CRIA_ID	Reach Name	Fish Metric Score	Fish Bin Score	Habitat Metric Score	Habitat Bin Score	Flow Metric Score	Flow Bin Score
3219	**Mill Creek (Reach 2)**	194	3	13.3	2	12	2
3220	**Mill Creek (Reach 3)**	194	3	16.5	3	17	3
3222	**Doan Creek**	48	1	7	1	7	1
3223	**Cold Creek**	48	1	7	1	6	1
3224	**Blue Creek**	132	3	13.6	2	14	2
3225	**East Little Walla Walla River**	96	2	10	2	18	3
3226	**Patit Creek**	56	1	3	1	14	2
3227	**West Patit Creek**	56	1	14.6	3	17	3
3228	**Yellowhawk Creek**	120	2	5	1	12	2
3229	**Cottonwood Creek**	84	2	5	1	14	2
3230	**Whisky Creek**	68	2	6	1	12	2
3231	**Titus Creek (Reach 1)**	84	2	3.9	1	5	1
3232	**Titus Creek (Reach 2)**	102	2	11.3	2	5	1
3233	**Walsh Creek**	84	2	8	1	6	1
3234	**Caldwell Creek**	36	1	6	1	7	1
3235	**Wolf Fork**	166	3	17.7	3	18	3
3236	**Garrison Creek**	45	1			3	1
3237	**Stone Creek**	45	1			6	1
3238	**Russell Creek**	36	1			9	1
3501	**Snake River (Reach 1)**	531	3	6.5	1	17	3
3502	**Snake River (Reach 2)**	410	3	8.3	1	17	3
3503	**Tucannon River (Reach 1)**	330	2	8.3	1	20	3
3504	**Tucannon River (Reach 2)**	362	3	14.2	3	19	3
3505	**Tucannon River (Reach 3)**	321	2	17.9	3	15	2
3506	**Pataha Creek (Reach 1)**	205	2	2	1	15	2
3507	**Pataha Creek (Reach 2)**	112	1	11.2	2	16	3
3508	**Asotin Creek (Reach 1)**	357	3	10.9	2	16	3
3509	**Asotin Creek (Reach 2)**	329	2	14.9	3	18	3
3510	**Charley Creek**	224	2	13.7	2	11	2
3511	**Alkali Flat Creek**	172	1	3	1	14	2
3512	**Almota Creek**	108	1	12	2	19	3
3513	**Alpowa Creek**	155	1	11	2	21	3
3514	**Penawawa Creek**	172	1	2.9	1	12	2
3515	**Deadman Creek**	172	1	3.9	1	18	3
3516	**North Deadman Creek**	112	1	7	1	10	1
3517	**Deadman Gulch**	112	1	1	1	10	1
3518	**Tenmile Creek**	132	1	9	2	8	1
3519	**Mill Creek**	36	1	8	1	8	1
3520	**Couse Creek**	156	1	10.1	2	8	1
3521	**Tumalum Creek**	265	2	11.9	2	10	1

CRIA_ID	Reach Name	Fish Metric Score	Fish Bin Score	Habitat Metric Score	Habitat Bin Score	Flow Metric Score	Flow Bin Score
3522	**Grande Ronde River**	264	2	11.9	2	15	2
3523	**Buford Creek**	56	1	8.3	1	9	1
3524	**Menatchee Creek**	88	1	15.8	3	15	2
3525	**Joseph Creek**	80	1	13.3	2	11	2
3526	**Cottonwood Creek**	56	1	13.8	2	9	1
3527	**Cougar Creek**	56	1	13.4	2	9	1
3528	**Rattlesnake Creek**	56	1	10.4	2	13	2
3529	**West Branch Rattlesnake Creek**	56	1	11	2	9	1
3530	**Meadow Creek**	108	1			10	1
3531	**North Meadow Creek**	0	1			8	1
3532	**South Meadow Creek**	0	1			9	1
3701	**Lower Yakima River (Reach 1)**	341	3	9.6	2	16	0
3702	**Lower Yakima River (Reach 2)**	341	3	7.5	2	14	0
3703	**Lower Yakima River (Reach 3)**	341	3	12.6	3	16	0
3704	**Lower Yakima River (Reach 4)**	397	3	15.8	3	14	0
3705	**Lower Yakima River (Reach 5)**	373	3	14.9	3	17	0
3706	**Satus Creek**	138	2	11.8	2	11	0
3707	**Toppenish Creek**	132	1	8.7	2	12	0
3708	**Simcoe Creek**	70	1	7.6	2	12	0
3709	**Ahtanum Creek**	316	3	10.1	2	12	0
3710	**North Fork Ahtanum Creek**	209	2	13.8	3	10	0
3711	**Wide Hollow Creek**	163	2	4	1	7	0
3801	**Naches River (Reach 1)**	330	3	10.6	2	15	0
3802	**Naches River (Reach 2)**	263	3	14.8	2	12	0
3803	**Cowiche Creek**	151	2	11	2	9	0
3804	**South Fork Cowiche Creek**	110	1	17	3	9	0
3805	**Tieton River**	241	3	8.6	1	14	0
3806	**Rattlesnake Creek**	231	3	15	3	18	0
3807	**Gold Creek**	196	2	13.3	2	13	0
3808	**Little Naches River**	217	2	18	3	9	0
3809	**Bumping River**	141	2	19	3	14	0
3901	**Upper Yakima River (Reach 1)**	306	3	7.9	1	17	0
3902	**Upper Yakima River (Reach 2)**	216	3	13.2	2	17	0
3903	**Upper Yakima River (Reach 3)**	212	3	14.8	2	15	0
3904	**Upper Yakima River (Reach 4)**	211	3	19.2	3	15	0
3905	**Upper Yakima River (Reach 5)**	277	3	18.2	3	14	0
3906	**Wenas Creek**	128	2	3.2	1	14	0
3907	**Burbank Creek**	72	1	6	1	7	0
3908	**Wilson Creek**	128	2	2.2	1	13	0

CRIA_ID	Reach Name	Fish Metric Score	Fish Bin Score	Habitat Metric Score	Habitat Bin Score	Flow Metric Score	Flow Bin Score
3909	**Cherry Creek**	128	2	3	1	10	0
3910	**Park Creek**	128	2	3.3	1	6	0
3911	**Cooke Creek**	128	2	2.8	1	11	0
3912	**Caribou Creek**	128	2	2.3	1	10	0
3913	**Naneum Creek**	128	2	1.3	1	9	0
3914	**Coleman Creek**	128	2	2	1	11	0
3915	**Schnebly Creek**	72	1	2.1	1	11	0
3916	**Mercer Creek**	86	1	2	1	6	0
3917	**Reecer Creek**	128	2	4.4	1	11	0
3918	**Whiskey Creek**	72	1	1	1	6	0
3919	**Currier Creek**	86	1	4.4	1	11	0
3920	**Manastash Creek**	114	2	9.7	2	18	0
3921	**Dry Creek**	72	1	2.1	1	6	0
3922	**Taneum Creek**	128	2	10.6	2	11	0
3923	**Swauk Creek**	131	2	12.1	2	9	0
3924	**First Creek**	36	1	15.7	3	12	0
3925	**Williams Creek**	93	1	11.4	2	11	0
3926	**Teanaway River**	252	3	13.6	2	12	0
3927	**North Fork Teanaway River**	239	3	16.5	3	16	0
3928	**Cle Elum River**	211	3	18.7	3	13	0
3929	**Big Creek**	191	2	14.3	2	9	0
3930	**Little Creek**	130	2	11.8	2	16	0
3931	**Crystal Creek**	24	1	9.2	2	10	0
3932	**Tillman Creek**	60	1	10	2	9	0
3933	**Spex Arth Creek**	0	1	8.8	1	12	0
3934	**Peterson Creek**	60	1	17.6	3	12	0
3935	**Fowler Creek**	0	1	12.8	2	13	0
3936	**Tucker Creek**	60	1	11	2	12	0
4501	**Wenatchee River (Reach 1)**	306	3	10.2	1	11	2
4502	**Wenatchee River (Reach 2)**	338	3	14.2	2	14	1
4503	**Wenatchee River (Reach 3)**	338	3	14.7	2	13	1
4504	**Mission Creek**	194	2	4.2	1	9	1
4505	**Brender Creek**	176	2	6	1	13	1
4506	**Peshastin Creek**	260	3	9.9	1	10	1
4507	**Ingalls Creek**	255	3	11.7	2	22	3
4508	**Derby Canyon**	146	2	7.5	1	14	1
4509	**Chumstick Creek**	194	2	8.4	1	11	1
4510	**Eagle Creek**	132	2	9.6	1	14	1
4511	**Little Chumstick Creek**	12	1	12.7	2	9	1
4513	**Chiwaukum Creek**	282	3	17.1	2	18	2

CRIA_ID	Reach Name	Fish Metric Score	Fish Bin Score	Habitat Metric Score	Habitat Bin Score	Flow Metric Score	Flow Bin Score
4514	**Sand Creek**	108	1	7.2	1	15	2
4515	**Skinney Creek**	170	2	11	1	15	2
4516	**Beaver Creek**	158	2	13.8	2	13	1
4517	**Chiwawa River**	282	3	21	3	14	1
4518	**Icicle Creek (Reach 1)**	287	3	12.4	2	16	2
4519	**Icicle Creek (Reach 2)**	287	3	16	2	14	1
4520	**Icicle Creek (Reach 3)**	287	3	11.4	2	21	3
4521	**Icicle Creek (Reach 4)**	287	3	12.2	2	22	3
4522	**Icicle Creek (Reach 5)**	57	1	16.8	2	15	2
4523	**Diversion Channel**	0	1	1	1	6	1
4524	**Snow Creek**	36	1	-2.7	1	20	3
4525	**Eightmile Creek**	36	1	-2.9	1	24	3
4526	**Mountaineer Creek**	36	1	-1.3	1	19	3
4527	**Colchuck Lake outlet**	0	1	-2	1	18	2
4528	**French Creek**	81	1	21.2	3	26	3
4529	**Klonaqua Lake outlet**	0	1	-2	1	19	3
4530	**Leland Creek**	81	1	23.1	3	20	3
4531	**Prospect Creek**	81	1	-2	1	23	3
4601	**Entiat River (Reach 1)**	287	3	16.6	2	9	1
4602	**Entiat River (Reach 2)**	337	3	17.8	3	11	2
4603	**Entiat River (Reach 3)**	337	3	21.9	3	19	3
4604	**Roaring Creek**	116	2	9.8	1	10	1
4605	**Mad River**	296	3	14.4	2	13	2
4606	**Tillicum Creek**	236	3	16.5	2	20	3
4607	**Stormy Creek**	96	1	12	2	13	2
4801	**Methow River (Reach 1)**	284	3	11.8	2	9	1
4802	**Methow River (Reach 2)**	311	3	10.4	2	12	2
4803	**Methow River (Reach 3)**	311	3	17.8	3	10	2
4804	**Squaw Creek**	48	1	2.4	1	11	2
4805	**French Creek**	60	1	4	1	8	1
4806	**Petes Creek**	60	1	2.6	1	5	1
4807	**McFarland Creek**	60	1	4.4	1	12	2
4808	**Cow Creek**	132	2	5	1	6	1
4809	**Libby Creek**	186	2	11.9	2	12	2
4810	**Texas Creek**	60	1	5	1	9	1
4811	**Puckett Creek**	96	1	3	1	8	1
4812	**Leecher Canyon**	96	1	3.6	1	6	1
4813	**Benson Creek**	96	1	2	1	10	2
4814	**Alder Creek**	96	1	4.5	1	9	1
4815	**Beaver Creek (Reach 1)**	226	3	5.8	1	12	2

CRIA_ID	Reach Name	Fish Metric Score	Fish Bin Score	Habitat Metric Score	Habitat Bin Score	Flow Metric Score	Flow Bin Score
4816	**Beaver Creek (Reach 2)**	166	2	12.9	2	9	1
4817	**Black Canyon Creek**	150	2	6.5	1	12	2
4818	**Booth Canyon Creek**	96	1	3.4	1	11	2
4819	**Frazer Creek**	96	1	9.7	2	10	2
4820	**Twisp River**	291	3	14.7	3	10	2
4821	**Poorman Creek**	219	3	12.6	2	9	1
4822	**Little Bridge Creek**	174	2	13.7	2	16	3
4823	**Buttermilk Creek**	202	2	16.2	3	20	3
4824	**Thompson Creek**	0	1	4.2	1	8	1
4825	**Bear Creek**	16	1	7	1	8	1
4826	**Chewuch River**	279	3	13.7	2	11	2
4827	**Cub Creek**	174	2	11.4	2	9	1
4828	**Ramsey Creek**	96	1	6.3	1	12	2
4829	**Little Boulder Creek**	186	2	10	2	16	3
4830	**Wolf Creek**	295	3	15.2	3	7	1
4831	**Little Falls Creek**	132	2	7	1	12	2
4832	**Fawn Creek**	60	1	6.5	1	10	2
4833	**Goat Creek**	214	3	10	2	19	3
4834	**Gold Creek**	259	3	11	2	17	3
4835	**Early Winters Creek**	259	3	11.7	2	14	3
4901	**Okanogan River (Reach 1)**	129	3	6.9	1	9	2
4902	**Okanogan River (Reach 2)**	129	3	9.6	2	7	1
4903	**Okanogan River (Reach 3)**	129	3	12	3	13	3
4904	**Tonasket Creek**	80	2	8.8	2	8	1
4905	**Bonaparte Creek**	96	3	7.3	2	11	3
4906	**Loup Loup Creek**	96	3	11.7	3	6	1
4907	**Ninemile Creek**	98	3	10.2	2	7	1
4908	**Aeneas Creek**	92	3	8.8	2	12	3
4909	**Omak Creek**	96	3	10.3	2	9	2
4910	**Palmer Creek**	0	1	14	3	16	3
4912	**Antoine Creek**	92	3	9.6	2	8	1
4913	**Siwash Creek**	15	1	8	2	7	1
4914	**Tunk Creek (Reach 1)**	84	2	10.7	2	11	3
4915	**Tunk Creek (Reach 2)**	0	1	6.4	1	4	1
4916	**Salmon Creek (Reach 1)**	92	3	5.4	1	10	2
4917	**Salmon Creek (Reach 2)**	92	3	14.9	3	8	1
4918	**Chiliwist Creek**	0	1	5.1	1	8	1
4919	**Tallant Creek**	32	1	7.4	2	8	1
4920	**Reed Creek**	0	1	8.9	2	12	3
4921	**Whitestone Creek**	92	3	3.1	1	16	3

CRIA_ID	Reach Name	Fish Metric Score	Fish Bin Score	Habitat Metric Score	Habitat Bin Score	Flow Metric Score	Flow Bin Score
4922	**Chewiliken Creek**	0	1	4.7	1	11	3
4923	**Similkameen River (Reach 1)**	121	3	13.4	3	8	1
4924	**Similkameen River (Reach 2)**	0	1	10.8	2	10	2
4925	**Toats Coulee Creek**	0	1	14	3	7	1
4926	**Sinlahekin Creek**	0	1	10.6	2	7	1
5001	**Foster Creek**	93	3	3	1	20	3
5002	**East Foster Creek**	0	1	8.1	3	14	1
5003	**West Foster Creek**	0	1	5	2	17	2
5004	**Middle Foster Creek**	0	1	7	3	18	2

Appendix 2. Six CRIA habitat scoring attributes and associated scoring criteria on a scale of 1 to 4 (Source: Jonathan Kohr; Columbia River Instream Atlas 2011 Appendix A).

A. Habitat Scoring Attributes

After much consideration, six habitat attributes were chosen by the CRIA team as best representing overall habitat condition relative to salmonid utilization: Off-channel habitat; Floodplain connectivity; Riparian condition; Spawning suitability; Rearing suitability; and Passage conditions.

A four step scale of poor, fair, good, and excellent (scores 1, 2, 3, and 4, respectively) was developed to score each component. Scoring criteria for each attribute are detailed below. Definitions remain the same throughout the evaluation process.

Floodplain Zone

1. Off Channel Habitat (OCHs)

Off-channel habitats provide important flood and winter refuge for fish as well as spawning habitat for some salmon species. OCH's are considered as side channels or backwaters (including floodplain sloughs, oxbows, ponds, and wetlands).

1=Poor - Reach has few or no (<10% of reach length) OCHs.

2=Fair - Reach has OCHs that are present within 10-50% of the reach, including both side channels and backwaters.

3=Good - Reach has OCHs are present within 50-80% of reach length, including both side channels and backwaters.

4=Excellent - Reach is virtually undisturbed (near-pristine), such that OCHs (including both side channels and backwaters) are present in over 80% of reach length.

2. Floodplain Connectivity

Floodplain connectivity addresses the relative condition of native flora, streambank erosion, stream crossings, and roads. These are visible signs of the relative value of wetland function in preserving water quality, temperature, and cover for rearing and migrating salmonids.

1=Poor - Reach has a severe reduction in hydrologic surface water connectivity and wetland function via loss of overbank (channel-forming) flows, such that riparian vegetation is altered significantly (<25% natural vegetation within the riparian corridor) . Greater than 50% of floodplain surface water connectivity is lost due to incision/channelization, roads, trails, powerlines, dikes, bank armoring, etc., such that streambank erosional damage is extensive (>50%), stream crossings (by roads, trails, powerlines, etc.) greatly exceed 3 per stream mile, and road density is high (>3 mi/mi2 of watershed area).
2=Fair - Reach has a moderate reduction in hydrologic surface water connectivity and wetland function via loss of overbank (channel-forming) flows, such that riparian vegetation is altered significantly (25-50% natural vegetation within the riparian corridor). Up to 50% of floodplain surface water connectivity is lost, such that streambank erosional damage is moderate (20-50%), stream crossings exceed 3 per stream mile, and road density is moderately high (2-3 mi/mi2 of watershed area).
3=Good - Reach has a moderately low reduction in hydrologic surface water connectivity and wetland function via loss of overbank (channel-forming) flows, such that riparian vegetation is altered to some extent (50-85% natural vegetation within the riparian corridor). Up to 20% of floodplain surface water connectivity is lost, such that streambank erosional damage is moderately low (10-20%), stream crossings are below 3 per stream mile, and road density is moderately low (1-2 mi/mi2 of watershed area).
4=Excellent - Reach is virtually undisturbed (near-pristine), such that hydrologic surface water connectivity and wetland function are excellent and riparian vegetation is virtually unaltered (>85% natural vegetation within the riparian corridor). There is little or no loss of floodplain surface water connectivity, such that streambank shows minor (<10%) erosion damage and stream crossings (<<3 per stream mile), and road density (<1 mi/mi2 of watershed area) are both low.

3. Riparian Condition

Riparian vegetation provides shade, cover (including large wood that later provides channel complexity), and food-sources to salmonids, all of which are needed for adequate spawning and rearing. The right kind of vegetation can shield streams from adjacent land use impacts.
1=Poor - Reach has a severe reduction in riparian condition (<70% intactness of native-growth forms), by being fragmented (poor connectivity) and with little woody vegetation, thus providing inadequate habitat (shade, refugia, and wood- and food-source) protection (buffering of land-use impacts) for sensitive aquatic species.
2=Fair - Reach has a moderate reduction of riparian condition, with moderately low woody vegetation, intactness of native-growth forms (70-80%), and thus habitat protection for sensitive aquatic species.
3= Good - Reach has a moderately low reduction of riparian condition, with moderately high woody vegetation, intactness of native-growth forms (>80%), and thus habitat protection for sensitive aquatic species.
4=Excellent - Reach is virtually undisturbed (near-pristine), such that the riparian corridor has a good mix of taller (including woody) and shorter vegetation, i.e., obvious growth-form diversity and high intactness of native-growth forms (>>80%).

Aquatic Zone

4. Spawning Suitability

Spawning salmonids need good hyporheic flow (mixing of shallow groundwater and surface water) free of fine sediments that can smother eggs. Substrates having large rocks and/or a high degree of fine sediment are poor for salmonid spawning.

1=Poor - Reach has a major reduction in suitable salmonid and riffle-invertebrate (salmonid-food) substrata, because lotic-reach embeddedness (% sandy/muddy fines) and/or large-rock composition (LRC) greatly exceeds 30%. Reach is lacking in hyporheic flow, and thus salmonid spawning and zoobenthic rearing. Fast-water (riffle/run) habitats show embeddedness levels of 50% or more.
2=Fair - A moderate portion of the reach is suitable for salmonid spawning because reach embeddedness and LRC are both moderately high (<30% each) and fast-water habitats show embeddedness levels of 15-50%.
3= Good – A majority of the reach is suitable for salmonid spawning because reach embeddedness and LRC are both moderately low (<20% each) and fast-water habitats show embeddedness levels of 5-15%.
4=Excellent - Reach is is virtually undisturbed (near-pristine), with reach embeddedness and LRC both low (<<20% each), such that gravel recruitment and substratum conditions are optimal for salmonid spawning and riffle- zoobenthic rearing. Fastwater habitats show embeddedness levels under 5%.

5. Rearing Suitability

High mesohabitat diversity (i.e. various morphological stream habitats such as a pool, riffle, pool tail-out, or glides/runs) and moderate cover levels (e.g., large-woody debris) are important components for salmonid rearing because they provide food and refuge for juvenile fish. Stream reaches having swift flow and few pools do not provide enough sanctuary or feeding sites.
1=Poor - A majority of the reach is unsuitable for salmonid and pool zoobenthic rearing, for which aquatic cover (consisting of woody debris, undercut banks, boulders, overhanging vegetation, etc.) is low (<2%) or causes major choking (>>25%). Large-woody debris (LWD) is low (<<80 vs. <<20 pieces/mi on the West- vs. East-side, respectively). Few (<<3) mesohabitat types are evident here, and the reach is dominated by swiftly-moving water.
2=Fair - A moderate portion of the reach length is suitable for salmonid and pool-zoobenthic rearing, for which aquatic cover is moderately low (2-5%) or causes moderate choking (>25%). LWD is moderately low (<80 vs. <20 pieces/mi on the West- vs. East-side, respectively). Few (<3) mesohabitat types are evident here, and the reach is somewhat dominated by swiftly moving water.
3= Good - A majority of the reach is suitable for salmonid and pool-zoobenthic rearing, for which aquatic cover is moderate (5-10%) or with moderately low choking (<25%). LWD is moderately high (>80 vs. >20 pieces/mi on the West- vs. East-side, respectively). Several (>3) mesohabitat types should be important
here, notably a good mix of pools and riffles, with less dominance of swiftly moving water.
4=Excellent - Reach is virtually undisturbed (near-pristine), with moderately high (10-25%) levels of vegetative and other aquatic cover for fishes and pool zoobenthos. LWD is high (>>80 vs. >>20 pieces/mi on the West- vs. East-side, respectively). Several (>>3) mesohabitat types are evident here, notably a good mix of pools and riffles, without dominance by swiftly moving water.

6. Passage Conditions

Passage conditions can be affected by barriers (both natural and artificial) and presence of shallow or long riffles that inhibit fish distribution. Some barriers only become impassable at lower flow levels, while others are impassable only at high flows. Some stream reaches without visible barriers can inhibit adult fish movement when flows are too low, either because the water level is too low for swimming through dewatered riffles, or because there is not enough flow attracting fish to move upstream to their spawning grounds. The ability to freely move up and/or downstream is critical for anadromous salmonids returning to spawn or migrating to the ocean, but is also important for resident salmonids in order to find food, refuge, and avoid predation.

1=Poor - Numerous (> 3) artificial barriers and/or critical riffles exist within the reach that impede up- and/or downstream salmonid migrations at a broad range of flows (i.e., including one or more complete barriers for all fishes). Much money and time will be needed in repairs or project completion for salmonid passage.
2=Fair - A few (2-3) artificial barriers and/or critical riffles exist that reduce up- and/or downstream salmonid migrations at low (late summer/early fall) flows (i.e., no complete barriers). Minimal amounts of time and money will be needed for repairs or project completion.
3= Good - Minor impediments to salmonid passage exist, as artificial barriers have passage structures that allow adequate up- and/or downstream salmonid migrations at all but perhaps extremely low (‗drought') flows.
4=Excellent - Reach lacks impediments to upstream and/or downstream salmonid migrations (i.e., no partial or complete barriers).

Appendix 3. Scoring Flow Condition for the Columbia River Instream Atlas (Teresa L. Scott, 9-23-2016).

In 2011, the Columbia River Instream Atlas (CRIA) evaluated eight fish-critical basins for flow "condition" as the third element in the three-dimensional Columbia River Instream Atlas product. Those basins were WRIAs 32 (Walla Walla); 35 (Middle Snake); 37, 38, and 39 (Yakima/Naches); 45 (Wenatchee); 48 (Methow); and 49 (Okanogan). Those scores were grouped with "Fish" and "Habitat" scores to provide a CRIA score representing the intersection of all three elements.

The key questions driving initial development of CRIA included the following:

> "Where are what fish, and when?"
>
> "What is the habitat like for fish in these reaches?" and
>
> "How do changes in water resource management (at the reach scale) affect these fish?"

Because we live in Washington, a state with a robust trust water program that can be used to protect instream flows, the following questions are also relevant as we develop the CRIA products:

> *"Where should I spend my last water acquisition dollar in the CRIA basins?*
>
> *"Where can I add water to benefit the most fish during the most life stages?"*
>
> *"Where can I add water to create the largest percent increase in reach flow?"*

So, knowing where to protect existing stream flows, and understanding where additional water can benefit fish most are the two main objectives for this product. Scoring flow condition for each CRIA reach can contribute key information to those decisions.

Overall, flow condition would seem to be the most objective and data-rich element to score. There is a fair amount of flow gauge data and a large database of information about surface water diversions from which to glean key scoring metrics. However, only about 32 percent of the reaches evaluated for CRIA have gauge data of any sort. And though Ecology is continually improving the quality and relevance of its surface water diversions information, precise linkages between water use (surface diversions and groundwater withdrawals) and stream flow condition remain elusive. With the available data, we have attempted to score reaches on five key metrics:

1. How much flow?
2. When is flow highest?
3. When are flows low, and for how long?
4. Are water right diversions limiting flows?
5. How vulnerable are flows to future climate change-related impairment?

Several approaches were tested and datasets reviewed before finalizing the flow scoring approach for CRIA. Flow data collected from stream flow gauges were loaded and summarized. In reaches lacking gauge data, estimates of flow based on catchment area and accumulated hydrologic effects from the NHDPlus[2] hydrography were generated using the downstream termini for each of the CRIA reaches. Information was also collected from Ecology regarding permitted water diversions/withdrawals in each reach. Water temperature impairment under climate change was examined for potential use in determining future vulnerability of stream flows. Datasets predicting streamflows under future climate scenarios were also investigated as a potential vulnerability metric. All of these data components were viewed from several angles to develop the scoring mechanism that seems to yield the best results in context with the other scored elements (Habitat and Fish) and planned applications of the CRIA product, and with the time available.

The 2011 CRIA product mentioned several planned improvements in scoring for the next forecast round. Persisting data limitations mean that flow condition scoring metrics developed in 2016 have not varied significantly from the 2011 CRIA, nor have the results changed dramatically for reaches evaluated for the 2011 product. Improvements were achieved through better access to the full complement of Ecology historic gauge data; use of data from a broader suite of U.S. Geographic Survey (USGS) and U.S. Bureau of Reclamation (Reclamation) streamflow gauges (including some that are no longer active); and the availability of mean monthly flows generated for all CRIA reaches from NHDPlus. Especially, the availability of monthly means from NHDPlus provide a better means to determine whether spotty gauge data or NHDPlus would be the better source for scoring flow condition for a particular reach, and monthly means could be incorporated into more than one scoring metric.

Also, during the interim between 2011 and 2016, climate modelers have developed and evaluated flow and water temperature impairment at a finer scale than the original regional-scale results. More literature is available postulating the effects of climate change to stream inhabitants, and more insights have been gained about the distribution of impairments. This has been very helpful when screening potential datasets for scoring the 2016 CRIA.

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[2] U.S. Environmental Protection Agency, 2006. National Hydrography Dataset Plus (NHDPlus) . USEAP Office of Water, Washington, D.C. NHDPlus Home Page: http://www.horizon-systems.com/nhdplus/

Reaches

The 2011 CRIA analyzed a total of 189 reaches in 8 basins. For 2016, four basins were added (one with two subbasins): 29A (Wind), 29B (White Salmon), 30 (Klickitat), 46 (Entiat), and 50 (Foster). We also redefined some 2011 reaches and added reaches for the 2016 project. This brings the count of CRIA 2016 stream reaches to 316. (See Table 1 for the number of reaches per WRIA.)

Gauge Data

We collected and compiled data for 113 gauges; forty-one from USGS, fourteen from Reclamation, and fifty-eight from Ecology. We later replaced twelve of the Ecology gauges with NHDPlus-generated data. Non-gauged reaches for which NHDPlus-Generated data were used) number 215. (Table 1).

Table 1 Number of reaches by WRIA, by gauge owner, subtotals, and proportion of reaches that are non-gauged

WRIA	Total Reaches	ECY Gauges Used	Reclam-ation	USGS	Gauged Reaches	Non-gauged (Used NHDPlus)	Ppn non-gauged	ECY Gauges Not Used
29	45	4		1	5	40	0.89	3
30	46	1		3	4	42	0.91	
32	36	12		4	16	20	0.56	3
35	32	10		3	13	19	0.59	
37	11		2	6	8	3	0.27	
38	9	2	5		7	2	0.22	1
39	36	4	7	2	13	23	0.64	1
45	30	6		5	11	19	0.63	1
46	7	1		2	3	4	0.57	1
48	35			9	9	26	0.74	
49	25	6		6	12	13	0.52	2
50	4					4	1.00	
Total	316	46	14	41	101	215	0.68	12

Table 2 provides a summary of gauges used for each CRIA reach, and the year-range from which the daily or monthly mean is calculated.

Table 2 Summary of Information for Streamflow Gauges used for CRIA

Gauge Owner	WRIA	CRIA_ID	Site_No	Gauge_Name	Start Year	End Yar	Number of Records
ECY	29	2904	29C100	Wind R at Stabler	6/2008	6/2016	2,835
ECY	29	2908	29G060	Panther Ck nr Carson	6/2008	9/2012	1,516
ECY	29	2909	29F050	Bear Ck at mouth	6/2008	9/2012	1,543
ECY	29	2911	29J060	Trout Ck at Stabler	6/2008	9/2012	131
ECY	29	2912	29K060	Martha Ck at Stabler	6/2008	9/2012	89
ECY	29	2916	29A070	Rock Ck at Stevenson	6/2008	9/2013	1,931
ECY	29	2921	29L050	Ltl. White Salmon R at mouth	6/2008	9/2012	94
USGS	29	2926	14123500	White Salmon R Nr Underwood	1916	2015	366
USGS	30	3001	14113000	Klickitat R Nr Pitt	1909	2015	366
USGS	30	3002	14111400	Klickitat R Bl Summit Ck Nr Glenwood	1997	2015	366
USGS	30	3003	14107000	Klickitat R Abv West Fork Nr Glenwood	1945	2015	366
ECY	30	3014	30C070	Little Klickitat R nr Wahkiacus	6/2000	6/2016	3,852
USGS	32	3201	14018500	Walla Walla R Nr Touchet	1952	2015	366
ECY	32	3202	32A100	Walla Walla R at E. Detour Rd	1/2007	6/2016	319,662
ECY	32	3203	32A105	Walla Walla R at Beet Rd	6/2002	6/2016	4,996
ECY	32	3205	32B075	Touchet R at Cummins Rd	6/2002	6/2016	4,874
ECY	32	3206	32B100	Touchet R at Bolles	a		3,576
ECY	32	3207	32B110	Touchet R at County Line	6/2002	9/2009	2,607
ECY	32	3208	32G060	Coppei Ck nr mouth	12/2002	4/2012	3,276
ECY	32	3210	32L070	S.F. Touchet R abv Dayton	2/2003	9/2009	294
ECY	32	3211	32E050	N.F. Touchet R abv Dayton	12/2002	6/2016	4,795

Gauge Owner	WRIA	CRIA_ID	Site_No	Gauge_Name	Start Year	End Yar	Number of records
ECY	32	3212	32E150	N.F. Touchet R abv Jim Ck	12/2002	9/2009	2,742
ECY	32	3215	32F150	Dry Ck at Hwy 125	12/2002	9/2009	2,453
ECY	32	3218	32C070	Mill Ck at Swegle Rd	5/2003	9/2009	258
USGS	32	3219	14015000	Mill Ck @ Walla Walla	1941	2015	366
USGS	32	3220	14013000	Mill Ck Nr Walla Walla	1914	2015	366
USGS	32	3224	14013500	Blue Ck Nr Walla Walla	1940	1970	366
ECY	32	3225	32H090	East Prong Little Walla Walla at Stateline Rd	1/2003	9/2010	356
ECY	32	3228	32D060	Yellowhawk Ck nr mouth	[b]		367
ECY	32	3229	32M100	Cottonwood Ck at Hood Rd	[c]		175
ECY	32	3235	32K070	Wolf Fork Touchet R at Mountain Home Pk	2/2003	9/2009	297
USGS	35	3502	13334300	Snake R Nr Anatone	1958	2015	366
USGS	35	3503	13344500	Tucannon R Nr Starbuck	1915	2015	366
ECY	35	3504	35B150	Tucannon R nr Marengo	6/2003	6/2016	4,709
ECY	35	3506	35F050	Pataha Ck nr mouth	6/2003	6/2016	4,638
ECY	35	3507	35F100	Pataha Ck nr Pataha	6/2003	6/2010	228
USGS	35	3508	13335050	Asotin Ck @ Asotin	1991	2015	366
ECY	35	3509	35D100	Asotin Ck abv George Ck	2/2005	6/2016	4,022
ECY	35	3512	35L050	Almota Ck at mouth	6/2003	7/2010	2,554
ECY	35	3513	35K050	Alpowa Ck at mouth	6/2003	6/2016	4,693
ECY	35	3515	35M060	Deadman Ck nr mouth	6/2003	7/2010	2,470
ECY	35	3518	35J050	Tenmile Ck at mouth	5/2003	9/2013	[d]
ECY	35	3520	35H050	Couse Ck at mouth	5/2003	9/2013	[e]
ECY	35	3525	35G060	Joseph Ck nr mouth	5/2003	9/2012	3,309

Gauge Owner	WRIA	CRIA_ID	Site_No	Gauge_Name	Start Year	End Yar	Number of Records
USGS	37	3701	12510500	Yakima R @ Kiona	1934	2015	366
USBR	37	3702	YRPW	Prosser	1981	2015	12
USGS	37	3703	12508990	Yakima R @ Mabton	1971	2015	366
USBR	37	3704	PARW	Parker	1981	2015	12
USGS	37	3705	12500450	Yakima R Abv Ahtanum Ck @ Union Gap	1967	2015	366
USGS	37	3707	12506000	Toppenish Ck Nr Fort Simcoe	1909	2015	366
USGS	37	3709	12502500	Ahtanum Ck @ Union Gap	1961	2015	366
USGS	37	3710	12500500	NF Ahtanum Ck Nr Tampico	1910	1978	366
USBR	38	3801	NRYW	Naches	1981	2015	12
USBR	38	3802	CLFW	Cliffdell (Naches)	1981	2015	12
ECY	38	3803	38G070	Cowiche Ck at Powerhouse Rd	f		93
ECY	38	3804	38H050	S.F. Cowiche Ck at mouth	g		31
USBR	38	3805	TICW	Tieton	1981	2015	12
ECY	38	3806	38C070	RattlesnakeCk Nr Nile	6/2004	11/2004	Na
USBR	38	3808	LNRW	Little Naches	1981	2015	12
USBR	38	3809	BUM	Bumping	1981	2015	12
USBR	39	3901	RBDW	Roza	1981	2015	12
USGS	39	3902	12484500	Yakima R @ Umtanum	1934	2015	366
USBR	39	3903	YUMW	Cle Elum	1981	2015	12
USBR	39	3904	EASW	Easton	1981	2015	12
USBR	39	3905	KEE	Martin	1981	2015	12
ECY	39	3906	39F050	Wenas Ck	4/1999	12/1999	Na
USBR	39	3909	CHRW	Cherry	1981	2015	12

Gauge Owner	WRIA	CRIA_ID	Site_No	Gauge_Name	Start Year	End Yar	Number of Records
USGS	39	3913	12483800	Naneum Ck Nr Ellensburg	1957	1977	366
ECY	39	3920	39J090	Manastash Ck at Manastash Rd	4/2005	9/2009	1,328
ECY	39	3922	39P080	Taneum Ck at Brain Ranch	4/2005	6/2016	2,575
ECY	39	3923	39M100	Swauk Ck at Lauderdale Junction	2/2005	2/2009	1,395
USBR	39	3926	TNAW	Teanaway Forks	1981	2015	12
USBR	39	3928	CLE	Yakima at Cle Elum	1981	2015	12
ECY	39	3929	39Q060	Big Ck nr mouth	2/2005	2/2009	1,422
USGS	45	4501	12462500	Wenatchee R @ Monitor	1963	2015	366
USGS	45	4502	12459000	Wenatchee R @ Peshastin	1929	2015	366
USGS	45	4503	12457000	Wenatchee R @ Plain	1912	2015	366
ECY	45	4504	45E070	Mission Ck nr Cashmere	h		4,150
ECY	45	4505	45D070	Brender Ck nr Cashmere	j		268
ECY	45	4506	45F070	Peshastin Ck at Green Bridge Rd	9/2002	6/2016	4,637
ECY	45	4509	45C060	Chumstick Ck nr mouth	7/2003	6/2016	3,956
ECY	45	4510	45Q060	Eagle Ck nr mouth	10/2002	9/2009	33
ECY	45	4513	45G060	Chiwaukum Ck nr mouth	5/2002	10/2011	2,899
USGS	45	4517	12456500	Chiwawa R Nr Plain	1911	2015	366
ECY	45	4518	45B070	Icicle Ck nr Leavenworth	5/2007	6/2016	1,859
USGS	45	4522	12458000	Icicle Ck Abv Snow Ck Nr Leavenworth	1937	2015	366
USGS	46	4601	12452990	Entiat R Nr Entiat	1996	2015	366
ECY	46	4603	46W004	Entiat at Cottonwood	11/2015	6/2016	k
ECY	46	4604	46B060	Roaring Ck nr mouth	8/2002	6/2016	4,489
USGS	46	4605	12452890	Mad R @ Ardenvoir	2002	2015	366

Gauge Owner	WRIA	CRIA_ID	Site_No	Gauge_Name	Start Year	End Yar	Number of records
USGS	48	4801	12449950	Methow R Nr Pateros	1959	2015	366
USGS	48	4802	12449500	Methow R @ Twisp	1919	2015	366
USGS	48	4803	12448500	Methow R @ Winthrop	1922	2015	366
USGS	48	4815	12449710	Beaver Ck Nr Mouth Nr Twisp	2001	2001	366
USGS	48	4816	12449600	Beaver Ck Blw SF Nr Twisp	1960	1978	366
USGS	48	4820	12448998	Twisp R Nr Twisp	1975	2015	366
USGS	48	4826	12448000	Chewuch R @ Winthrop	1992	2015	366
USGS	48	4830	12447387	Wolf Ck Blw Diversion Nr Winthrop	2001	2003	366
USGS	48	4835	12447382	Early Winters Ck Nr Mazama	2001	2003	366
USGS	49	4901	12447200	Okanogan R @ Malott	1966	2015	366
USGS	49	4902	12445000	Okanogan R Nr Tonasket	1929	2015	366
USGS	49	4903	12439500	Okanogan R @ Oroville	1943	2015	366
ECY	49	4904	49H080	Tonasket Ck nr Oroville	6/2002	9/2010	63
ECY	49	4905	49F070	Bonaparte Ck at Tonasket	6/2002	2/2016	4,061
USGS	49	4907	12438900	Ninemile Ck Nr Oroville	2006	2015	366
ECY	49	4909	49C100	Omak Ck nr St. Mary's Mission	6/2002	9/2012	3,215
ECY	49	4912	49G060	Antoine Ck nr mouth	6/2002	9/2010	96
ECY	49	4915	49E080	Tunk Ck nr Riverside	6/2002	9/2012	3,485
USGS	49	4921	12444100	Whitestone Ck Nr Tonasket	1959	1972	366
ECY	49	4923	49B070	Similkameen R at Oroville	10/1996	9/2012	3,346
USGS	49	4924	12442500	Similkameen R Nr Nighthawk	1929	2015	366
ECY	49	4925	49K090	Toats Coulee Ck nr Loomis	6/2002	9/2010	1,902
ECY	49	4926	49L100	Sinlahekin Ck nr Loomis	6/2002	9/2010	2,469

[a] Sep-Nov 2002, Jan 2007 - Jun 2016

GAUGE OWNER	WRIA	CRIA_ID	SITE_NO	GAUGE_NAME	START YEAR	END YAR	NUMBER OF RECORDS
b	Sep 2003 - Nov 2003, May 2004 - Nov 2004, Jun 2005 - Nov 2005						
c	Sep 2003 - Nov 2003, Jun 2004 - Nov 2004						
d	2003-2009 = 208; 2010-2013 = 75,040						
e	2003-2009 = 222; 2010-2013 = 72,940						
f	Nov 2004 - Feb 2007, Jun 2010 - Oct 2010						
g	Aug 2003 - Nov 2003, May 2004 - Nov 2004, May 2005 - Jan 2006						
h	10/1996 - 9/2000, 6/2002 - 6/2016						
j	Oct 1996 - Sep 2000, Sep 2002 - Sep 2009						
k	Stage only (Used NHDPlus)						

Federal Gauge Data

USGS data came to WDFW already summarized to daily means for a year (366 daily records per gauge)[3]. All years in the USGS period of record were used for CRIA analysis, and every currently-active USGS gauge has a robust number of years of data. The oldest year in the period of record for USGS is 1909, and we collected flow data through mid-2016. We also conducted some data mining to obtain data for stream reaches having historic USGS gauges with shorter periods of record. The maximum number of years in the period of record for USGS was 96, and most reaches had ten or more years of data; the minimum was 1 year. After data were parsed into Excel spreadsheet columns, minimal editing was needed in order to summarize for the CRIA analysis. We accepted all USGS data as the best available information for the CRIA analysis.

Reclamation data came to WDFW summarized to monthly mean flows[4]. Reclamation data represent the 1981-2010 thirty-year base period and are summarized to monthly means (12 monthly data points per gauge). These also represent the best available information.

3 Many thanks to Marijke van Heeswijk for her assistance, and the link to the USGS Statistics Web Service beta URL generation tool at http://waterservices.usgs.gov/rest/Statistics-Service-Test-Tool.html . Documentation for this beta tool is available at the above link. All data except Yakima Basin gauges were downloaded 6/23/2016; Yakima data were downloaded on 8/29/2016.

4 Reclamation data for fourteen Yakima Basin gauges were compiled and provided by Joel Hubble of Reclamation on August 30, 2016.

Ecology Gauge Data

Downloading and compiling Ecology streamflow monitoring data and compiling it into a usable format was the most time-intensive step in the CRIA flow analysis[5]. Ecology operates gauges in mainstems and in smaller stream reaches as “control points” for measuring achievement of instream flow rule targets, and to meet other research or compliance objectives. In comparison to the federal gauges, most Ecology gauges are “new,” implemented mostly within the last decade, and have short periods of record. A lot of Ecology gauges were established for short-term research and have since been discontinued. Data from all of Ecology’s gauges are helpful to determine CRIA scores, but some ECY data are not usable for scoring because of short periods of record or large data gaps.

Because Ecology flow gauge data are diverse, we set flexible data standards for reviewing Ecology gauge data. We strove not to use gauges with less than 3 years of daily mean flow data covering at least the months from March through November. The minimum number of records to “qualify” for CRIA use under the three-year guideline is 1,098 (366 days per year, including leap day, times three years). Out of the fifty-eight Ecology gauges, nineteen had fewer than the requisite records or season coverage (Table 3). Three of these had no flow data, or the data provided were judged inadequate by Ecology. For four reaches, NHDPlus-generated flows were determined to be more appropriate for analysis than the Ecology gauge information. Of the remaining eleven gauges, further determinations were made regarding the efficacy of Ecology data versus the NHDPlus alternative. For example, even though data for reach 4505 do not meet the minimum qualifications for use in CRIA, these few records were determined to better depict flows in this reach than the NHDPlus-generated alternative. Table 3 shows the nineteen irregular gauges and the determinations made on their use for CRIA.

Table 3 Gauged stream reaches evaluated for irregularity and their dispositions

Reach	Gauge ID	Gauge Name	Number of Records	Disposition & Remarks
2911	29J060	Trout Ck at Stabler	131	Use NHDPlus; too few ECY records; Feb, Dec truncated in ECY
2912	29K060	Martha Ck at Stabler	89	Use NHDPlus; too few ECY records; Feb truncated in ECY
2921	29L050	Ltl. White Salmon R at mouth	94	Use NHDPlus; too few ECY records jump all over the place
3210	32L070	S.F. Touchet R abv Dayton	294	Use ECY as for 3225, 3235. No reason to not use the ECY data.

[5] Many thanks to Jeff Marti and Casey Clishe of Ecology for their assistance in accessing, downloading, and converting the Ecology flow gauge information!

Reach	Gauge ID	Gauge Name	Number of Records	Disposition & Remarks
3218	32C070	Mill Ck at Swegle Rd	258	Use NHDPlus. Few ECY records but NHDPlus provides a good fit.
3225	32H090	East Prong Little Walla Walla at Stateline Rd	356	Use ECY. NHDPlus hovers at zero; ECY has more than minimal data that make sense given the location.
3228	32D060	Yellowhawk Ck nr mouth	367	Use NHDPlus; ECY is missing Dec-April
3229	32M100	Cottonwood Ck at Hood Rd	175	Use NHDPlus; ECY data only 2 years with 7 months missing.
3235	32K070	Wolf Fork Touchet R at Mountain Home Pk	297	Use ECY. NHDPlus is lots higher, has same shape, ECY has as many records as reach 3225, so for consistency, go with ECY.
3507	35F100	Pataha Ck nr Pataha	228	Use ECY as for 3225, 3235, 3210. No reason to not use the ECY data.
3803	38G070	Cowiche Ck at Powerhouse Rd	93	Use ECY; avg of gauges for 3803 and 3804 (38G&38H). NHDPlus significantly higher flows than actually occur.
3804	38H050	S.F. Cowiche Ck at mouth	31	
3806	38C070	RattlesnakeCk Nr Nile	0	Use NHDPlus; Mostly "no data" in the ECY data file.
3906	39F050	Wenas Ck	0	Use NHDPlusPlus; Only 2 years of ECY data.
4505	45D070	Brender Ck nr Cashmere	268	Use ECY; These few ECY records better depict flows in this reach than the NHDPlus estimated alternative.

Reach	Gauge ID	Gauge Name	Number of Records	Disposition & Remarks
4510	45Q060	Eagle Ck nr mouth	33	Use NHDPlus. Too few ECY records. NHDPlus is significantly higher, but same curve and actually has data points for Sep-Oct (missing in ECY).
4603	46W004	Entiat at Cottonwood	0	Use NHDPlus; ECY data are stage only
4904	49H080	Tonasket Ck nr Oroville	63	Use NHDPlus; ECY data missing Sep-Nov, Jan all yrs.
4912	49G060	Antoine Ck nr mouth	96	Use NHDPlus; ECY too few days.

NHDPlus

In reaches lacking gauge data, or for which gauge data were insufficient, estimates of flow based on catchment and cumulative hydrologic effects were generated from the NHDPlus dataset (coded as "NHD" in the "Source" column of the flow scoring table). We used the flow estimates generated at the lower boundary for each CRIA reach. Although NHDPlus-generated flows sometimes overstated the "normal" flow for reaches, the general magnitudes and, more importantly, the patterns of runoff make sense when considered with adjacent gauge data. In the end, there are five reaches for which even NHDPlus-generated flows are not available. These remain coded as "NHD" in the "Source" column of the flow scoring table, but show as "No data" or "#na" in the data fields. In 2016 scoring, missing data do not automatically result in the lowest score (refer to rubrics), whereas, in 2011 the many reaches with missing data were automatically scored and binned with the worst possible score to reflect the high level of uncertainty.

Flow data review and screening

Data for each gauge were reviewed as follows:

- Did the data values transfer into CRIA spreadsheets as numbers and not text?
- Are there any unexplained outliers (this often occurred when the flow values were missing for a given date/day, or when quality codes downloaded into the flow data column)?
- Were dates standardized (some month values were recorded as text, some as numbers; Excel sees these differently);
- Do the data make sense vis-à-vis the location of the gauge?

Data for the group of gauges within a WRIA, along with the NHDPlus-generated flows for the non-gauged reaches, were reviewed as follows:

- Do magnitudes of flow make sense given the gauge location within the basin?

  In some cases, the magnitudes of NHDPlus-generated flows for small tributaries were off. This also helped us spot other potential data issues. By itself, this was not a reason to reject NHDPlus data, but might have affected flow scoring for some reaches.

- Do hydrographs make sense in the context of the basin?

  Sometimes NHDPlus-generated flow values were used in spite of a magnitude problem because overall they adequately represented that reach in context with its ecosystem and WRIA.

Addressing lessons from 2011

In 2011, the CRIA team was attempting to identify stream reaches with the highest flow impairment. In 2016, we approached the problem from a more positive perspective and cast a broader net to develop metrics for each of the basic hydrologic attributes: magnitude, timing, frequency, duration, and rate of change. Mean monthly flows and minimum monthly flows were examined for 2011; in 2016 we again evaluated both mean and minimum flow metrics. Ultimately we used only mean monthly and mean annual flows for CRIA 2016 scoring. Scoring emphasis for 2016 also incorporated examination of the shape of each reach's hydrograph in a primitive attempt to classify reaches into types. CRIA 2011 used a flow volume metric to adjust score for other attributes; CRIA 2016 still discounts reaches having high flow volumes, but not as directly as in 2011.

Symbology:

In 2011, we tooled scoring metrics to use high scores to indicate high flow impairment, which was the inverse of the approach taken for Habitat and Fish elements. A change to a consistent interpretation was made for 2011 products, but the symbology for flow metrics on CRIA maps - a wide line depicted low flow - was confusing for developers and users alike. So, having developed the 2011 scoring metrics with "impairment" in mind, we wanted the 2016 version to represent good flow condition using higher score numbers. Interestingly, this down-side-up change did not manifest in dramatically different scores in 2016.

Metrics:

In 2011, we used both daily means and minimums for scoring reaches. While minimums were collected and evaluated for the 2016 effort, only the means are used for 2016 scoring.

Missing Flow Data:

In 2011, NHDPlus only generated estimates for the mean annual flow; the CRIA team developed a method to downscale the mean to an estimated August flow so both mean and August could be used at metrics for 2011 scoring. In 2016, we were able to extract mean monthly flows (12 monthly means) for each location from the NHDPlus data. As noted in Table 1, a total of 215 reaches (68%) are without gauge data. Twelve of those reaches actually have Ecology gauge information, but those data are insufficient for this analysis. This leaves 203 reaches with no data source for flow. By using the NHDPlus-generated estimates, we were able to reduce the number of data-free reaches down to five of the total of 318 reaches, or about 2%. This represents a significant improvement in data availability since the 2011 CRIA version.

Superficial examinations of the adequacy of the 2016 NHDPlus-generated estimates were made, but we did not complete an exhaustive analysis comparing gauged and NHDPlus-generated results. In general, NHDPlus-generated data tend to overestimate the quantity of flow that would be expected in the non-gauged reaches they represent. However, overall tendency and hydrograph remain consistent in context with other reaches in the same WRIA, and/or similar reaches elsewhere.

Periods of Record:

In 2011, choosing the most recent 30-year periods for USGS gauges was extremely time intensive. Gaps in the USGS historical record remain (early 1970s and most of the 1980s are completely missing for most USGS gauges), however for the 2016 exercise there was insufficient time to find only the most recent 30-year periods for each USGS gauge. A decision was made to use all years in the period of record for all USGS gauges for the 2016 analysis.

Most Ecology gauges have relatively short periods of record, primarily within the last decade. We examined data for each gauge, as outlined above, in order to determine which Ecology gauges had sufficient data for CRIA use. We requested a base period of 1981-2010 for the data we received from Reclamation.

Flow targets:

The 2011 CRIA employed flow targets as a scoring metric, and used instream flows set in administrative rule as those targets for scoring. This severely limited the number of reaches that were scored using the "flow target" metric in 2011 (Table 4). Scores are missing for this metric for 91% of 2011 reaches, which could have biased those results.

Table 4 Number of Reaches scored for flow targets in 2011 CRIA

WRIA Number	Reaches scored for flow target	Total reaches
32	4	35
35	0	29
37, 38, 39	0	50
45	5	17
48	5	35
49	4	26

In 2016, the CRIA team determined that instream flow rules or other targets did not provide enough insight into current or future risk of flow impairment in comparison to the low number of reaches benefitting from that scoring metric. Therefore, no scoring metric was devised in 2016 to measure achievement of instream flow rules.

Yakima Basin prioritization scoring:

After the 2011 product was made available, it was determined that the CRIA scores did not add value to the body of knowledge for the Yakima Basin. This is primarily because descriptions of limiting factors for each reach had already been developed and, in many cases, actions to remedy those limiting factors were already planned and prioritized. Also, flows within Yakima mainstem reaches, and many tributaries, are regulated by Reclamation at quantities determined using a federal decisionmaking process. This is a mixed blessing in the Yakima: Federal flow control means that there are both more opportunities to manage flows for fish (by manipulating stored water) and fewer opportunities (because of irrigation delivery obligations). Those decisions are independent from state agency decisionmaking processes, so there is no audience for the CRIA blended score in the Yakima. For 2016, the CRIA team presents the fish, habitat, and most flow condition metrics, but do not combine them to provide priority scores for the Yakima Basin. Because of this, some detailed analyses, such as compilation of water right information, were not conducted for the Yakima Basin.

Water Rights:

In 2011, the CRIA team summed the quantified water rights data (diversion flows) as one scoring metric and employed the number of water right "claims" in each reach as a metric indicating risk that diversions are actually greater than the values gleaned from the water rights data. Ecology has warned that water rights diversion values from the Water Rights Tracking System (WRTS) potentially do not accurately reflect the actual water use. Many team members liked the concept of scoring number of claims as a way to capture risk, but the flow scoring lead was very uncomfortable with this metric. In 2016, the CRIA team agreed not to use a count of the number of claims per CRIA reach, instead hoping that Ecology had made improvements to the flow values within the WRTS data.

Unfortunately, although many data records have been edited and updated, overall the WRTS data are still insufficiently reflective of actual diversions. Because of this, the CRIA team thinks it would be unwise to place heavy reliance on these data for 2016 CRIA scoring. We also placed more emphasis in 2016 on screening WRTS records for use. More details about processing the WRTS data are provided below.

Flow Scoring

Introduction

2011 starting point

In 2011, four separate scoring metrics were used.

Component A (% of months with flow less than the flow target) was helpful for scoring because it captures the true management risk associated with underachievement of instream flow rules. Reaches having mean monthly flow below the flow target for nine months or more annually scored worst. Unfortunately, so few reaches have instream flow targets set in rule that this component is impractical for CRIA scoring, especially with the expanded WRIA coverage.

Component B (withdrawals as a percentage of mean annual flow) might logically be the only scoring element used – if total volume of withdrawals was known with certainty for every reach. For CRIA 2011, withdrawals over 15% of total flow were deemed worst. We are using a similar metric in 2016.

Component C referred to the count of water right claims for a particular stream reach. As mentioned above, this metric represents the level of risk that actual withdrawals are greater than depicted in the WRTS database. This metric being a very indirect measure of risk of over-appropriation, the CRIA team decided not to use it in 2016.

Component D (August flows as a percentage of mean annual flow) provided a means to determine whether the reduction in summer flow is severe: August flows more than 66% below average were considered worst in 2011. We use a similar metric in 2016.

Flow Volume factor E was computed using mean annual flows, either directly from gauge data or estimated using the NHDPlus method. The thinking for this factor was that any of the already scored elements are less likely to be a problem in a high-flow reach than in a low-flow reach. We multiplied a bad score by three, for example, for a reach having less than 5 cfs, and halved the score for reaches of 1000 cfs or more. Although we used a flow volume metric in 2016, it was not used as a factor to adjust the other scores.

Results for each analysis were converted to a score using the rubrics as presented in the 2011 report, and results symbolized on 2011 CRIA maps.

2016 flow scoring approach

Flow scoring for CRIA 2016 started with a review of the literature relating to stream reach prioritization for flow restoration. The 2015 drought in Washington provided a classic preview of conditions predicted to occur more regularly later in the twenty-first century. This changed our perspective on flow restoration from a “restore the worst reaches” emphasis to one more considering of future predicted flows and hydrographs. Also, recent scientific literature includes development of concepts and methods for evaluating stream segments. The CRIA team became more thoughtful about stream types (hydrographs, ecosystems), limiting factors (temperature, flow diversions), levels of vulnerability for each of those types (predicted climate effects), and how to provide thoughtful scoring metrics to contribute to decisions about the types of management actions that should be directed at those vulnerabilities.

Considered but not used

One metric we considered to help score vulnerability is water temperature. Water temperature turned out to be our Achilles Heel during the 2015 drought response - state biologists were caught off-guard by the rapid increases in water temperature and consequent environmental effects - so we are sensitized to the way this element can directly impact fish when stream flows are low. Also, water temperature predictions have been the subject of climate modeling, and 2040 and 2080 projections of stream temperature are now available as geo-referenced information[6] at a fine enough scale for use in the CRIA analysis. In the end, we did not have the time needed to adequately understand those modeling results and adapt them for CRIA use. So although this will be a fruitful factor to investigate for future CRIA analyses, the difficulty matching up geographic references led us to drop this line of inquiry for 2016.

Frequency is an important hydrologic attribute not adequately measured using the CRIA 2016 scoring approach. We would need to determine flow levels comprising "drought" (or "flood") conditions for each reach, then measure how often those conditions were reached during the period of record. Another approach would be to examine frequency of curtailment of junior water right holders in order to meet instream flow rules. For the CRIA basins (other than the Yakima and Walla Walla), this frequency matches the frequency that "drought" is declared, which is about 10-to-15 years for CRIA basins. The limitations of such an analysis include the possibility that instream flow rules are not good indicators for low-flow impacts and that drought frequency is likely to increase at an unknown rate. For CRIA 2016, the assumption is that low flows will be an issue more often for almost every reach being scored, so the work to find an adequate metric would not be justified in providing further clarity to reach scoring.

Climate streamflow modeling predictions[7] were examined to determine whether predicted flows or stream temperature changes over time could be used as a measure of risk of low flow impacts. We encountered the same inability to match up geographic scales for this analysis, however, and elected not to proceed to develop this idea.

Overall, existing and future hydrologic and climate modeling work should be more deeply evaluated for their potential contributions to evaluating flow conditions.

2016 flow scoring metrics

Poff, et al. (2009)[8], Reidy Liermann et al. (2011), and many others have identified key variables necessary for analyses of hydrologic classification. Stream segments can be distinguished by measuring

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the frequency, duration, magnitude, timing, and rate of change of streamflows, and that information, in turn, can help us understand vulnerabilities and potential flow management strategies. With an eye toward these key attributes, metrics (Table 4) and scoring components (Table 5) were identified for each stream reach. For CRIA, we are examining low flows and not flood flows, though both are important to determining fish value.

Table 5 CRIA 2016 flow scoring metrics and why they are important

METRIC	WHAT IT MEANS	REMARKS
Mean monthly flow	Mean of the daily flow values for each month in each year of the period of record. (Daily values are themselves averaged from the 15-minute values recorded at the gauge)	Foundation for scoring
"Mean annual flow"	The average of the mean monthly flows	Gives a frame of reference for "flow volume class"
Maximum of mean monthly flow	Maximum of the mean monthly flows	Tells us when the hydrograph peaks
Minimum of mean monthly flow	Minimum of the mean monthly flows.	Gives us an idea how bad flow can be, on average.
MAX month and MIN month	The months in which the max and min values occurred	Helps us further distinguish reaches by generalized hydrograph types (snow, rain, combo) to help us understand the risk of future impairment.
Mean August flow	(August flow value)	Intended to represent the flow during the highest diversion month. We use August as the peak month for irrigation demand

new framework for developing regional environmental flow standards. Freshwater Biology 55: 147-170. doi:10.1111/j.1365-2427.2009.02204.x.

		and August is sometimes the lowest flow month. Most Washington streams are actually lower in September or October, but this is the best we can do for 2016.
Hydrograph classification	Text code for classification after Reidy Liermann et al. 2010	Hydrographs were charted and grouped into like-shaped hydrograph sets, then assigned to a hydrograph classification.
Number of records (water rights) in the reach	From the "ECYPOD" spreadsheet	See spreadsheet documentation
Sum of diversions (Qi) for the reach	From the "ECYPOD" spreadsheet	See spreadsheet documentation

Those metrics were used alone or in combination to provide the following scoring components:

Table 6 CRIA 2016 Flow Scoring Components

ITEM	COMPONENT	HOW IT'S CALCULATED	WHAT WE THINK IT MEANS
A	Magnitude difference between mean and August (minimum) flows	August flow / mean flow	Measures distance between the mean and minimum flows. How bad are low flows in this reach?
B	Duration of flows less than the mean	Counts the number of months the mean monthly flow is below the mean annual flow.	The concept behind this score is the assumption that more months spent below the mean annual flow can indicate vulnerability or flashiness.[B]

C	Flow volume class	Scores assigned based on relative discharge.	Assumption is that reaches with lower flows are at more risk from low flows that higher-flow reaches.
D	Hydrologic vulnerability	Scores based on "shape" of hydrograph (as representation of hydrologic classification)	Hamlet et al., Reidy Liermann et al., and others have posited that climate vulnerability can be predicted based on hydrologic classification.[D]
E	Deviation in mean monthly flows	Standard Deviation of monthly mean flows / average of monthly mean flows	Helps us understand the amount of variability in flows through the year.[E]
F	Scaling the risk of human-caused low flows: Diversions in proportion to mean August flows	Sum of water right diversion quantities / mean August flow (cfs)	We assume that a high proportion of diverted flow is bad.[F]
G	Count of diversions	Count of water right records in the WRTS database for a reach	Assesses risk that high diversions impact fish.[G]
B	Finer-scale analyses (e.g., Julian day) might provide better distinction between the reaches (Reidy Liermann, et al. 2011). We are assuming for this metric that more low flow months are riskier for fish.		
D	There are many schemes for determining hydrologic classification; CRIA attempts to conflate these complex ideas and analysis results into an easily score-able scheme. Scores are based on hydrologic classifications after Reidy Liermann et al., and general understanding of vulnerability based on Elsner 2010, Littell 2014, Mantua 2010, Steward 2004, Tohver 2014, and Vano 2015. CRIA scoring was based on the assumptions that snow-driven or ultra-snow have high risk, snow and rain driven have medium high risk, rain and snow driven have medium risk, rain driven has medium low risk and groundwater or groundwater/rain mixes have low risk. Classes were assigned independently of relative volume (i.e. based on shape of hydrograph alone) so no penalty points are given for low volume. These assignments and assumptions are for this analysis only, probably don't adequately reflect the broad range of science on this topic, over-simplify the huge complexity of these problems, and may not hold up under		

	evolving science. Also note an assumption that flow estimates (on which the hydrographs are based) are independently derived, which is clearly untrue for the NHDPlus-generated values. This is the best we can do for this analysis, and hope users agree that it adds value to the scoring system.
E	In the quest to provide low scores for reaches with a lot of variation between monthly flows, we also impose an assumption that less dynamic streams are better for salmonids, which we know to be incorrect
F	High diversion volumes compared to the existing August flow (or a negative number showing more is diverted on paper than exists instream) signifies greater risk of critically-low flows impacting fish regularly. Note that potential for missed or mis-assigned diversions is high. If diversions are more than twice the August flow in WRTS, then risk is high that actual diversions are impairing August flows. This analysis doesn't need a "nice" distribution across reaches, because more than twice the existing (mean August flow) is the same as more than 20 times for this analysis.
G	We are being cautious, and possibly redundant, using our available data. Because WRTS does not necessarily provide an accurate depiction of total diversions, we assume that a larger number of records ("water rights") means that more water is diverted than we actually evaluated in the previous metric. One or the other of these metrics might be sufficient for future analyses - we're keeping both for CRIA 2016 "just to make sure" we capture the differences in diversion risk between reaches.

Every potential scoring rubric was tested to ensure that scoring results would distribute broadly (if not statistically evenly) across all CRIA reaches, ensuring that the scoring metric would be useful in distinguishing among reaches. We did not perform statistical analyses of the distributions of scores.

Scoring metrics using WRTS water rights data

In 2016, CRIA retrieved about 11,000 water rights data records from WRTS, which included all records (having geographic identification information) located in any of the CRIA basins. Records were screened based on several criteria. Records that did not represent certified or permitted water rights were excluded from further analysis, as were records for non-consumptive uses, new applications, change applications, groundwater (in spite of many GW records being locations affecting surface flows), see below

- Purpose of Use information was parsed, and then records were filtered based on this information.
    - Irrigation ("IR") and Stockwater ("ST") data were aggregated as "Ag" data. (Note, in hindsight, "Frost Protection" and "Heat Protection" also belong in this category.)
    - An "industry" category combined CI, CO, FP, FR, and EN records.

- Drinking water and municipal/domestic landscape watering includes the DC DG DM DS and MU (would also have included MI intertie records if any had existed - none were).
- All records not belonging with one or more of the above use codes were removed from the analysis.

- Records with document types including “Newapp”, “ChgApp”, and “TempDonation” were removed from the analysis.
- Duplicate records were deleted. “Duplicate” was defined as records where the Document number, document type, cfs, af, and name were identical. This removed about 1,000 records from the analysis.
- Sorted records looking for oddities. For example, a record in the name of Department of Ecology was deleted because it lacked a purpose of use and was large; we determined it was clearly a trust water right. Spent maybe an hour on this, and by no means were all aberrant records found or handled.
- Removed “B4” document IDs, all groundwater records (including certificates), and all reservoir records. About 8,800 records remained after this screen.

We assigned the remaining records to adjacent CRIA reaches using a crosswalk generated by the CRIA team translating HUC12 to CRIA reach. Some records did not match CRIA reaches. After all that was accomplished, we summed the reach-specific diversion quantity (Qi) for scoring purposes. A water rights spreadsheet shows the process and records that were used for CRIA scoring.

Flow scoring for hydrologic vulnerability

Hydrographs can help us classify stream reaches, which in turn can aid in determining relative vulnerability to flow-related changes through climate change. Elsner et al. (2010) classified Pacific Northwest watersheds into rain-dominated, transitional, and snow-dominated based on the ratio of peak snow water equivalent (SWE) to accumulated winter (October to March) P (precipitation). Vano et al. (2015) segregated months into seasons using OND=1, JFM=2, AMJ=3, JAS=4. Vano further classifies basins based on sensitivity to warm and cool season warming. Reidy Liermann et al. (2011) analyzed stream segments across Washington State to determine stream classifications based on their dominant flow source, and evaluated them for vulnerability. Reidy Liermann determined stream segments fit into one of several hydrographic classifications: Groundwater; rainfall; rain-snow; snow-rain; snowmelt; and “ultra-snowmelt” are the ones we use for CRIA. Snowmelt and ultra-snowmelt systems are dominated by a strong spring snowmelt without tails showing response to rainfall; rainfall reaches are controlled by winter rains with negligible influence of snow; transition classes (the rain and snow combinations) reflect hybrid hydrographs where both sources are important contributors and having higher frequencies and lower durations of high pulse flows than other types. Groundwater controlled reaches are characterized by relatively uniform mean monthly discharge. We classified as “Odd” the reaches that are likely groundwater-controlled, or otherwise don’t fit into the other classifications. Our determination that “Odd” reaches are low-vulnerability” is based on the “groundwater” classification.

Of the types Reidy Liermann found in eastern Washington basins, Table 7 shows distinguishing characteristics for each that were important in developing the CRIA score.

Table 7 Hydrologic classifications as used for CRIA scoring

TYPE	MONTH OF MAXIMUM FLOW	VARIABILITY
Groundwater or “Odd”	Multiple peaks	Low monthly variability
Rainfall	Peak winter flows (December, January)	High variability
Rain-snow	Often bimodal; Higher winter, another lower peak in spring	Medium variability
Snow-rain	Often bimodal; Higher spring; 2nd peak winter rainfall	Medium variability
Snowmelt	Peak spring flows	Less winter rainfall influence; higher variability
Ultra snowmelt	Later spring	Even less winter rainfall influence; highest variability

Table 8 shows the number of CRIA reaches that were classified under each hydrologic class.

Table 8 Number of CRIA Reaches by hydrologic classification

	Hydrologic Classification							
WRIA	#na	Odd	RF	RS	SD	SR	US	Total Reaches
29	2		29	4		10		45
30		2	36	5	1	2		46
32	3	1	13	3		15	1	36
35		3	16	1	2	9	1	32
37								11
38								9
39								36
45		9	1	9	5	3	3	30
46				2	3		2	7

48			1	3	17	8	6	35
49		1	3	2	9	1	9	25
50		4						4
Grand Total	**5**	**20**	**99**	**29**	**37**	**48**	**22**	**316**

Note that Yakima/Naches Basin reaches were not evaluated for this metric.

Hydrograph grouping charts are provided as an appendix to this report.

Scoring Rubrics

Table 9 provides the scoring rubrics we used to complete flow scoring for CRIA 2016. For further details, refer to the flow scoring Excel spreadsheet.

Table 9 Flow Scoring Rubrics 2016

A	Aug / Mean #na = 0 <.1 = 0 <=.25 = 1 <=.5 = 2 <=.75 = 3 >.75 = 4
B	Duration (Months) Below Mean #na = 0 >=9 = 0 >=8 = 1 >=7 = 2 >=5 = 3 <5 = 4
C	Flow Volume (cfs) #na = 0 <=1 = 0 <=10 = 1 <=50 = 2 <=100 = 3 >100 = 4
D	Hydrologic Vulnerability Ultra-Snowmelt = 0 Snowmelt = 1 Rain-snow and Snow-rain = 2 Rainfall = 3 Odd = 4

E	Deviation from Mean #na = 2 >1.5 = 0 >1 = 1 >.75 = 2 >.5 = 3 <=.5 = 4
F	Diversions ratio Qi to Aug Flow #na = 1 >2 = 0 <=2 = 1 <=1 = 2 <=.1 = 3 0 = 4
G	Count of WR Diversions #na = 2 <=2 = 4 <=10 = 3 <=40 = 2 <=100 = 1 >100 = 0

2016 Binning

Binning is done for reaches within a WRIA. Simplicity in presentation of results led us to employ three "bins" as in 2011, with one bin containing all the "best" scoring reaches, another the worst. Binning for flow scores was done based on percentiles, with the worst (most flow impaired) 33% of scores binning as "1" and the best (67^{th} percentile; least flow impaired) binning as "3."

A reach binned as "1" for flow in one watershed will not necessarily be of the same overall priority as a reach binned as "1" in another watershed; several other factors, including fish status/utilization, habitat condition, and feasibility must be considered before priorities across WRIAs can be made. Reaches binned as "1" however are the highest priority for flow restoration - based on flow condition alone – within a particular watershed.

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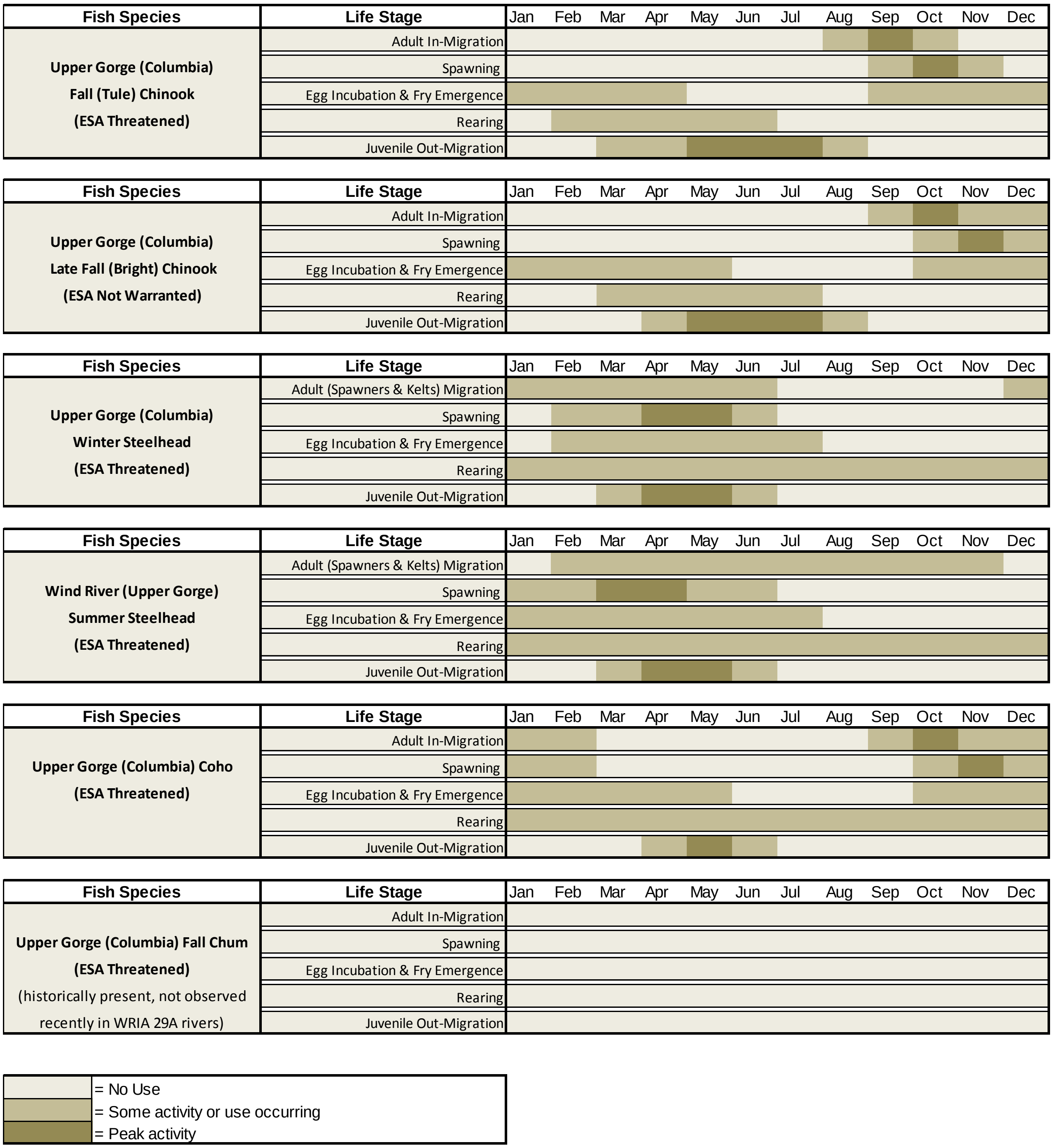
Appendix 4. Fish use timing by life history stage (Source: Anne Marshall, November 2016).

Wind R., Little White Salmon R. and Tributaries - WRIA 29A
Fish Use Timing by Species



White Salmon River and Tributaries - WRIA 29B
Fish Use Timing by Species

Fish Species	Life Stage	Jan	Feb	Mar	Apr	May	Jun	Jul	Aug	Sep	Oct	Nov	Dec
Big White Salmon River Fall (Tule) Chinook (ESA Threatened)	Adult In-Migration												
	Spawning												
	Egg Incubation & Fry Emergence												
	Rearing												
	Juvenile Out-Migration												

Fish Species	Life Stage	Jan	Feb	Mar	Apr	May	Jun	Jul	Aug	Sep	Oct	Nov	Dec
Big White Salmon River Spring Chinook (ESA Threatened)	Adult In-Migration												
	Spawning												
	Egg Incubation & Fry Emergence												
	Rearing												
	Juvenile Out-Migration												

Fish Species	Life Stage	Jan	Feb	Mar	Apr	May	Jun	Jul	Aug	Sep	Oct	Nov	Dec
Big White Salmon River Late Fall (Bright) Chinook (ESA Not Warranted)	Adult In-Migration												
	Spawning												
	Egg Incubation & Fry Emergence												
	Rearing												
	Juvenile Out-Migration												

Fish Species	Life Stage	Jan	Feb	Mar	Apr	May	Jun	Jul	Aug	Sep	Oct	Nov	Dec
Big White Salmon River Summer/Winter Steelhead (ESA Threatened)	Adult (Spawners & Kelts) Migration												
	Spawning												
	Egg Incubation & Fry Emergence												
	Rearing												
	Juvenile Out-Migration												

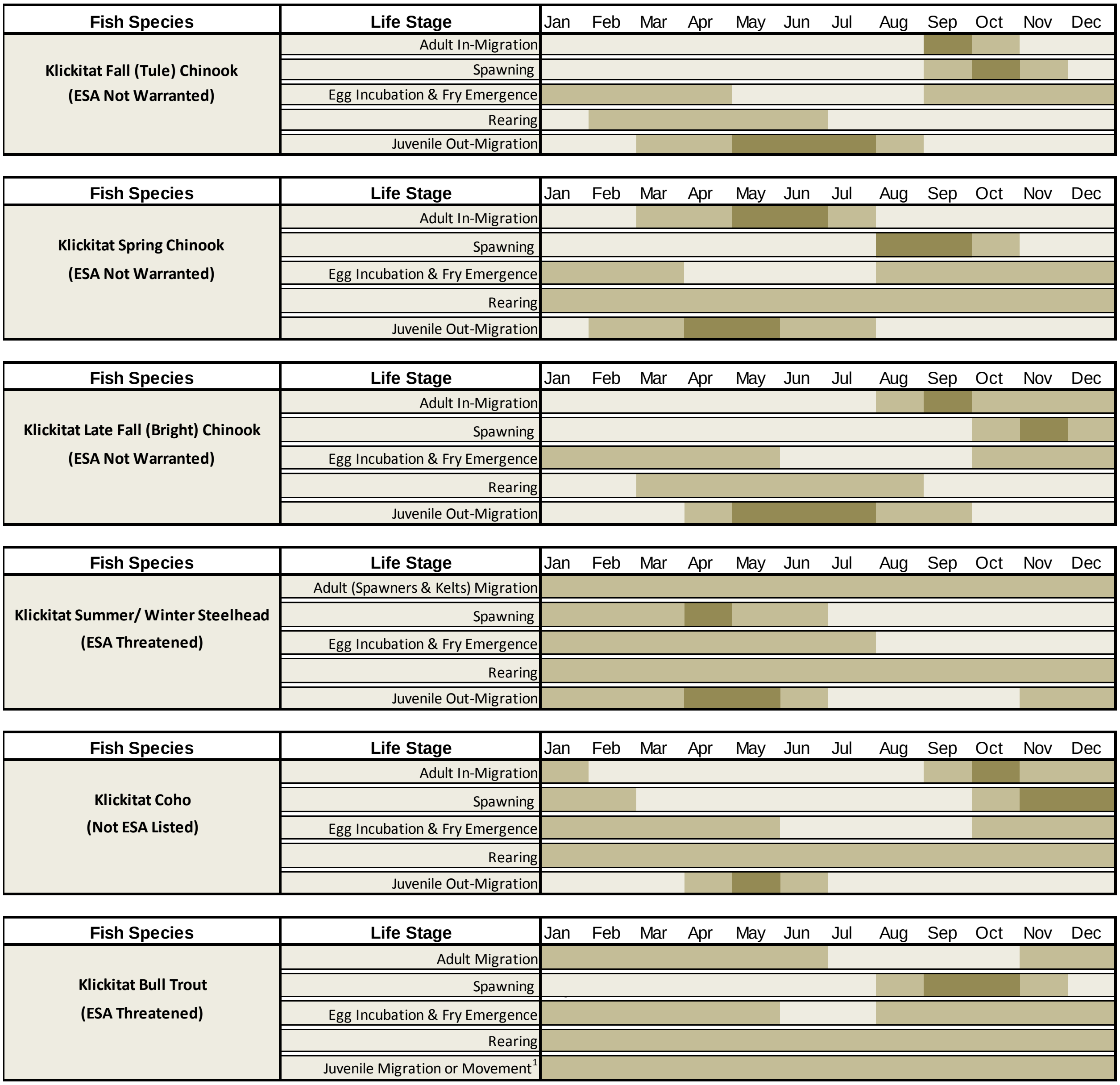
Fish Species	Life Stage	Jan	Feb	Mar	Apr	May	Jun	Jul	Aug	Sep	Oct	Nov	Dec
Upper Gorge (Columbia) Coho (ESA Threatened)	Adult In-Migration												
	Spawning												
	Egg Incubation & Fry Emergence												
	Rearing												
	Juvenile Out-Migration												

Fish Species	Life Stage	Jan	Feb	Mar	Apr	May	Jun	Jul	Aug	Sep	Oct	Nov	Dec
Upper Gorge (Columbia) Fall Chum (ESA Threatened) (spawning not yet observed)	Adult In-Migration												
	Spawning												
	Egg Incubation & Fry Emergence												
	Rearing												
	Juvenile Out-Migration												

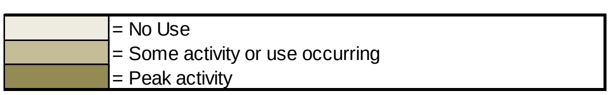
Fish Species	Life Stage	Jan	Feb	Mar	Apr	May	Jun	Jul	Aug	Sep	Oct	Nov	Dec
White Salmon River core area Bull Trout (ESA Threatened) (spawning not yet observed)	Adult Migration												
	Spawning												
	Egg Incubation & Fry Emergence												
	Rearing												
	Juvenile Migration or Movement												

	= No Use
	= Some activity or use occurring
	= Peak activity

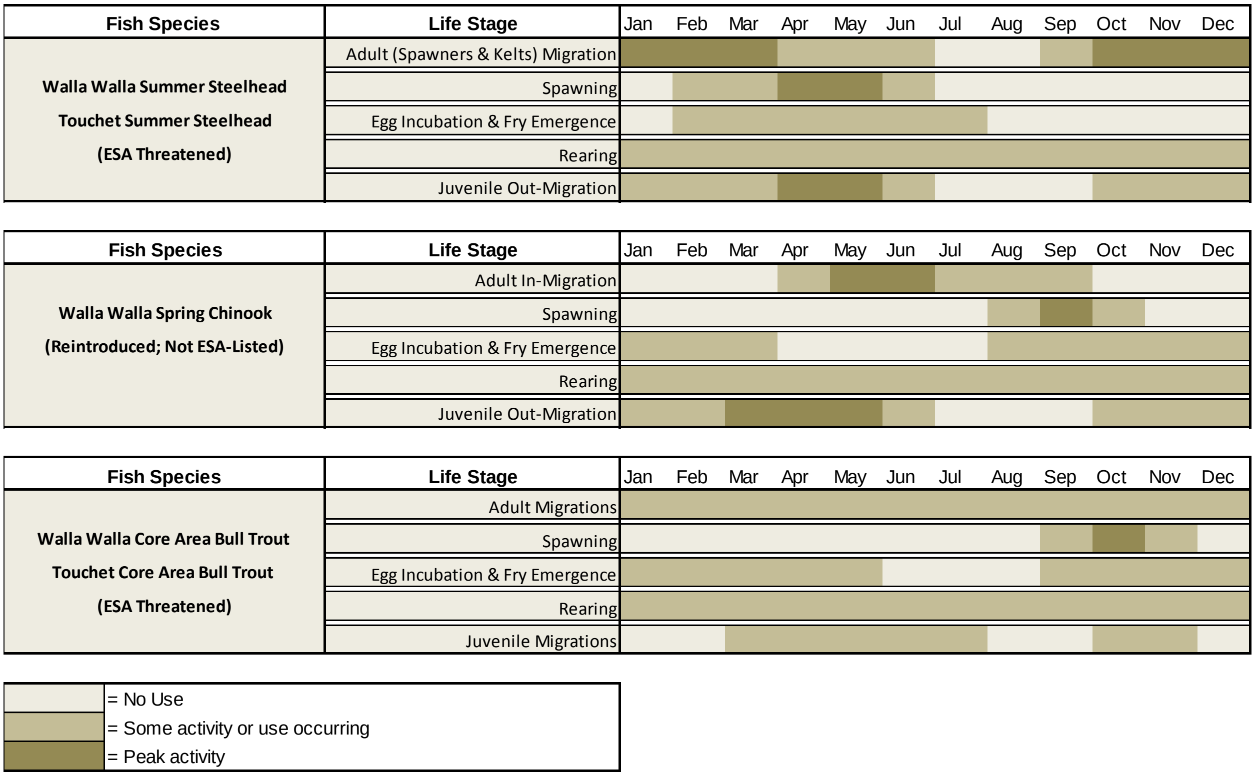
Klickitat River Basin - WRIA 30
Fish Use Timing by Species



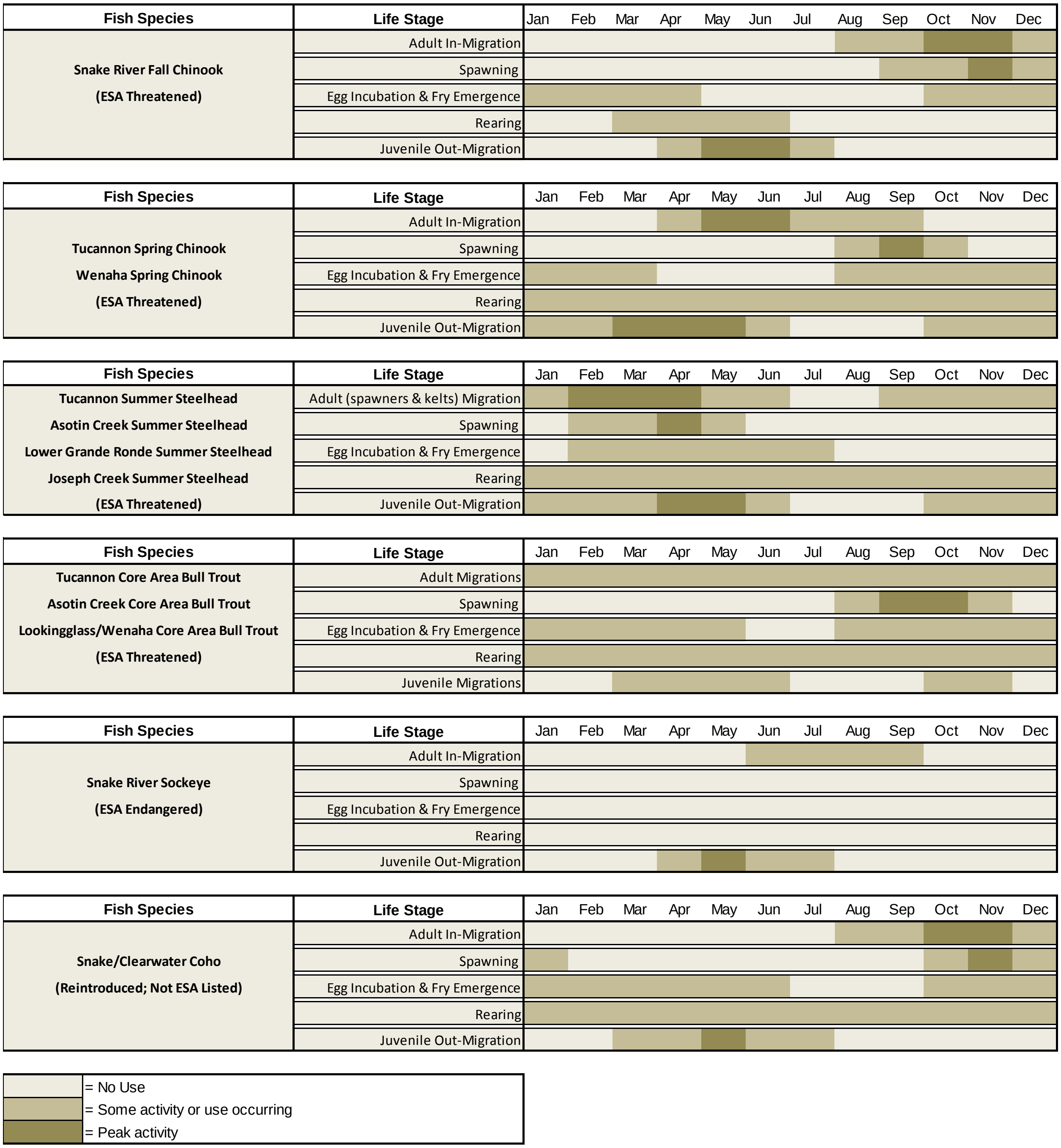
[1] Due to uncertainty about timing of juvenile (non-spawning age) bull trout movements within or among streams, all months were scored for some activity



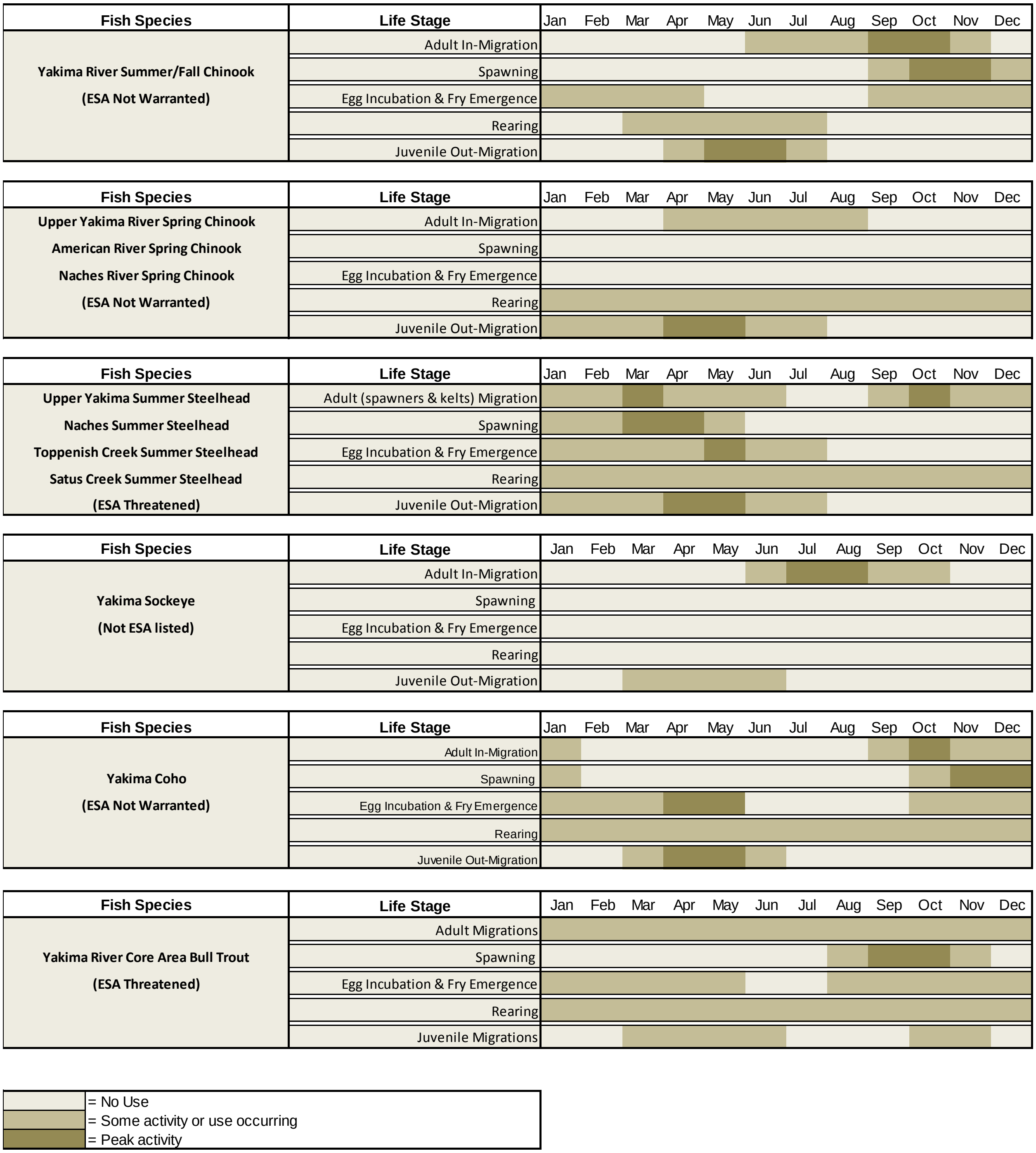
Walla Walla River Basin - WRIA 32
Fish Use Timing by Species



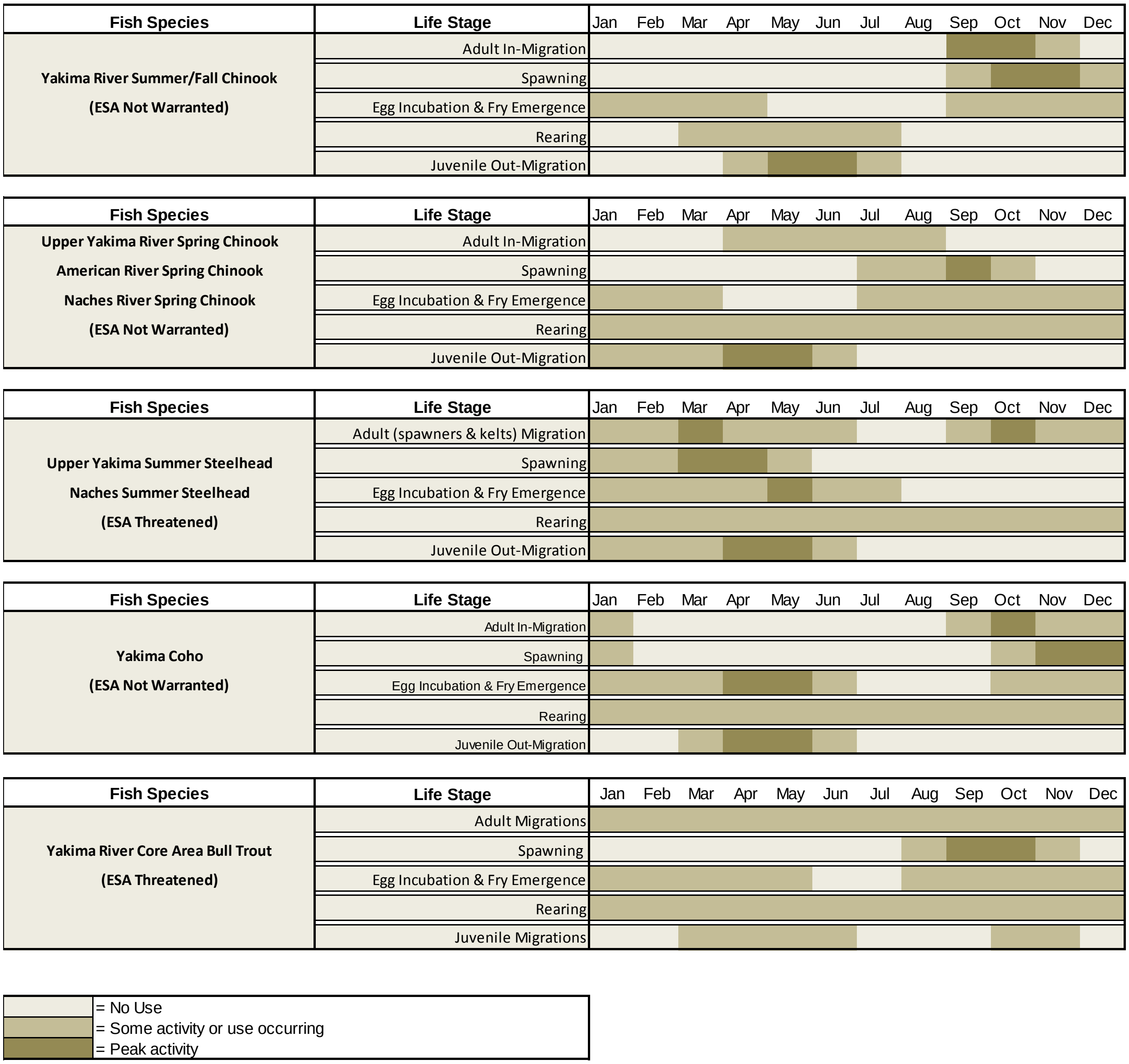
Middle Snake - WRIA 35
Fish Use Timing by Species



Lower Yakima River - WRIA 37
Fish Use Timing by Species



Naches - WRIA 38
Fish Use Timing by Species



Upper Yakima - WRIA 39
Fish Use Timing by Species

Fish Species	Life Stage	Jan	Feb	Mar	Apr	May	Jun	Jul	Aug	Sep	Oct	Nov	Dec
Yakima River Summer/Fall Chinook	Adult In-Migration												
(ESA Not Warranted)	Spawning												
	Egg Incubation & Fry Emergence												
	Rearing												
	Juvenile Out-Migration												

Fish Species	Life Stage	Jan	Feb	Mar	Apr	May	Jun	Jul	Aug	Sep	Oct	Nov	Dec
Upper Yakima River Spring Chinook	Adult In-Migration												
American River Spring Chinook	Spawning												
Naches River Spring Chinook	Egg Incubation & Fry Emergence												
(ESA Not Warranted)	Rearing												
	Juvenile Out-Migration												

Fish Species	Life Stage	Jan	Feb	Mar	Apr	May	Jun	Jul	Aug	Sep	Oct	Nov	Dec
Upper Yakima Summer Steelhead	Adult (spawners & kelts) Migration												
Naches Summer Steelhead	Spawning												
(ESA Threatened)	Egg Incubation & Fry Emergence												
	Rearing												
	Juvenile Out-Migration												

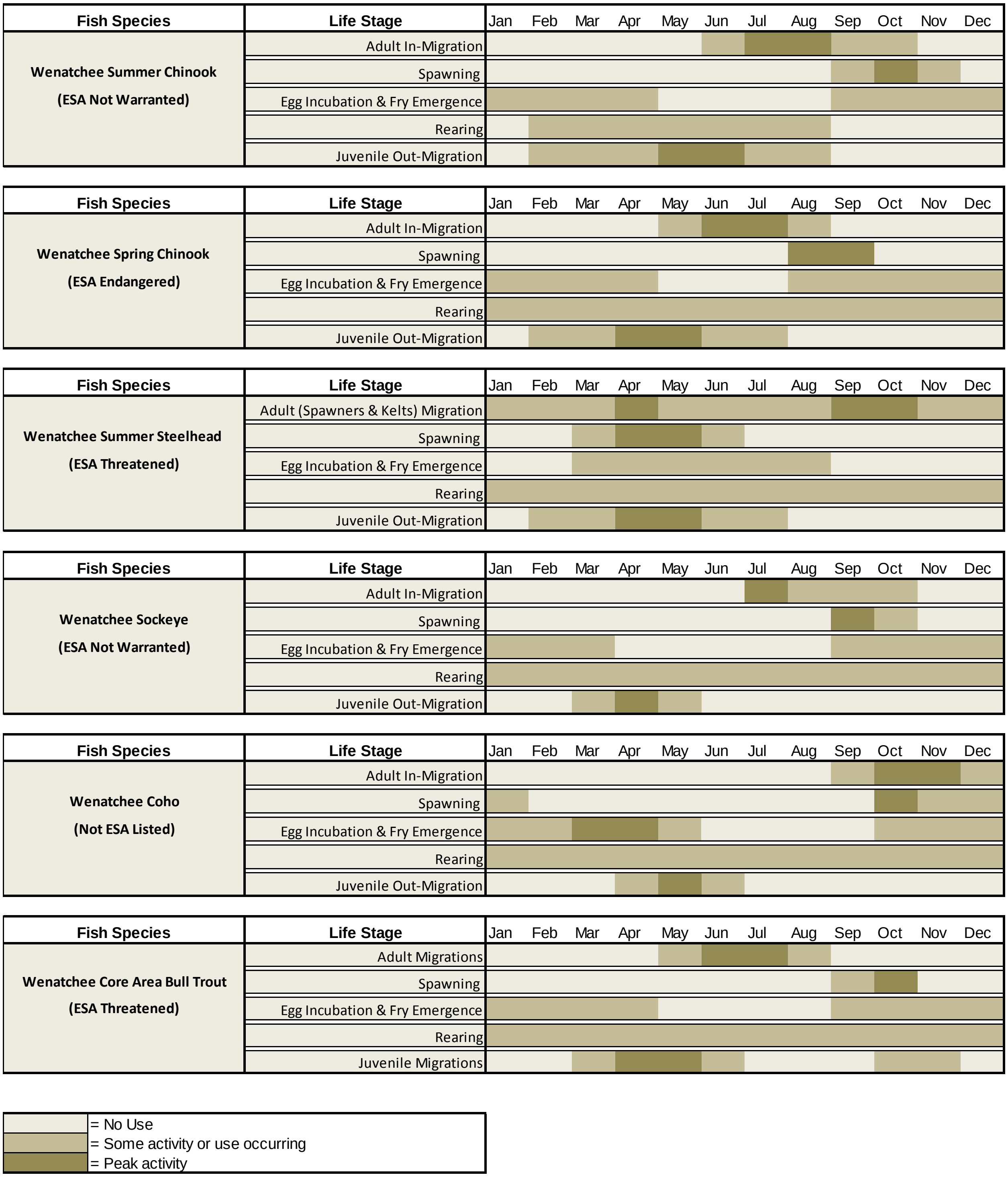
Fish Species	Life Stage	Jan	Feb	Mar	Apr	May	Jun	Jul	Aug	Sep	Oct	Nov	Dec
Yakima Sockeye	Adult In-Migration												
(Not ESA listed)	Spawning												
	Egg Incubation & Fry Emergence												
	Rearing												
	Juvenile Out-Migration												

Fish Species	Life Stage	Jan	Feb	Mar	Apr	May	Jun	Jul	Aug	Sep	Oct	Nov	Dec
Yakima Coho	Adult In-Migration												
(ESA Not Warranted)	Spawning												
	Egg Incubation & Fry Emergence												
	Rearing												
	Juvenile Out-Migration												

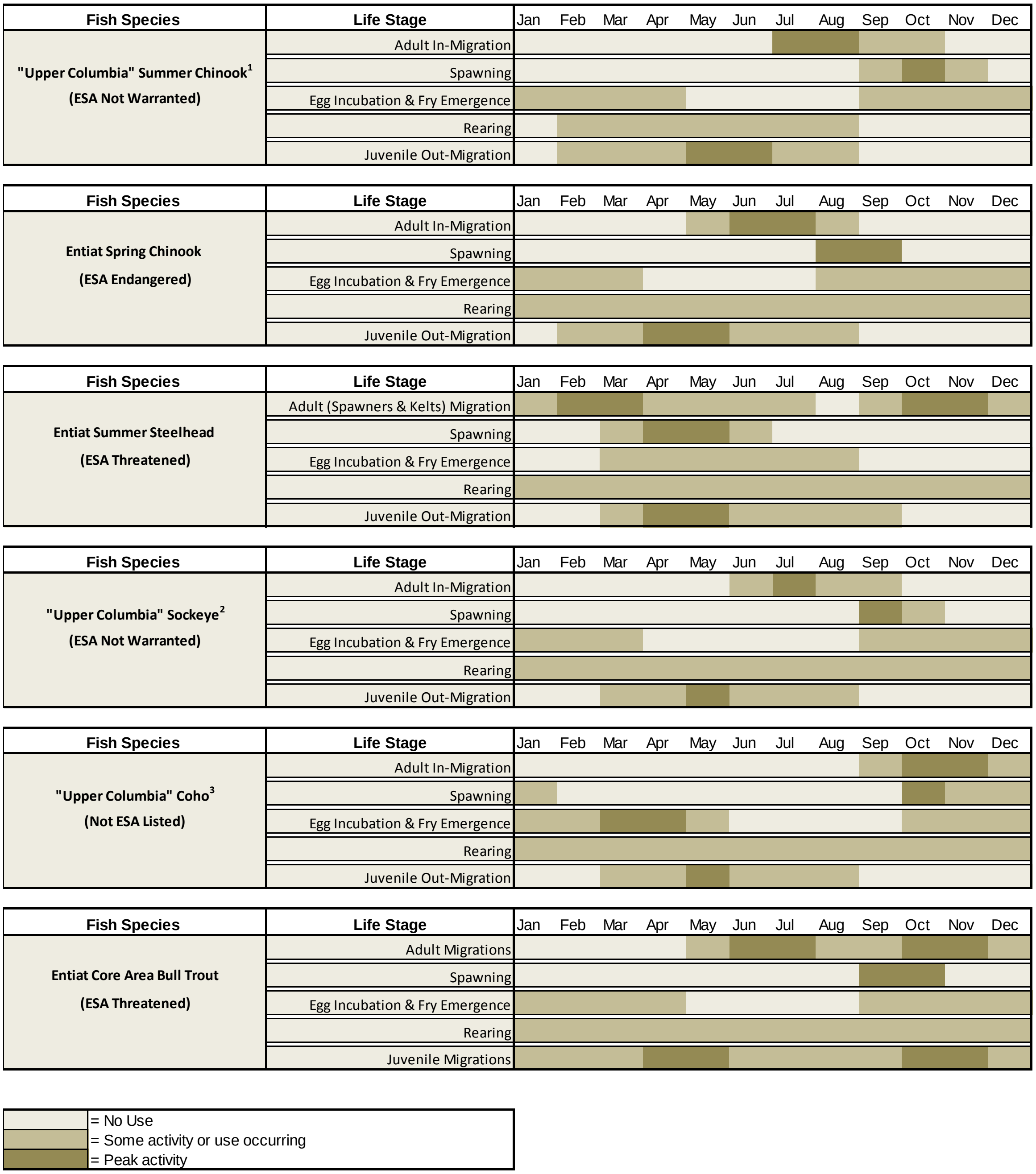
Fish Species	Life Stage	Jan	Feb	Mar	Apr	May	Jun	Jul	Aug	Sep	Oct	Nov	Dec
Yakima River Core Area Bull Trout	Adult Migrations												
(ESA Threatened)	Spawning												
	Egg Incubation & Fry Emergence												
	Rearing												
	Juvenile Migrations												

	= No Use
	= Some activity or use occurring
	= Peak activity

Wenatchee River Basin - WRIA 45
Fish Use Timing by Species



Entiat River Basin - WRIA 46
Fish Use Timing by Species

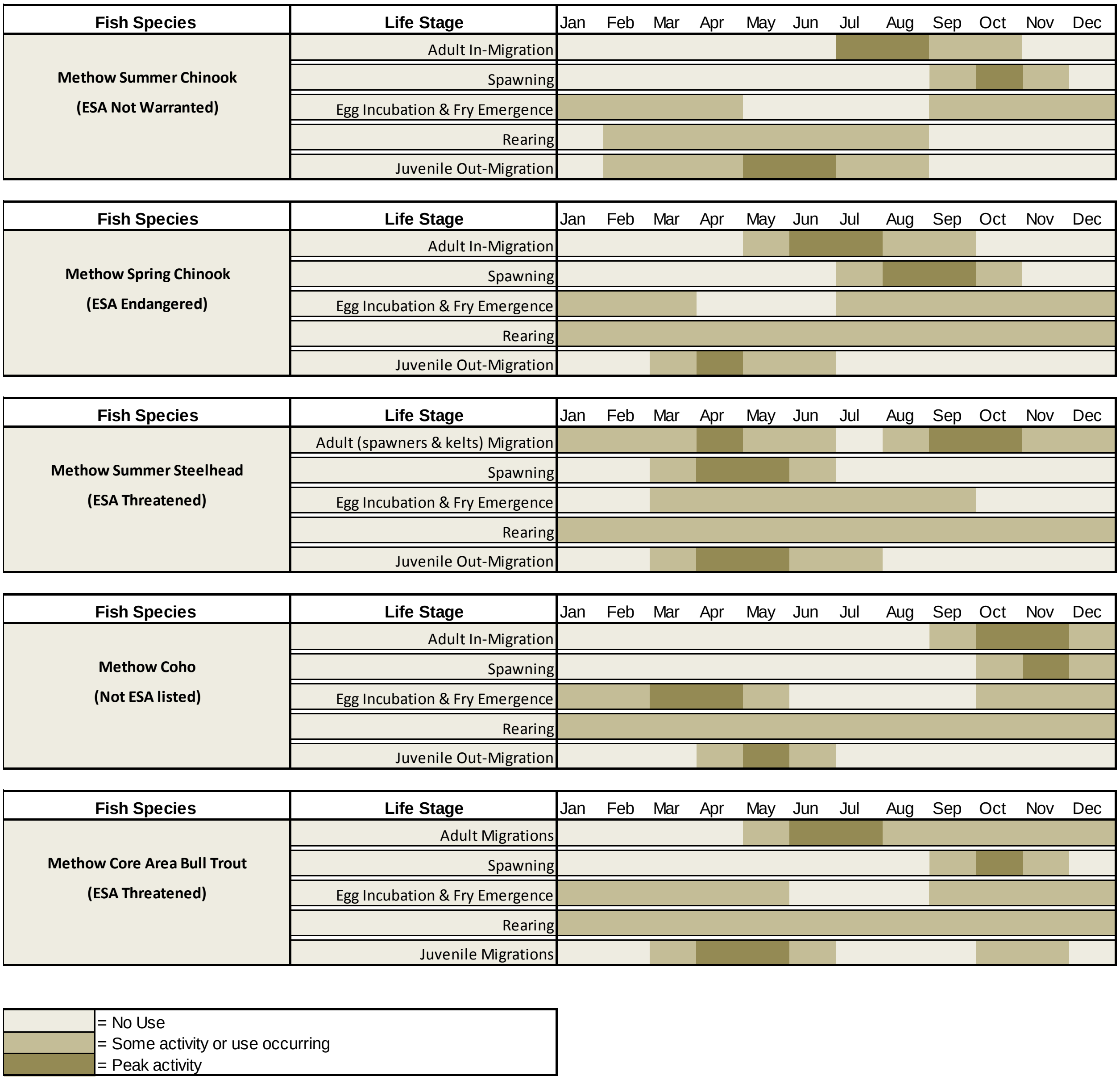


[1] A summer Chinook population in Entiat Basin has not been formally designated; existing summer Chinook are derived from upper Columbia sources.

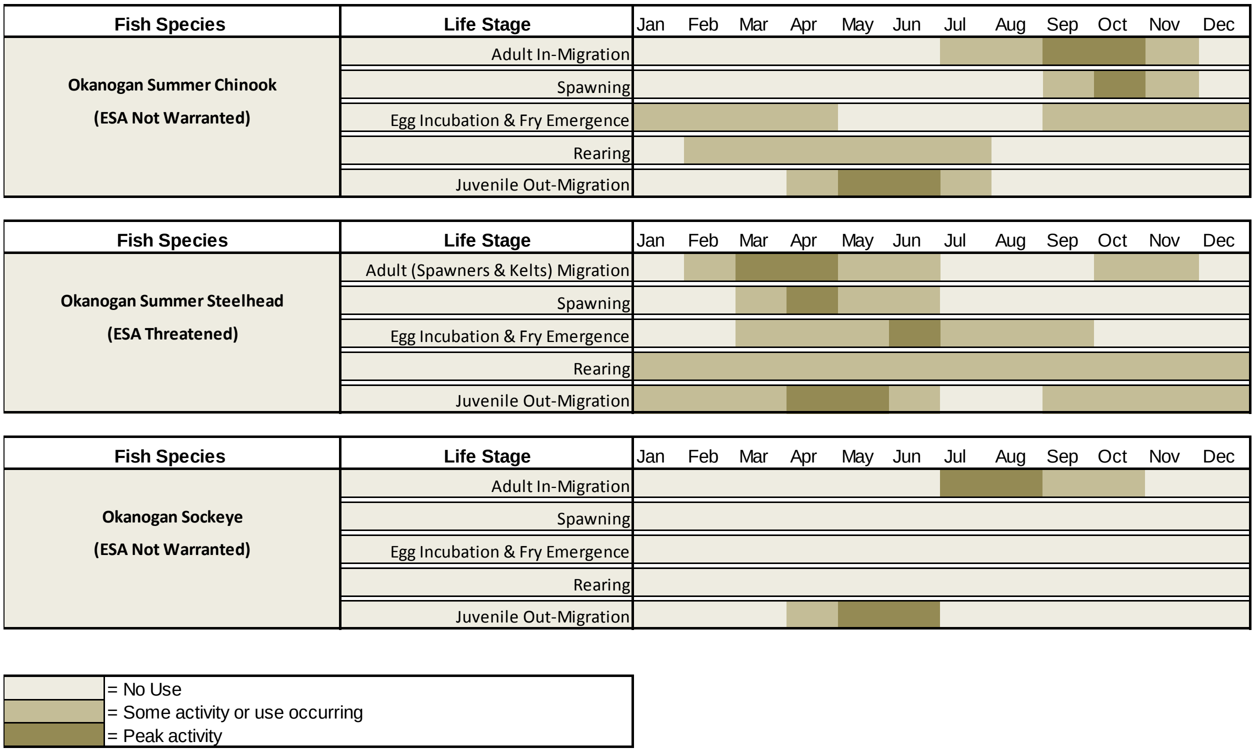
[2] A sockeye population in Entiat Basin has not been formally designated; existing sockeye likely are derived from non-ESA-listed upper Columbia sources.

[3] A coho population in Entiat Basin has not been formally designated; coho have been reintroduced into upper Columbia tributaries, and were derived from several sources.

Methow River Basin - WRIA 48
Fish Use Timing by Species



Okanogan River Basin - WRIA 49
Fish Use Timing by Species



Foster - WRIA 50
Fish Use Timing by Species

Fish Species	Life Stage	Jan	Feb	Mar	Apr	May	Jun	Jul	Aug	Sep	Oct	Nov	Dec
"Upper Columbia" Summer Chinook[1] (ESA Not Warranted)	Adult In-Migration												
	Spawning												
	Egg Incubation & Fry Emergence												
	Rearing												
	Juvenile Out-Migration												

Fish Species	Life Stage	Jan	Feb	Mar	Apr	May	Jun	Jul	Aug	Sep	Oct	Nov	Dec
"Upper Columbia" Spring Chinook[2] (ESA Endangered)	Adult In-Migration												
	Spawning												
	Egg Incubation & Fry Emergence												
	Rearing												
	Juvenile Out-Migration												

Fish Species	Life Stage	Jan	Feb	Mar	Apr	May	Jun	Jul	Aug	Sep	Oct	Nov	Dec
"Upper Columbia" Summer Steelhead[3] (ESA Threatened)	Adult (Spawners & Kelts) Migration[4]												
	Spawning												
	Egg Incubation & Fry Emergence												
	Rearing												
	Juvenile Out-Migration												

[1] Foster Creek does not have a formally designated summer Chinook population; juvenile Chinook are assumed to be progeny of summer Chinook spawning in mainstem Columbia that are derived from upper Columbia sources.

[2] Foster Creek does not have a formally designated spring Chinook population; spring Chinook juveniles (from upper Columbia sources) possibly may use Foster Creek for rearing, but this has not been conclusively documented.

[3] Foster Creek does not have a formally designated summer steelhead population; assumed that existing steelhead are derived from upper Columbia sources.

[4] This scoring indicates that steelhead adults do not enter or hold in Foster Creek during pre-spawning months, and instead overwinter in other nearby areas, such as the Columbia mainstem.

	= No Use
	= Some activity or use occurring
	= Peak activity