Prepared in cooperation with the Upper Columbia United Tribes

Risk Assessment for the Reintroduction of Anadromous Salmonids Upstream of Chief Joseph and Grand Coulee Dams, Northeastern Washington

Open-File Report 2017–1113

U.S. Department of the Interior
U.S. Geological Survey

Cover: Photograph showing Chief Joseph Dam tailrace, with Tribal fishing scaffold and fish ladder in immediate background, and Chief Joseph Dam in far background. Photograph by Casey Baldwin, Confederated Tribes of the Colville Reservation, August 15, 2015. Used with permission.

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RYAN K. ZINKE, Secretary

U.S. Geological Survey
William H. Werkheiser, Acting Director

U.S. Geological Survey, Reston, Virginia: 2017

Suggested citation:
Hardiman, J.M., Breyta, R.B., Haskell, C.A., Ostberg, C.O., Hatten, J.R., and Connolly, P.J., 2017, Risk assessment for the reintroduction of anadromous salmonids upstream of Chief Joseph and Grand Coulee Dams, northeastern Washington: U.S. Geological Survey Open-File Report 2017–1113, 87 p., https://doi.org/10.3133/ofr20171113.

ISSN 2331-1258 (online)

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Conversion Factors

U.S. customary units to International System of Units

Multiply	By	To obtain
	Length	
inch (in.)	2.54	centimeter (cm)
mile (mi)	1.609	kilometer (km)

International System of Units to U.S. customary units

Multiply	By	To obtain
	Length	
micrometer (µm)	0.000039	inch (in.)
millimeter (mm)	0.03937	inch (in.)
centimeter (cm)	0.3937	inch (in.)
kilometer (km)	0.6214	mile (mi)
	Area	
square kilometer (km^2)	0.3861	square mile (mi^2)
square kilometer (km^2)	247.1	acre
	Volume	
liter (L)	1.057	quart (qt)

Abbreviations

BKD	Bacterial Kidney Disease
BCWD	Bacterial Coldwater Disease
CJD	Chief Joseph Dam
CJH	Chief Joseph Hatchery
CTCR	Confederated Tribes of the Colville Reservation
DPS	Distinct Population Segment
ENFH	Entiat National Fish Hatchery
ESA	Endangered Species Act
ESU	Evolutionarily Significant Unit
FL	fork length
GCD	Grand Coulee Dam
GIS	geographic information system
ICTRT	Interior Columbia Technical Recovery Team
IHN	infectious hematopoietic necrosis
IHNV	infectious hematopoietic necrosis virus
IPNV	Infectious pancreatic necrosis virus
LNFH	Leavenworth National Fish Hatchery
LCR	lower Columbia River
LR	Lake Roosevelt
MCR	middle Columbia River
NFH	National Fish Hatchery
pHOS	percent hatchery-origin spawners
PNI	proportionate natural influence
rkm	river kilometer
RW	Rufus Woods
UCR	upper Columbia River
UCUT	Upper Columbia United Tribes
USGS	U.S. Geological Survey
VHSV	viral hemorrhagic septicemia virus
WDFW	Washington Department of Fish and Wildlife
WNFH	Wenatchee National Fish Hatchery
WSIV	White Sturgeon iridovirus

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Executive Summary

The Upper Columbia United Tribes (UCUT; Spokane, Colville, Kootenai, Coeur d'Alene, and Kalispel Tribes) and the Washington Department of Fish and Wildlife want to reintroduce anadromous salmon to their historical range to restore ecosystem function and lost cultural and spiritual relationships in the upper Columbia River, northeastern Washington. The UCUT contracted with the U.S. Geological Survey to assess risks to resident taxa (existing populations in the reintroduction area upstream of Chief Joseph and Grand Coulee Dams) and reintroduced salmon associated with reintroduction. We developed a risk assessment framework for reintroduction of anadromous salmonids upstream of Chief Joseph and Grand Coulee Dams. To accomplish this goal, we applied strategies identified in previous risk assessment frameworks for reintroduction. An initial list of potential donor sources for reintroduction species was developed from previous published sources for Chinook Salmon donors in the Transboundary Reach of the Columbia River, British Columbia, ecological risk assessment of upper Columbia River hatchery programs on non-target taxa of concern, and a review of existing hatchery programs.

During two workshops, we further identified and ranked potential donor sources of anadromous Redband Trout (steelhead; *Oncorhynchus mykiss*), Chinook Salmon (*O. tshawytscha*,), Sockeye Salmon (*O. nerka),* and Coho Salmon (*O. kisutch*). We also identified resident fish populations of interest and their primary habitat, location, status, and pathogen concerns to determine the potential risks of reintroduction. Species were deemed of interest based on resource management and potential interactions (that is, genetics, competition, and predation) with introduced species. We developed tables of potential donors by species and characterized potential sources (hatchery and natural origins), populations (individual runs), broodstock management and history, and potential constraints (that is, Endangered Species Act [ESA] listing, Evolutionarily Significant Unit concerns, pathogens, and availability). During the workshops, a group of regional fisheries and topic experts subjectively ranked the relative risks of pathogens, genetic effects, predation, and competition to resident fish and reintroduced salmonids. We assessed the pathogen risk of each potential donor for introducing new pathogens and the increased burden to existing pathogens for resident species upstream of the dams. We considered genetic risks to resident and downstream conspecifics and ecological impacts, including competition for food and space, predator-prey interactions, and ecosystem benefits/impacts. Each donor

source was ranked based on abundance/viability (demographic risk to source and feasibility of collection), ancestral/genetic similarity (evolutionary similarity to historical populations), local adaptation (geographic proximity/similarity of source conditions to reintroduction conditions), and life history compatibility (including migration; spawn timing; and relative usage of reservoir, main-stem, or tributary habitats) with environmental conditions in the reintroduction area. We synthesized this information by species for all potential donors, in which an overall score and ranking system was established for decision support in donor selection for reintroduction into the upper Columbia River (UCR). We also provided information outside of the ranking process by:

1. Identifying predator-prey interactions and competition for food and space among species,
2. Developing a decision support framework for donor selection, and
3. Providing decision support for reintroduction strategies.

Multiple donor sources were identified and evaluated for each species considered for reintroduction. During workshop discussions, conservation of the existing UCR Redband Trout population was deemed a high priority. Therefore, in the context of conservation goals for the native Redband Trout, this population was considered a viable donor source for reintroducing the anadromous life history and was ranked the highest among steelhead donor sources. The next highest ranking steelhead donor sources were Eastbank Hatchery (Wenatchee River run) and Wells and Winthrop Hatcheries (Methow River run). For spring Chinook Salmon reintroduction, Chief Joseph Hatchery (CJH; non-ESA listed, lower Columbia River spring Chinook Salmon) ranked highest and the Eastbank/Wenatchee River Hatchery program (ESA listed) ranked second highest. This risk assessment did not attempt to evaluate the policy decisions regarding the use of ESA-listed fish as part of the reintroduction. Evaluation of summer/fall Chinook Salmon sources also resulted in the CJH (Okanogan River summer-run Chinook Salmon) ranking highest, and the Hanford Reach upriver bright Chinook Salmon ranking second highest. In recent years, the availability of fall Chinook Salmon at Priest Rapids Hatchery likely would be higher than the abundance at CJH, which could alter the donor selection depending on the desired abundance of reintroduced fish. Flesh quality is another factor not assessed in this risk assessment but that is of interest to Tribal harvest, and may affect donor choice selection. Summer Chinook Salmon arrive earlier and have higher flesh quality in the terminal fishing areas than Hanford Reach upriver bright Chinook Salmon, and, therefore, may be more desirable to the Tribal fishery. For Sockeye Salmon reintroduction, Lake Roosevelt native kokanee ranked the highest by a slim margin over Okanogan River natural-origin Sockeye Salmon, due primarily to conservation concerns regarding the native kokanee. However, native kokanee are not available as a brood source, so a policy decision will need to be made regarding the conservation priority of kokanee compared to the desire to have Sockeye Salmon upstream of Grand Coulee Dam. For Coho Salmon, the highest ranking donor source was Leavenworth Hatchery (Wenatchee River run), and second-highest donor source was Winthrop Hatchery (Methow River run).

All pathogens of concern were detected within the resident region except infectious hematopoietic necrosis virus (IHNV), which is highly virulent in steelhead. Therefore, introduction of IHNV would pose a risk to extant Redband Trout and reintroduced steelhead. The most important risk factor of IHNV disease occurring in juvenile fish is the presence of anadromous adults in the same water body, and in conservation hatcheries the most effective control strategy is surveillance and biosecurity (for example, well water and equipment decontamination). All other pathogens of concern were detected at higher frequency in candidate donor populations than in resident populations, indicating that nearly all potential donors impose the risk of increasing pathogen burden in the resident region. It is a general phenomenon in microbial pathogenesis that the greater the number of causative microbes, the greater the chance is of developing disease (for example, dose response). The most important pathogens in this risk category were for the bacterial pathogens *Renibacterium salmoninarum*, the causative agent of Bacterial Kidney Disease, and *Flavobacterium psychcrophilum*, the causative agent of Bacterial Coldwater Disease. Pharmacological treatments are available for these conditions, and so the most effective control strategy is surveillance, biosecurity, and treatment.

During the workshops, 14 resident species of interest were identified, consisting of six native species and eight non-native species. Several non-native species were selected because they were potential predators or competitors of introduced salmonids. Workshop participants identified Redband Trout, triploid Rainbow Trout, kokanee, and Burbot (*Lota lota*) as the primary competitors of introduced salmonids. For predation, workshop participants identified Smallmouth Bass (*Micropterus dolomieu*), Walleye (*Sander vitreus)*, and Northern Pike (*Esox Lucius*) as the greatest predation risks to juvenile salmon. White Sturgeon (*Acipenser transmontanus*), Redband Trout, Burbot, and Northern Pikeminnow (*Ptychocheilus oregonensis*) also were identified as potential predators of juvenile salmon, but with a lower relative predation risk.

A conceptual design of a decision support framework for selection of a reintroduction strategy was developed for managers and decision makers to better understand the interplay between reintroduction program goals, release strategies, and donor selection. Four reintroduction strategies were evaluated: (1) natural colonization, (2) transplanting natural origin adults, (3) transplanting hatchery adults, and (4) releasing hatchery juveniles. The development of program goals was not part of this risk assessment, but will be important in selecting a reintroduction strategy. A few case studies of successful species reintroduction strategies are provided to inform this study. Additionally, examples of how the reintroduction strategy decision support process could inform release strategy selections are provided for each species, in the context of the donor ranking results and potential program goals as discussed during workshops.

For all the species that may be reintroduced, a series of potential release strategies will need to be considered by resource managers in which the potential risks and critical uncertainties are identified (for example, reservoir survival, density-dependent competition, etc.) for each reintroduction strategy and location. Other factors that are important to consider include habitat availability, species interactions, biotic resistance, density dependence, and productivity of reservoirs and tributaries. Careful planning for successful reintroduction programs can reduce many of the risks; however, some uncertainty always is involved in the implementation of a new reintroduction program. Experimental releases may be a way to reduce uncertainty about many of the reintroduction release strategies; however, potential adverse impacts and reversibility (or mitigation) of these actions need to be considered. Furthermore, monitoring of management actions to detect any unanticipated adverse impacts will be critical to an adaptive management approach.

Introduction

The construction of Grand Coulee and Chief Joseph Dams in northeastern Washington blocked the upstream migration of salmon (*Oncorhynchus spp.*) to the upper Columbia River (UCR), cut off access to more than 1,770 km (1,100 mi) of spawning habitat, and altered the natural flow regime of the river (Brennan, 1938; U.S. Columbia Basin Tribes and Canadian First Nations, 2015). Additionally, these changes resulted in the annual loss of about 3 million salmon to indigenous people of the Columbia Basin (U.S. Columbia Basin Tribes and Canadian First Nations, 2015). Substantial damming of the Columbia River occurred with the ratification of the Columbia River Treaty between the United States and Canada in 1964. Dams in the UCR were constructed to reduce flood risk and generate hydropower. In the case of Grand Coulee and Chief Joseph Dams, the U.S. government decided that fish passage was not worth the effort and expense (Brennan, 1938). Instead, the mitigation for the loss of wild fish runs was hatchery production, which lead to the 1939 Grand Coulee Fish Maintenance project that intercepted fish and distributed them to other areas of the basin up until the project ended in 1943 (Brannon and others, 2004). This was the origin of the Leavenworth, Entiat, Winthrop, and eventually the Chief Joseph Hatcheries. Impoundment also harmed the viability of downstream salmon populations and created a challenge for restoration of anadromous fish to the UCR. Recently, U.S. Native American Tribes and Canadian First Nations proposed reintroduction of anadromous fish in the UCR (U.S. Columbia Basin Tribes and Canadian First Nations, 2015).

The Columbia River Treaty, between the United States and Canada, is in a review process (2014/2024), and is being reconsidered, with the Tribes and First Nations seeking to add ecosystem function as an equal objective to flood risk management and hydropower generation. A watershed restoration approach also has been proposed that includes restoration of fish passage in historical habitats and restoration of ecosystem function with reintroduction of anadromous fish. The Upper Columbia United Tribes (UCUT; Colville, Spokane, Kootenai, Coeur d'Alene Tribe, and Kalispel Tribes) and Washington Department of Fish and Wildlife (WDFW) agreed that risk assessment is a critical first step to reintroduction of anadromous fish. A request for proposals was initiated in February 2016 to identify and rank potential donor sources for reintroduction of *Oncorhynchus spp.* that have life history strategies consistent with habitat upstream of Chief Joseph and Grand Coulee Dams. Reintroduction has potential risks to consider including pathogen transmission, ecological impacts to resident fish species, and potential constraints to implementation (Pearsons and Hopley, 1999; Anderson and others, 2014; Houde and others, 2015).

Reintroduction strategies generally are used to establish or expand a self-sustaining natural population after local extirpation (Dunham and others, 2011; Seddon and others, 2014; Allen and others, 2016). Pacific salmon and steelhead, with their anadromous life history traits, merit additional consideration for planning reintroduction programs that contribute to the recovery of populations listed under the Endangered Species Act (ESA; Anderson and others, 2014). Reintroduction programs require thoughtful planning to increase the likelihood of success and further understand the benefits, risks, and constraints (Pearsons and Hopley, 1999; Dunham and others, 2011; Anderson and others, 2014). The selection of prospective donor sources for reintroduction can inform success and risk associated with introduction of specific hatchery-origin and natural-origin populations (Nelitz and others, 2007; Anderson and others, 2014; Warnock and others, 2016).

We developed a risk assessment framework for reintroduction of anadromous salmonids upstream of Chief Joseph and Grand Coulee Dams. To accomplish this goal, we applied strategies identified in previous reintroduction risk assessment frameworks (Pearsons and Hopley, 1999; Dunham and others, 2011; Anderson and others, 2014; Houde and others, 2015). Next, a list of potential donor sources was developed from Warnock and others (2016), Mackey and others (2014), and a review of existing hatchery programs. Donor sources included hatchery- and natural-origin populations, identified by the hatchery source or population from which collection would be possible (hereinafter, “donors”). Warnock and others (2016) did an analysis of prospective Chinook Salmon (*O. tshawytscha*) donors that might be considered for reintroduction in the free-flowing Transboundary Reach (Hugh Keenleyside Dam, British Columbia, downstream to Lake Roosevelt, Washington). Mackey and others (2014) did an ecological risk assessment of hatchery programs for non-target taxa in the upper Columbia River watershed (Columbia, Wenatchee, Methow, and Okanogan Rivers). Several key features of prospective donors can inform risk assessments:

1. Assessing genetic ancestry and life history strategies of historical runs,
2. Considering habitat and ecosystem processes requiring local adaptation for reservoir flow regimes and conditions, and
3. Evaluating donor morphological and behavioral traits of donors within existing habitat and ecological constraints in the blocked areas.

A review of existing potential donor sources in the area were compiled in a database with input provided by UCUT, WDFW, and First Nations members.

The risk assessment addresses potential ecological interactions and impacts to the resident species (existing populations in the reintroduction area upstream of Chief Joseph and Grand Coulee Dams) of interest that may result from reintroduction of Chinook Salmon, Coho Salmon (*O. kisutch*), Sockeye Salmon (*O. nerka*), and anadromous Redband Trout (steelhead; *O. mykiss*). A list of potential donors was compiled and ranked with consideration to abundance/viability (demographic risk to source and feasibility of collection), ancestry/genetics (evolutionary similarity to historical populations), local adaptation (geographic proximity/similarity of source conditions to reintroduction conditions), life history compatibility (including migration, spawn timing, and relative usage of reservoir, main-stem, or tributary habitats most likely to match reintroduction location conditions), and risk to existing fish assemblages within and downstream of the reintroduction area. We assessed the pathogen risk of each potential donor for introduction of new pathogens and increased burden to existing pathogens for resident species upstream of the dams. We considered genetic risks to resident and downstream conspecifics and ecological impacts, including competition for food and space, predator-prey interactions, and ecosystem benefits/impacts. Four reintroduction strategies were evaluated:

1. Natural colonization,
2. Transplanting natural origin adults,
3. Transplanting hatchery adults, and
4. Releasing hatchery juveniles.

Geographic Area of Interest

We developed a risk assessment for the UCR from Chief Joseph Dam [river kilometer (rkm 877)] upstream to the United States-Canada border (rkm 1,199; fig. 1). Our focus area included Rufus Woods Lake, Lake Roosevelt, and their respective tributaries. We considered the Spokane River and tributaries upstream to Spokane Falls, Washington. Chief Joseph Dam is a run-of-the-river dam and is the second-largest hydropower producer in the United States; Grand Coulee Dam is the largest producer. Impounded by Chief Joseph Dam, Rufus Woods Lake has a surface area of 34 km^2 and extends 82 km upstream to Grand Coulee Dam. Grand Coulee Dam is a gravity dam that impounds Lake Roosevelt. Lake Roosevelt stretches about 240 km upstream to the United States-Canada border, with more than 966 km of shoreline and a surface area of 320 km^2. Our focus area is within Colville and Spokane Tribal lands, Washington State lands, and some privately owned land.

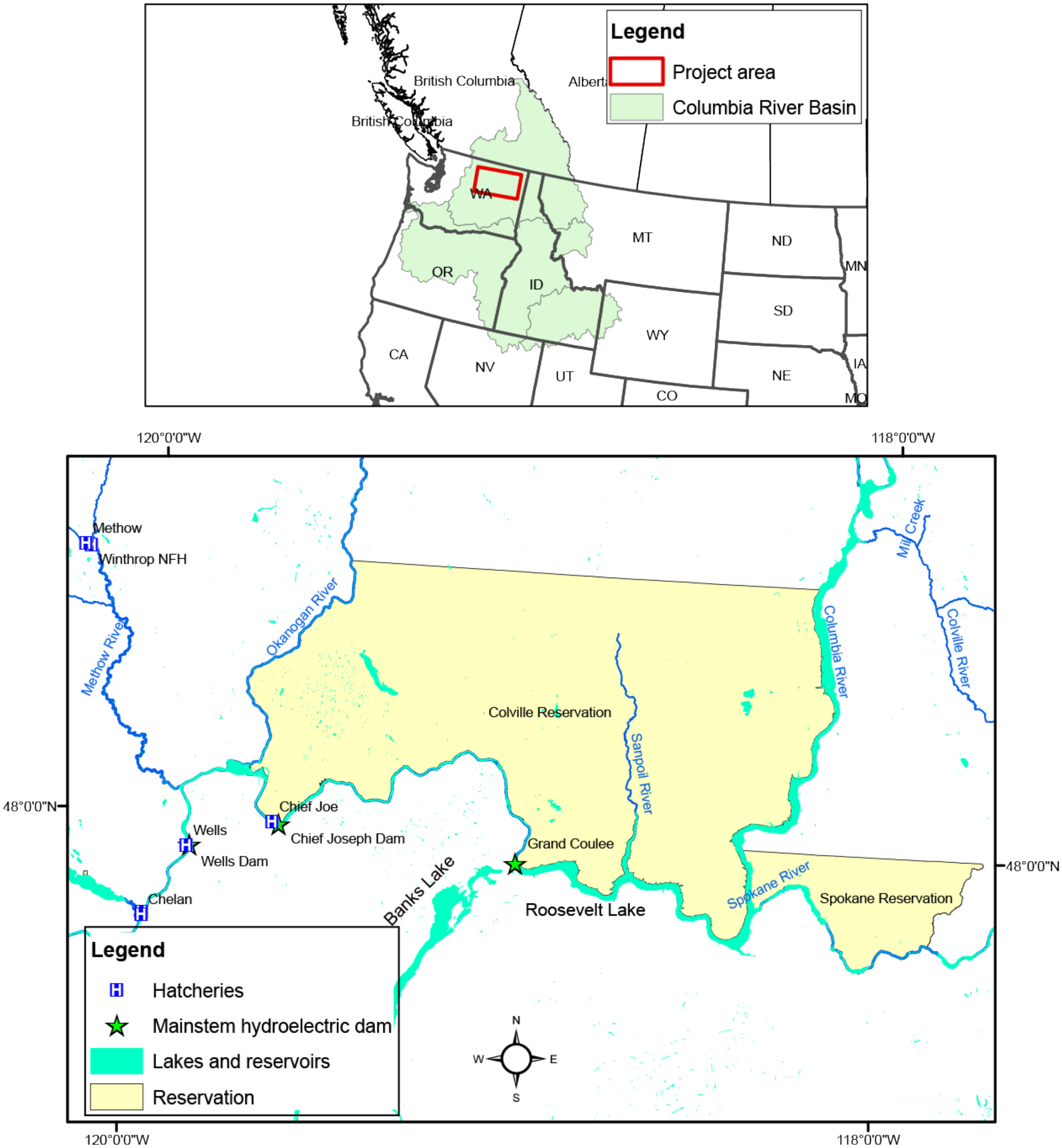

Figure 1. Project area— upper map identifies the project area within the Columbia River Basin. Lower map—project area in the upper Columbia River showing some of the major Dams, hatcheries, and tributaries, and the Colville and Spokane Reservations.

Methods

General Approach

The U.S. Geological Survey (USGS) worked with UCUT to assess the risk of reintroducing anadromous salmonids upstream of Chief Joseph and Grand Coulee Dams. Two workshops were held in Spokane, Washington, with the members of the UCUT work group, WDFW, First Nations, and USGS. The first workshop (workshop 1) was held August 15–17, 2016, and the second (workshop 2) was held January 4–5, 2017. The goals of the workshops were to present and solicit information from regional experts to gather key information about the local fish assemblages, potential for species interactions, and factors to consider for a reintroduction program.

In workshop 1, we identified resident fish species of interest and their primary habitat uses by life stage, population status, pathogen concern, primary location, and information needs. A species was deemed of interest based on resource management (that is, conservation of native species, fishery resource) and ecological interactions (that is, competition and predation) with reintroduced species. The USGS developed risk assessment tables fashioned after Pearsons and Hopley (1999) and solicited input during both workshops to rank the potential risks of reintroduction. The following risks were considered during workshop 1:

- Pathogen risks to resident species,
- Genetic risks to resident and downstream anadromous conspecifics,
- Competition with resident species, and
- Predation on reintroduced salmonids by resident species.

A risk assessment table of potential donors also was presented at workshop 1. Donor tables identified sources of fish, (for example, hatchery- or natural-origin), management history, and constraints on donors (ESA listing, Evolutionarily Significant Unit [ESU] concerns, demographic risk, and pathogens). During workshop 1, preliminary rankings of attributes for donors were evaluated. These attributes consisted of ancestral/genetic similarities (evolutionary similarity to historical populations), local adaptation (geographic proximity of a donor source to the reintroduction area), and life history compatibility (including migration; spawn timing; and relative usage of reservoir, main-stem, or tributary habitats most likely to match reintroduction location conditions). An additional attribute was added to address availability/viability (demographic risk to source and feasibility of collection) of a donor source to be presented at workshop 2. We used expert-based subjective ranks ranging from low-high (0-5).

During workshop 2, we refined the risk assessment tables, donors and their ranks, and presented conceptual designs of decision support frameworks for donor selection and release strategy. We also revisited risk assessment tables to highlight information changes and allow for further discussion of ranks. To summarize donor attributes and risks in species-specific tables for donor selection, we also developed donor synthesis tables. The donor, attribute and risk scores were summarized in the synthesis tables using the decision support framework to provide a means for ranking among the potential donors.

The donor synthesis tables were organized by species and provided the source locality (hatchery- or natural-origin), ESU designation, ESA status, and rankings for six attributes:

1. Abundance/viability,
2. Ancestry (genetics) match,
3. Local adaptation (geographic proximity),
4. Life history strategies (compatibility),
5. Genetic risks to conspecifics, and
6. Disease risk to resident species.

For each potential donor, attributes and risks were assigned a rank, with higher scores indicating a better match for donor selection. The tables provided a grand total of the attribute rankings—the sum of all of the attributes (including risks) combined. During workshop 2, weights were assigned to the attributes that were considered to be more important for a particular species reintroduction. Using the weights and individual ranks, we calculated a weighted grand total for each potential donor. The higher scores implied a more suitable donor match.

Resident Fish Species

To assess the impacts of donors on resident fish species, USGS and Confederated Tribes of the Colville Reservation (CTCR) biologists compiled a list of resident fish species presented during workshop 1 (appendix A, table A1). This list was narrowed down to species of interest for the risk assessment. A species was deemed of interest based on resource management (that is, conservation of native species, fishery resource value) and potential ecological interactions (that is, competition, hybridization, and predation) with reintroduced species.

To better understand the potential ecological interactions between reintroduced salmonids and resident species, a table was developed following Pearsons and Hopley (1999) to identify life stage-specific habitat use, population status, disease/pathogen concern, and the primary locations of resident species (appendix B, table B1). Resident fish were categorized based on their use of large and small tributary, main-stem and reservoir habitats within life stage (that is, adult, spawning adult, egg, fry, parr, smolt, or all life stages). Large tributaries were defined as third order or greater streams, and small tributaries were defined as first or second order. Main-stem habitats were defined as more free-flowing stretches of the Columbia (upstream of Kettle Falls) and Spokane Rivers, and reservoir habitats were defined as impounded sections. Population status was ranked from 0 to 5 (that is, extirpated, low, moderate, or high) to categorize abundance, trend (that is, decreasing, stable, increasing, or unknown), and distribution (that is, rare, narrow, wide, or unknown).

Disease/Pathogen Risks

We assessed disease risk using extant pathogen surveillance data collected using standardized protocols (American Fisheries Society, 2014). We assumed that diseases that are problematic in anadromous hatchery programs would not occur if the causative pathogen was not present. We also assumed that established pathogen surveillance programs upstream and downstream of Chief Joseph Dam would be sufficient to detect pathogens. Furthermore, we prioritized fish species upstream of Chief Joseph and Grand Coulee Dams that were identified by the UCUT work group as species of interest (appendix B, table B1).

Disease risk was separated into two risk categories—pathogen introduction and increased pathogen burden. Pathogen introduction was defined as no detection of the pathogen upstream of Chief Joseph Dam, but detected at least once in the last 5 years downstream of Chief Joseph Dam. Disease risk is important because resident fish populations likely would be susceptible to the newly introduced pathogen and could be subject to morbidity and mortality if it were introduced. Pathogen burden increase was defined as being detected in at least one highly valued fish population in the last 5 years upstream of Chief Joseph Dam and being detected more than once in the last 5 years in the candidate donor population. Pathogen burden is important because the progression from pathogen presence to disease often is density-dependent for both the pathogen and the fish host. The more host fish in a water body that are infected with the pathogen, the more infectious pathogen is present, which increases exposure dose to uninfected animals. Uninfected animals that are overcrowded are more susceptible to infection.

The final component of the disease risk assessment was the impact of introduction or increased burden on disease management. The assumption was that pathogen surveillance would be continuous for all rearing practices. Disease management was defined as the tools available for resource managers to mitigate the impacts of the disease/pathogen on cultured fish, and can only be used in artificial rearing facilities. For each pathogen of concern, the tools available were incorporated in an overall assessment of control success. These tools were in two categories—pathogen avoidance and pharmacological treatments. Pathogen avoidance was defined as water supply security and biosecurity/disinfection. Water supply security referred to whether fish susceptible to the pathogen of concern are present in the same water body that supplies the rearing facility. All pathogens of concern can be transmitted horizontally through the water by infected fish if susceptible fish are present in the water supply. The metazoan parasites *Ceratonova shasta* (Ceratomyxomatosis disease) and *Myxobolus cerebralis* (Whirling disease) require intermediate hosts, which are present in the resident region, so a management program for horizontal pathogen also will control these pathogens. Biosecurity and disinfection are measures of bio-containment effectiveness (for example, Meyers, 1990). For example, cleaning equipment used in multiple rearing units should be disinfected after every use or only assigned to a single rearing unit. Personnel also should disinfect boots and wear waterproof clothing while doing work on multiple rearing units. Disinfection of eggs during water hardening (usually with iodine) is effective for elimination of any pathogens not vertically transmitted. Pharmacological treatments include antibiotic drugs, only available for bacterial pathogens. Vaccines are only available for a small number of viral and bacterial pathogens and their utility in hatchery rearing is limited. Therefore, these strategies were not fully explored. The most effective approach for disease management is to maximize pathogen avoidance and prevent the need for pharmacological treatments. Pathogens of concern were ranked based on whether pathogen avoidance alone or pathogen avoidance plus pharmacological treatments were available. These ranks were used to assess the risk level for pathogen introduction and increased pathogen burden.

Pathogens were identified and annotated according to known burden on species in the resident region, in order to prioritize those that pose substantial health problems relative to ubiquitous or low burden conditions (appendix B, table B2). This information was then used to identify species-specific high risk pathogens and the relative risk (that is, low, medium, or high) to the resident species if candidate reintroduction populations harbored the pathogen (appendix B. table B1). A risk is ranked low when the pathogen(s) are widespread in both resident and donor regions, and effective control measures exist. A risk is ranked medium when the pathogen(s) are detected in both resident and donor regions, and control measures have limited success. A risk is ranked high when one or more pathogens are either not detected in the resident region or no effective control measure exists.

Genetic Risks

The reintroduction of salmonids has genetic risks to existing wild populations, such as:

1. Fitness reductions through loss of local adaptations and disruption of interactions between co-adapted loci;
2. Changes in genetic diversity—for example, genetic homogenization, and
3. Reduction in effective population size (Waples, 1991; Campton, 1995; Reisenbichler and others, 2003; Naish and others, 2008).

Genetic risk occurs when introduced stocks hybridize with and pass non-native and (or) maladaptive genes into wild populations. Hybridization with conspecifics may occur through straying of introduced stocks and lack of spatial and (or) temporal segregation during spawning.

We evaluated the genetic risk that reintroduced steelhead, Chinook Salmon, Coho Salmon, and Sockeye Salmon may present to resident and anadromous conspecifics that occupy habitats upstream and downstream of Chief Joseph and Grand Coulee Dams. To evaluate genetic risks, four factors contributing to increased genetic risk were identified:

1. **Donor choice.** Several donors were assessed for each salmonid species considered for reintroduction. Donors were assessed by their relationship with other populations in the basin. The history of hatchery-origin donors also was considered, and this included founding source(s), potential genetic changes through hatchery practices, whether the donor was from a segregated or integrated hatchery, and the number of generations a stock has been artificially propagated.
2. **Likeliness of hybridization with existing assemblages.** For blocked areas upstream of the dams, we considered that introduced steelhead could hybridize with native Redband Trout and that introduced Sockeye Salmon could hybridize with native kokanee. For areas downstream of Chief Joseph Dam, we considered the likelihood of hybridization with anadromous conspecifics.
3. **Reintroduction strategy.** This included an assessment of natural recolonization, transplantation (hatchery-origin or natural-origin adults), and hatchery releases of juveniles. We considered that the risks imposed by the different reintroduction strategies may not be equal and, therefore, present different genetic risks to native populations of concern.
4. **Fitness declines with hatchery-origin donor use.** This was considered an important factor, as studies suggest that early-generation hatchery fish that spawn in the wild have lower reproductive success relative to wild fish (Araki and others, 2007; Araki and others, 2009; Christie and others 2014).

The evaluation process included an overview presentation of the major genetic risks including a risk assessment table summarizing relevant literature, and group discussions with UCUT and other stakeholders in the workshops. During workshop 1, each of the four primary factors contributing to genetic risk was discussed and ranked for the potential species interactions (appendix B, table B3). All the genetic risk assessment factors were scored subjectively on a scale of 0 to 5, with 0 being very high risk and 5 being low risk. Included in the genetic risk assessment table ranking process were an overall potential impact rank and an uncertainty rank (appendix B, table B3), also subjectively ranked on a scale of 0 to 5. During workshop 2, the four factors contributing to increased genetic risks were considered for each donor and a group consensus of the overall genetic risk imposed by each donor was derived. The genetic risk was scored on a scale of 0 to 5, with 0 being very high risk and 5 being low risk. Although this scoring may seem counterintuitive (that is, 0 being high risk and 5 being low risk), this scale allows for an additive ranking across all attributes and risks, where higher grand totals imply more suitable donors.

Donor Sources

We developed a list of potential donors for this assessment following Warnock and others, (2016) and Mackey and others (2014), and by reviewing existing hatchery programs (Hatchery Scientific Review Group, 2009). Donor tables were developed based on previous reintroduction frameworks (Pearsons and Hopley, 1999; Dunham and others, 2011; Anderson and others, 2014; Houde and others 2015) and were presented at workshop 1 for potential Chinook Salmon (spring and summer/fall), Coho Salmon, Sockeye Salmon, and steelhead donors. Donor tables identified potential sources (hatchery-origin and natural-origin locations), populations, broodstock and management history, and potential constraints (that is, ESA listing, ESU concerns, disease, feasibility, and availability). During workshop 1, we also assigned preliminary ranks (0–5; low to high) of donors for ancestral/genetic similarity (evolutionary similarity to historical populations), local adaptation (geographic proximity of a donor source to the reintroduction area), and life history compatibility (including migration, spawn timing, and relative usage of reservoir, main-stem, or tributary habitats most likely to match reintroduction location conditions). The median of all ranks from individual participants was used to obtain a final score for each category. However, during workshop 1, the focus was to identify any missing donors, remove donors that were not pertinent or available, and solicit feedback from the work group. Input from workshop 1 was incorporated in the donor table and was updated with supporting information and an additional ranking category to capture the abundance/viability of potential donors in the overall ranking process. Abundance/viability is an important aspect of donor selection. An additional table column was added to summarize the pathogen concerns for the individual donor sources.

During workshop 2, the updated donor table from workshop 1 was reviewed and participants re-ranked (0–5, low to high) abundance/viability, ancestral/genetic similarity, local adaptation, and life history compatibility. Individual participant scores were recorded; however, discussions often led to a consensus ranking score or little variation between individual ranks. The median was thought to be the best measure of central tendency for the attribute ranks based on workshop participant expert ranking scores. Workshop participants considered the potential demographic risk to the donor source in the abundance/viability ranks. Supporting information included the purpose of the hatchery program (that is, integrated, segregated, or harvest allowed), availability (abundance) and productivity of the source population, population status, and collection feasibility. Some assumptions were made in the ranks for the ancestral/genetic similarity. First, we assumed that nearby sources were more closely related to historical populations (Warnock and others, 2016). This assumption also was made for the local adaptation rank. We assumed that donor sources that were geographically closer (similar environmental conditions) might be better adapted to existing environmental conditions in the reintroduction area (Brannon and others, 2004). Workshop participants considered life history compatibility that included migration and spawn timing, and relative usage of reservoir, main-stem or tributary habitats that were most likely to match the existing reintroduction location conditions. We took the median rank of the individual participant ranks for each donor attribute and presented it to the workshop participants for discussion and consensus on day 2 of workshop 2.

We designed a decision support framework to rank donors within species in individual synthesis tables that incorporated attributes and risks (fig. 2). However, we did not include predation and competition risks in these tables because workshop participants were unable to differentiate between these risks among donors of the same species. Although predation and competition risks are important considerations in reintroduction programs, we did not have sufficient information in the reintroduction area to delineate these risks between donors of the same species.

The synthesis tables provided a transparent way to compare donor scores within species, and individually weight attributes and risks. Weights were assigned to attributes and risks that were considered to be more important for a particular species reintroduction by consensus in workshop 2. The synthesis tables were designed with an understanding that special considerations could be taken for donors that were ESA listed and (or) outside the UCR ESU. Donors were not numerically ranked based on ESA and ESU, but were given categorical ranks allowing for easy separation of donors. This risk assessment did not attempt to evaluate the policy decisions regarding the use of ESA-listed fish as part of the reintroduction. The framework was used to develop synthesis tables for the donors by summing the overall ranks across the attributes and risks for a grand total and weighted total scores. Higher ranks implied a more suitable donor choice. Species-specific synthesis tables were presented on day 2 with final ranks, attribute weights, and risks among species used to calculate a grand total score. Workshop participants worked toward consensus to develop scores and rankings.

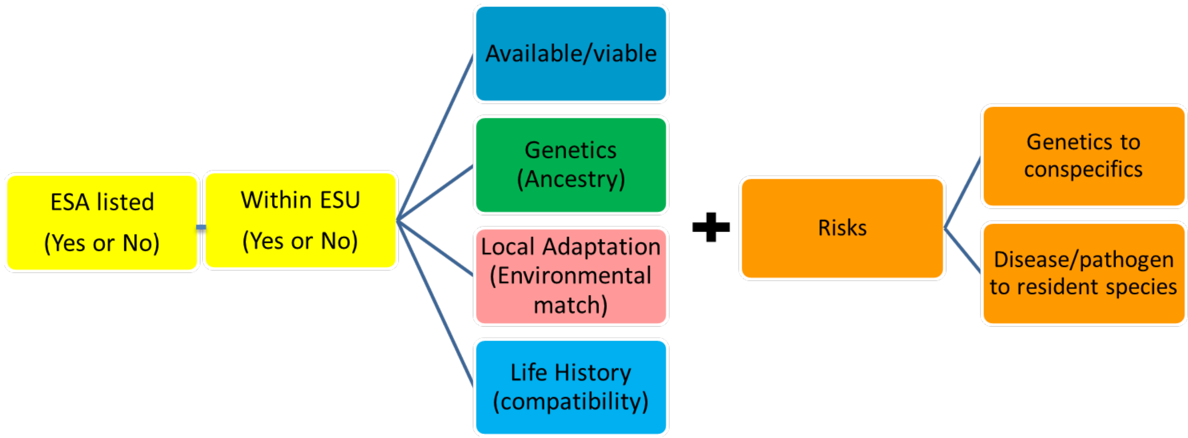

Figure 2. Conceptual diagram of a decision support framework incorporating attribute and risk considerations for donor selection. ESA, Endangered Species Act; ESU, Evolutionarily Significant Unit.

Ecological Impacts- Competition and Predation

We used two methods to characterize competition and predation risks associated with reintroduction of anadromous salmonids upstream of Chief Joseph and Grand Coulee Dams—(1) subjective ranks of a group of fisheries professionals with working knowledge of the reintroduction area summarized in risk tables, and (2) a literature review summarizing mostly published peer-reviewed literature on fish species identified as important by workshop participants through the ranking process. In this way, we hoped to fill substantial knowledge gaps in the peer-reviewed literature with the collective best professional judgment of workshop participants who were familiar with the biological interactions in the reintroduction area. By holding the workshops and developing risk scores from professional judgment, we attempted to use a consensus approach to vet the gray literature (for example, Bonneville Power Administration annual reports) before the workshop participants. Summarizing and interpreting gray literature was beyond the scope of this report. Therefore, we relied on the peer-reviewed literature and the consensus approach of risk scores assigned by fisheries professionals with firsthand knowledge of species interactions in the study area.

To summarize the professional judgment of the fisheries professionals, we used tables fashioned after Pearsons and Hopley (1999). Tables were constructed to assess the potential competition and predation risks to resident and anadromous fishes associated with the reintroduction of anadromous salmonids upstream of Chief Joseph and Grand Coulee Dams. Competition risk considered the potential for competition between resident fish and reintroduced salmonids for either food or space (for example, spawning locations), whereas predation risks were the potential for resident fish predating reintroduced salmonids. During workshop 1, we selected resident fish of interest (appendix B, table B1) and subjectively ranked the competition and predation risks (0–5, low to high) to existing resident fish populations in tributary, main-stem, and reservoir habitats. Each participant also was asked to provide an uncertainty value associated with their rank. These uncertainty ranks were collapsed into a median uncertainty rank (0–5, low to high). The workshop was attended by Federal, State, and Tribal fisheries managers who each provided a rank. Although we worked toward consensus, each individual provided their own rank. After draft tables were constructed using the results from workshop 1, they were sent out to all parties for suggestions and editing. At workshop 2, participants were allowed to revisit their original score and change it based on further group discussion. In some cases, individual participant scores were changed and the scores were updated. During workshop 2, scores and general table format were further refined to capture the professional judgment of participants.

For each of three general habitat types (tributaries, main stem, and reservoir), we calculated a median score from all the participant rankings for an individual fish taxon. From these three median scores, we calculated an overall score (mean location risk) by calculating the mean from the three medians for each predator taxa. Because of the lack of information concerning introduction (species, life stage, location, and habitat) during the ranking process, we did not develop donor-specific ranks, but instead used overall competition and predation scores for the introduction of a salmon species (for example, juvenile Chinook salmon) across the three habitat types.

Separate tables were formulated for competition and predation risks. Each table had differing species assemblages as identified by workshop participants as the primary competitors and predators of interest. For the predation risk table, scores represented a risk to introduced salmonids from a particular predator species. For competition risks, we evaluated the risks to individual resident species from the introduction of specific salmon life stages (fry, parr, and smolts) as identified by fishery professionals. Individual competition risks represented a score that included competition risks for food and space. Spatial competition risks were defined as displacement of resident spawners by anadromous spawners. We also assessed the potential for spawning displacement (competition for space) of resident spawners from introduced anadromous spawners.

Reintroduction Strategies

The four potential reintroduction strategies (natural recolonization, hatchery-origin adults, natural-origin adults, and hatchery juveniles) were discussed during both workshops. It was recognized in workshop 1 that program goals and risk levels for each species influence reintroduction strategy choice. Workshop 1 participants identified conservation, harvest, and sustainability as program goals of reintroduction (table 1). Potential release location scenarios in the study area for donor species also were discussed in workshop 1. It was recognized that location, life-stage, and release numbers were all considerations of specific program goals and would vary by species and donor. In considering the management and policy decisions needed for establishing program goals and selecting the best reintroduction strategy, a few relevant case studies are presented here to establish a reintroduction program in the UCR. A decision support framework for selection of a reintroduction strategy was presented at workshop 2 and was further refined with input from workshop participants. The decision support framework can be used to emphasize the interplay of program goals, reintroduction strategies, and donor selection. During workshop 2, participants discussed potential priorities for reintroduction and strategies associated with these priorities in the short term (<5 years, no fish passage) and the long term (>5 years, with fish passage restored). Each of the four reintroduction strategies and an experimental release strategy and time periods were considered for Rufus Woods Lake and the region upstream of Grand Coulee Dam.

Table 1. Potential program goals for reintroduction of anadromous salmon species in the upper Columbia River, northeastern Washington.

[Program goal was listed in order of priority as discussed during workshop 2 with special consideration given to Endangered Species Act-listed species]

Life history/species	Program goal
Spring Chinook Salmon	Conservation / harvest
Summer/fall Chinook Salmon	Harvest / conservation
Steelhead	Conservation / sustainable population / Tribal harvest (small)
Sockeye Salmon	Harvest / conservation
Coho Salmon	Harvest / conservation

Results

Resident Fish Species

During the workshops, 14 current resident species of interest were identified, consisting of 6 native species and 8 non-native (including hatchery-origin) species (appendix B, table B1). Extirpated anadromous species also were listed in the species of interest table to document their historical presence. Differences between White Sturgeon by origin (hatchery and wild) were noted, with an emphasis on wild fish (Jason McLellan, Confederated Tribes of the Colville Reservation, oral commun., January 4, 2017). Several non-native species were selected because they were potential predators or competitors of introduced salmonids. Native Redband Trout and kokanee also were listed as a species of interest because conserving the natural genetic diversity of native populations was identified as a concern during reintroduction. Stocked triploid Rainbow Trout and kokanee were considered species of interest because they likely would have ecological interactions (competition for resources) with introduced salmonids. Although other species were recognized by fishery professionals, they were not deemed to be important competitors or predators of juvenile salmon and were not listed in the table.

Disease/Pathogen Risks

Introduction Risk

All pathogens of concern were detected within the resident region except infectious hematopoietic necrosis virus (IHNV), which is highly virulent in steelhead (appendix B, table B2). There are three genetically and phenotypically distinct forms of this virus in the Columbia River Basin, and only one of them is currently present in the resident region. The Sockeye Salmon-specific form of IHNV (UP subgroup) is present at low levels in the resident region. The M genogroup of IHNV, which poses a high disease risk to *O. mykiss*, is not present in the region but is present in candidate donors. The third group of IHNV (UC subgroup), is not present in the resident region, but is present in candidate donors and is frequently found in Chinook Salmon. The effect of this form of IHNV on juvenile Chinook Salmon morbidity and mortality is unknown. However, the UC subgroup of IHNV also can cause morbidity and mortality in *O. mykiss*. Therefore, despite the lack of an extant Chinook Salmon population[1] in the reintroduction area, the introduction of UC subgroup IHNV could pose a risk to extant Redband Trout and reintroduced steelhead.

Infectious hematopoietic necrosis virus can be transmitted from parent to offspring on the surface of eggs. Therefore, disinfection of fertilized eggs is an effective control strategy. It also can be spread horizontally from infected fish of all ages. Evidence for lifelong infections of anadromous fish with transmissible virus is lacking, but circumstantial evidence indicates low transmission frequency. The greatest infection risk of IHNV to juvenile hatchery salmonids is from anadromous adults. Rare events are important in disease ecology; therefore, managers should assume that returning anadromous adults harbor infectious IHNV. Surveillance testing of adults and egg decontamination can reduce this risk.

[1] Some Chinook Salmon exist in Lake Roosevelt because of emigration of non-endemic Chinook Salmon from Lake Coeur d'Alene.

Increased Pathogen Burden Risk

All pathogens of concern that were detected in resident species of concern also were detected at lower frequency than in candidate donor populations, indicating that nearly all potential donors carry an increased risk of pathogen burden. This was particularly true for the bacterial pathogens *Renibacterium salmoninarum*, the causative agent of Bacterial Kidney Disease (BKD), and *Flavobacterium psychcrophilum*, the causative agent of Bacterial Coldwater Disease (BCWD). Both diseases can cause morbidity and mortality in juvenile salmonids. Bacterial Kidney Disease has the highest impact on Chinook Salmon, whereas BCWD can have negative health impacts on all donor candidates.

Management Strategies for Mitigating Disease Risks

Pathogen avoidance is the only control strategy for trout-specific IHNV, the only pathogen identified as a risk. Avoidance can decrease the risk of bacterial pathogens, but there also are antibiotic treatments. These results indicate that pathogen avoidance through the use of a secure water supply is the most effective strategy for reintroduction. Furthermore, because most pathogens of concern are found in high levels in anadromous fish, ongoing surveillance for pathogen presence is an indispensable component of successful disease management.

Disease Risk Synthesis in Donors

We used two metrics to rank candidate donors. The first metric was the relative burden of disease in the candidate population, based on the molecular surveillance data of all pathogens summarized by operating agencies. These data have an inverse ranking relative to the attribute ranking, so that the lowest risk populations have the highest number, similar to genetic risks. For example, summer/fall Chinook Salmon at Chief Joseph Dam have no history of UC subgroup IHNV infection or disease, but they reside and migrate in areas that had high infection pressure in the past. Therefore, this population has risk of 4. The second metric was the weighting strategy, which was the relative risk of the species to other species during reintroduction. For example, *O. nerka* disease risks were weighted lower than *O. mykiss* risks because the *O. nerka* specific UP subgroup of IHNV already exists in the resident region, whereas the *O. mykiss* specific M genogroup of IHNV does not. In this manner, the candidate donor populations were ranked for their disease risk to resident populations and to the region as a whole.

Donor Selection

To compare donors among species, donor attributes, genetics risks, and pathogen risks were combined in species synthesis tables using a decision support framework (fig. 1). The results for the donor selection process were summarized and ranks were provided within each species synthesis table. The risk assessment tables with supporting information for resident species, genetics, pathogens, and donors are provided in appendix B (tables B1–B8).

Steelhead Donors

All seven steelhead donors identified for potential reintroduction were in the UCR ESU, and all are listed as threatened under the ESA (table 2; appendix B, table B4), with the exception of native Redband Trout (not ESA listed). The UCR steelhead Distinct Population Segment (DPS) includes all naturally spawned steelhead populations downstream of natural and man-made impassable barriers in the Columbia River Basin between the United States-Canada border downstream to the confluence of the Columbia and Yakima Rivers in Washington. All steelhead hatchery programs in the UCR also are part of the listed DPS (National Oceanic and Atmospheric Administration, 2015). Hatchery-origin steelhead sources were the Eastbank Hatchery (Wenatchee River run), Wells and Winthrop Hatcheries (Methow River run), Omak Creek Hatchery[2], (Okanogan River run) and Wells/Ringold Hatchery (composite adult collections at Wells Dam). The natural-origin runs on the Wenatchee, Methow, Okanogan, and Entiat Rivers also were considered. The native Redband Trout within the reintroduction area of Lake Roosevelt, Sanpoil River, UCR tributaries, and the Spokane River tributaries also were considered a potential source for reintroduction because anadromous life history traits may be retained in resident Redband Trout populations (Holecek and Scarnecchia, 2013; Jones and McLellan, 2017).

The abundance/viability attribute for steelhead donors was given a weighting factor of 2×, owing to the relative importance of availability to a reintroduction program. The Eastbank (Wenatchee River run), Wells, and Winthrop Hatcheries (Methow River run) were all assigned ranks of 3.0 for abundance/viability. Additionally, Redband Trout in the reintroduction area also were assigned a rank of 3.0. Reintroduction of an anadromous run using resident fish could be slow with limited brood source availability, and primarily would be for conservation and likely without harvest. The remaining donors—Omak Creek (Okanogan River run); the natural-origin runs on the Wenatchee, Methow, Okanogan, and Entiat Rivers; and the Wells/Ringold Hatchery (Columbia River composite population)—were all assigned ranks of 1.0 because those populations are not meeting abundance minimum thresholds (for ESA recovery) and, therefore, do not have fish to spare to support a reintroduction program.

Conservation of the genetic integrity of the native Redband Trout was considered a priority. Therefore, they were assigned a rank of 5.0 as the best ancestry/genetic match, assuming an anadromous life history trait still exists. The next highest-ranked ancestry/genetic matches were the natural-origin sources (rank of 3.5) and the Wenatchee River run from the Eastbank Hatchery program (rank of 3.0). The Omak Creek (Okanogan River run) source (rank of 2.5) was ranked slightly higher than the Wells and Winthrop Hatcheries, and Methow River run (2.0). The Wells/Ringold Hatchery (Columbia River composite population) was assigned the lowest rank of 1.0 and was not considered a good donor source.

Native Redband Trout were considered the best locally adapted donor source and ranked 5.0. The natural-origin runs were considered the next-best locally adapted matches and ranked 4.0, as was the Omak Creek donor source. The Eastbank (Wenatchee River run), Wells, and Winthrop Hatcheries (Methow River run) all ranked 3.0 for local adaptation. The life history compatibility ranked similarly to the local adaption ranks, with native Redband Trout ranked 5.0, natural-origin runs ranked 4.0, and the remaining hatchery-origin sources ranked 3.0.

[2] Recently, the Omak Creek locally adapted hatchery program has expanded to include the Okanogan River Basin. Wells Hatchery-origin fish formerly were used to supply 80 percent of the overall hatchery program in the Okanogan River Basin. For this document, we will refer to the Okanogan hatchery population as the Omak Creek Hatchery so as not to confuse it with past practices of releasing Wells Hatchery-origin fish into the Okanogan River Basin.

Table 2. Synthesis table for steelhead donors.

[Attributes and risk rankings for steelhead donors. Highest grand total and weighted grand total scores imply the more suitable donor selection, and were consecutively ranked as the most suitable choice (that is, 1). Weights are assigned to attributes and risks considered more important for species reintroduction. **Within UCR:** Within upper Columbia River. **ESA status:** Endangered Species Act status. **Abbreviation:** tribs, tributaries]

Attribute weights (1, 2, or 3)				2.00	1.00	1.00	1.00		3.00	3.00				
				Attributes rank 0–5, low to high					Risk rank 5–0, low to high					
Locality source	Population run designation	Within UCR	ESA status	Abundance/ viability	Ancestry (genetics)	Local adaptation	Life history	Sub-total	Genetic risk to resident species	Disease risk to resident species	Sub-total	Grand total	Weighted grand total	Selection rank
Lake Roosevelt/Sanpoil River/upper Columbia River tribs/Spokane River and tribs	Redband Trout - native	Yes	Not	3.0	5.0	5.0	5.0	18.00	5.0	5.0	10.00	28.00	51.00	1
Eastbank Hatchery—Wenatchee and Chiwawa Rivers, and Nason Creek	Wenatchee River summer steelhead	Yes	Threat-ened	3.0	3.0	3.0	3.0	12.00	2.0	1.0	3.00	15.00	24.00	2
Wells Hatchery—Columbia, Methow, and Twisp Rivers	Methow River summer steelhead	Yes	Threat-ened	3.0	2.0	3.0	3.0	11.00	2.0	1.0	3.00	14.00	23.00	3
Winthrop Hatchery—Methow River	Methow River summer steelhead	Yes	Threat-ened	3.0	2.0	3.0	3.0	11.00	2.0	1.0	3.00	14.00	23.00	3
Wenatchee, Methow, Okanogan, Entiat Rivers	Natural-origin run	Yes	Threat-ened	1.0	3.5	4.0	4.0	12.50	2.0	1.0	3.00	15.50	22.50	5
Omak Creek Hatchery—Okanogan and Similkameen Rivers	Okanogan River, (Omak and Salmon Creeks) summer steelhead	Yes	Threat-ened	1.0	2.5	4.0	3.0	10.50	2.0	1.0	3.00	13.50	20.50	6
Wells/Ringold Hatchery—Columbia River	Columbia River lower-middle main-stem summer steelhead	Yes	Threat-ened	1.0	1.0	1.0	1.0	4.00	2.0	1.0	3.00	7.00	14.00	7

For steelhead donors, genetic risks to resident species were given a weight of 3× to emphasize the conservation of Redband Trout genetic diversity and to emphasize the risk of hybridization between Redband Trout and reintroduced steelhead. Native Redband Trout inhabiting the UCR and tributaries were identified as the donor source posing the lowest genetic risk to existing Redband Trout (table 2). All other donors received a genetic risk rank of 2.0, implying that non-native steelhead may pose a moderate-to-high risk to eroding the genetic structure of native Redband Trout.

Disease risk to resident species for steelhead donors also was given a weight of 3×, owing to the potential risk of disease for the native Redband Trout from the high risks of introduction and management of IHNV. All the donor sources were given a high disease risk ranking of 1.0, except the native Redband Trout, which were not considered a disease risk and were given a rank of 5.0. This high rating was given because, as they currently exist, the native Redband Trout are free of IHN virus. However, recent observations were shared during the workshops that native Redband Trout were passing the dams and presumably taking up an anadromous life history behavior. Jones and McLellan (2017) detected Sanpoil River Redband Trout migration downriver to the Columbia River Estuary in 2011 and potential adults moving upstream through Rock Island and Wells Dam fish ladders in spring 2015. If adult returns from these anadromous native Redband Trout are passed upstream of the dams as part of the restoration program, it is likely that their IHNV status will change. For steelhead, the single biggest risk factor for IHN disease is the presence of anadromous adults, and this means that every candidate reintroduction population, including the native Redband Trout, likely will introduce IHNV upstream of the dams. This leaves biosecurity and microbial surveillance as the best tools for managing the introduction of IHNV to the resident region.

In context of the conservation goal of native Redband Trout, using these fish as a donor source to reintroduce anadromous life history traits received the highest grand total and weighted grand total scores. The next-highest donor source ranks were the Eastbank Hatchery (Wenatchee River run), and the Wells and Winthrop Hatcheries (Methow River run).

Spring Chinook Salmon Donors

Ten spring Chinook Salmon donors were identified for potential reintroduction, and six of these donors are listed as endangered under the ESA (table 3; appendix B, table B5). Hatchery sources in the UCR ESU include:

- Eastbank /Wenatchee River Hatchery programs (Wenatchee River run),
- Methow and Winthrop Hatcheries (Methow River run), and
- Winthrop/Chief Joseph Hatcheries (section 10[j] program of Endangered Species Act) Okanogan River experimental population.

An additional four stocks were considered that are outside the UCR ESU and are not listed under the ESA. These include the Leavenworth National Fish Hatchery (LNFH), which is considered as being sourced outside the UCR ESU (lower Columbia River Carson origin stock); the Chief Joseph Hatchery (CJH), which gets its broodstock directly from Leavenworth; Cle Elum Hatchery (upper Yakima River run); and the McCall Hatchery (South Fork of the Salmon River spring/summer run). Natural-origin sources included the Wenatchee and Methow Rivers.

Table 3. Synthesis table for spring Chinook Salmon donors.

[Attributes and risk rankings for spring Chinook Salmon donors. Highest grand total and weighted grand total scores imply the more suitable donor selection, and were consecutively ranked as the most suitable choice (that is, 1). Weights are assigned to attributes and risks considered more important for species reintroduction. **Within UCR:** Within upper Columbia River. **ESA status:** Endangered Species Act status. **Abbreviations:** NFH, National Fish hatchery; tribs, tributaries]

Attribute weights (1, 2, or 3)				3.00	1.00	1.00	1.00		1.00	2.00				
				Attributes rank 0–5, low to high					Risk rank 5–0, low to high					
Locality source	Population run designation	Within UCR	ESA status	Abundance/ viability	Ancestry (genetics)	Local adaptation	Life history	Sub-total	Genetic risk to resident species	Disease risk to resident species	Sub-total	Grand total	Weighted grand total	Selection rank
Chief Joseph Hatchery—Columbia River, Leavenworth River	Lower Columbia River	No	Not	4.0	1.0	2.0	1.0	8.00	3.00	5.00	8.00	16.00	29.00	1
Eastbank /Wenatchee River Hatchery programs—Wenatchee Basin and Columbia River	Wenatchee River	Yes	Endan-gered	3.0	3.0	3.0	2.0	11.00	4.00	3.00	7.00	18.00	27.00	2
Winthrop Hatchery	Methow River	Yes	Endan-gered	3.0	2.0	3.0	2.0	10.00	3.00	3.00	6.00	16.00	25.00	3
Wenatchee River	Wenatchee River natural-origin	Yes	Endan-gered	1.0	4.0	3.0	3.5	11.50	4.00	3.00	7.00	18.50	23.50	4
Methow Hatchery—located in Winthrop	Methow River	Yes	Endan-gered	2.0	2.5	3.0	2.0	9.50	4.00	3.00	7.00	16.50	23.50	4
Methow River	Methow River natural-origin	Yes	Endan-gered	1.0	4.0	3.0	3.0	11.00	4.00	3.00	7.00	18.00	23.00	6
Leavenworth NFH	Leavenworth NFH—Spring Chinook	No	Not	3.0	1.0	2.0	1.0	7.00	3.00	3.00	6.00	13.00	22.00	7
Winthrop/ Chief Joseph Hatcheries/ section 10(j) program	Okanogan River	Yes	Endan-gered	1.0	2.0	3.0	2.0	8.00	4.00	3.00	7.00	15.00	20.00	8
Cle Elum Hatchery	Upper Yakima River	No	Not	3.0	0.0	1.0	1.0	5.00	2.00	3.00	5.00	10.00	19.00	9
McCall Hatchery	South Fork Salmon River spring-summer	No	Not	3.0	0.5	0.0	1.0	4.50	2.00	3.00	5.00	9.50	18.50	10

The abundance/viability attribute was given a weight of 3× the other attributes in the synthesis table (table 3), recognizing the importance of ESA-listed stocks and determining their availability as a donor source. The hatchery-origin donors generally were assigned a rank of 3.0 or greater. The CJH donor source had the highest abundance/viability rank, given a 4.0 owing to higher availability for collection of these fish[3]. The natural-origin donor sources on the Wenatchee and Methow Rivers were ranked as the least available (1.0), as was the Okanogan River run from the Winthrop/Chief Joseph Hatcheries section 10(j) program. The Methow Hatchery donor source also was ranked low (2.0) as a result of higher demographic risk to the source population in most years due to low numbers of returning adults. Given the endangered status of natural-origin populations in the extant part of the ESU and the use of ESA-listed hatchery-origin fish in the hatchery supplementation programs, we assumed that there would be unacceptable demographic risk in using them for the reintroduction. However, in recent years, there has been a surplus of hatchery-origin fish in the Wenatchee and Methow River Basins due to management goals that call for lower proportions of hatchery-origin fish spawning in the natural environment. Therefore, in some years there could be hundreds to thousands of ESA-listed hatchery-origin spring Chinook Salmon available for use in a reintroduction program, if the jurisdictional and regulatory processes could be negotiated.

The natural-origin Wenatchee and Methow Rivers donor sources were considered to have the most similar ancestry/genetics and were assigned ranks of 4.0. The Wenatchee River natural-origin run was considered to be genetically purer and more similar to UCR populations than the Methow River[4], which actually is closer in geographic proximity (Warnock and others, 2016). The hatchery-origin sources were ranked accordingly from this assumption and geographic proximity:

- Eastbank /Wenatchee River Hatchery programs were ranked 3.0;
- Methow Hatchery was ranked 2.5;
- Winthrop Hatchery, Methow River spring run, and the Winthrop /Chief Joseph Hatcheries section 10(j) program (Okanogan River spring-run) were ranked 2.0;
- Leavenworth and Chief Joseph Hatcheries, lower Columbia River spring-run Chinook Salmon, were ranked 1.0;
- McCall Hatchery, South Fork Salmon spring/summer run, was ranked 0.5; and
- Cle Elum Hatchery, upper Yakima spring-run Chinook Salmon, was ranked 0.0 (table 3).

The McCall Hatchery stock was assigned a higher value than the Cle Elum Hatchery source owing to genetics results reported by Warnock and others (2016), stating these fish were more genetically similar to the UCR ESU than the upper Yakima spring Chinook in spite of greater geographic separation.

[3] Adult spring Chinook will not begin to return from this program until 2017; therefore, this rating was not based on the observed abundance of available fish, but rather the anticipated future abundance and proximity/availability of collecting future returns at the CJH ladder.

[4] Due to past hatchery practices in the Methow River which included compositing local and non-local fish. Additionally, there have been high proportions of hatchery-origin fish on the spawning grounds.

For local adaptation, all the stocks in the UCR ESU were ranked 3.0. The LNFH was scored lower because of its location (farther away from) and mixing of broodstock from lower Columbia River stocks, which also was the case for the CJH. The Cle Elum Hatchery ranked 1.0 and McCall Hatchery 0.0, with the assumption that donors located farther away from reintroduction sites are less likely to be locally adapted to the reintroduction site.

The highest-ranked donor sources for life history compatibility were the Wenatchee River natural-origin run (3.5) and the Methow River natural-origin run (3.0). The hatchery-origin sources in the UCR ESU were assigned a ranking of 2.0. The hatcheries farther away to the reintroduction site, the LNFH and the CJH (lower Columbia River spring-run), and the Cle Elum and McCall Hatcheries were all assigned a ranking of 1.0.

Eastbank /Wenatchee River Hatchery programs, Wenatchee River natural-origin run, Methow Hatchery, Methow River natural-origin run, and Winthrop /Chief Joseph Hatcheries section 10(j) program Okanogan River donors were considered the lowest genetic risk, and all had rankings of 4.0 (table 3). The Cle Elum and McCall hatcheries were considered the highest genetic risk to the UCR Chinook Salmon populations, with rankings of 2.0.

The disease risk for spring Chinook Salmon was given a weight of 2×, owing to introduction and management risks of IHNV and management risks of *R. salmoninarum* (BKD). All donors were assigned a 3.0 for disease risk, with the exception of CJH which was assigned a 5.0 because it had no history of infection/disease (table 3).

Using the donor selection framework and the weighting factors assigned to the attributes and risks, the donor source with the highest weighted grand total was CJH (lower Columbia River spring Chinook Salmon). The Eastbank /Wenatchee River Hatchery program was ranked second, followed by Winthrop Hatchery (Methow River run) (third), and the Wenatchee River natural-origin run and the Methow River Hatchery (Methow River run) (tied for fourth). Weighting abundance/viability at 3× influenced the final ranking scores, causing them to differ from the grand total scores (unweighted). The unweighted grand total values had the highest additive score for the Wenatchee River natural-origin run, followed by the Eastbank /Wentachee Hatchery programs and the Methow River natural-origin run. Final donor selection will benefit by taking the program goal for Spring Chinook Salmon (harvest, conservation, or both) and the regulatory issues related to reintroduction of ESA-listed fish into consideration. This risk assessment did not attempt to differentiate ESA from non-ESA. Once managers decide on program goals for spring Chinook Salmon, they can revisit the risk assessment and select the donor(s) appropriate for achieving the program goals.

Summer/Fall Chinook Salmon Donors

Ten summer/fall Chinook Salmon donors were identified. All but one of the summer/fall Chinook Salmon donors were in the UCR ESU and were not ESA listed. The exception was the Lower Snake River fall Chinook Salmon from the Lyons Ferry/ Nez Perce Hatchery programs, which are ESA listed as threatened (table 4; appendix B, table B6). For summer/fall Chinook Salmon, the abundance/viability attribute was given a weight of 2×, owing to the importance of donor availability to the reintroduction program. Chief Joseph Hatchery source was ranked 5.0, for availability because surplus fish are frequently available[5] and there is an adequate collection facility. The Hanford Reach upriver bright fall Chinook Salmon from Priest Rapids[6] and Ringold Hatcheries were ranked next highest at 3.5, followed by Eastbank, Wells, and Chelan Falls Hatcheries assigned a ranking of 3.0. The Wenatchee River and Okanogan River natural-origin runs were ranked 2.0, as well as the Entiat National Fish Hatchery (NFH) source because of low escapement and availability of natural-origin fish. The Methow River natural-origin run was ranked the lowest at 1.0, owing to high demographic risk to the source population. The Lower Snake River fall Chinook Salmon also was ranked 1.0; because of ESA status and other low attribute rankings, it was not considered further as an acceptable donor source (table 4).

We considered the ancestry/genetics similar among the summer/fall Chinook Salmon UCR hatchery stocks and natural-origin populations (Hillman and others, 2015); thus, the rankings ranged from 3.0 to 4.0 (table 4; appendix B, table B6). The natural-origin populations from the Wenatchee, Methow, and Okanogan Rivers were considered most similar to ancestral UCR populations and were assigned ranks of 4.0. The CJH (Okanogan summer-run) and Eastbank Hatchery (Wenatchee River summer-run) donors were assigned rankings of 3.8 and 3.5, respectively[7]. All other UCR ESU hatchery sources were assigned a rank of 3.0.

The local adaptation ranks did not have a high variation among many of the donors. The highest rankings were from the natural run populations of the Methow and Okanogan Rivers at 4.5, with the Wenatchee River natural-origin population ranked 4.3. The CJH (Okanogan River, summer-run) and the Hanford Reach upriver bright fall-run from Priest Rapids and Ringold Hatcheries received rankings of 4.5. Eastbank Hatchery (Wenatchee River, summer-run Chinook Salmon) received a ranking of 4.0, and the Wells (Methow and Okanogan Rivers, summer-run), Chelan Falls, (Columbia River, fall-run Chinook Salmon), and Entiat Hatcheries (Entiat summer-run, Chinook Salmon) all received rankings of 3.0.

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[5] The first adult returns from CJH releases will occur in 2017; however, thousands of hatchery-origin fish from various programs have been removed at the CJH ladder since it began operation in 2013. It is anticipated that the ladder will be an effective means of obtaining CJH returns, as well as stray (or wandering) fish from other summer/fall Chinook Salmon hatchery programs in the upper Columbia River.

[6] Priest Rapids Hatchery has had record high abundance returns in 2013, 2014, and 2015, and is able to meet broodstock needs and has had surplus fish available. In considering collection of hatchery- and natural-origin fish at Priest Rapids Dam and Hatchery facilities, this source for abundance/viability could be ranked a 5.0. During the time of the workshop participant ranking, the focus was on Hanford Reach natural-origin upriver bright fall Chinook Salmon and collection potentially at Ringold facilities.

[7] Despite current similarities between UCR hatchery programs, there have been recent changes to several programs that provide a better opportunity for local adaptation to natal streams over time. The Okanogan was rated slightly higher than the Wenatchee to reflect a slightly higher similarity with systems in the UCR (that is, Sanpoil and Kettle Rivers) and the potential of future local adaptation from a population that migrates the farthest into a river with challenging temperature conditions.

For life history compatibility, Hanford Reach upriver bright Chinook Salmon received a ranking of 4.5, the highest of the donors, because they have high productivity, making use of main-stem habitat in a downstream reach of the Columbia River. The natural-origin donors from the Wenatchee, Methow, and Okanogan Rivers received a ranking of 4, the same as CJH (Okanogan River, summer-run Chinook Salmon) donor source. The Eastbank Hatchery (Wentachee River summer-run) received a ranking of 3.5, followed by Wells, Chelan Falls, and Entiat Hatchery sources, which received rankings of 3.0.

The genetic risk was given a weight of 0.5× owing to the low genetic variation and mixing among summer/fall-run Chinook Salmon donors. All upper Columbia River summer/fall-run Chinook Salmon donors received rankings of 4.0, indicating moderate-low genetic risks (table 4). The only donor source outside of the Columbia River that was considered, Lower Snake River fall Chinook Salmon, received a ranking of 2.0.

The disease risk was given a weight of 2× owing to the introduction and management risk of IHNV, and the management risks of *R. salmoninarum*. The CJH source received the lowest risk rank of 4. The Entiat NFH received a ranking of 1.0, whereas all other upper Columbia River donors were given disease risk rankings of 3.0.

The CJH (Okanogan River summer-run Chinook Salmon) received the highest weighted grand total score and ranked the highest among donors (that is, number 1; table 4). Hanford Reach upriver brights and Eastbank Hatchery (Wenatchee River, summer-run Chinook Salmon) received the next highest ranks, respectively. These results were similar to the non-weighted grand total scores.

Table 4. Synthesis table for summer/fall Chinook Salmon donors.

[Attributes and risk rankings for summer/fall Chinook Salmon donors. Highest grand total and weighted grand total scores imply the more suitable donor selection, and were consecutively ranked as the most suitable choice (that is, 1). Weights are assigned to attributes and risks considered more important for species reintroduction. **Within UCR:** Within upper Columbia River. **ESA status:** Endangered Species Act status. **Abbreviation:** NFH, National Fish hatchery]

Attribute weights (1, 2, or 3)				2.00	1.00	1.00	1.00		0.5	2.00				
				Attributes rank 0–5, low to high					Risk rank 5–0, low to high					
Locality source	Population run designation	Within UCR	ESA status	Abundance/ viability	Ancestry (genetics)	Local adaptation	Life history	Sub-total	Genetic risk to resident species	Disease risk to resident species	Sub-total	Grand total	Weighted grand total	Selection rank
Chief Joseph Hatchery	Okanogan River	Yes	Not	5.0	3.8	4.5	4.0	17.25	4.0	4.0	8.00	25.25	32.25	1
Priest Rapids and Ringold Hatcheries —Columbia River Hanford Reach	Columbia River—Hanford Reach-Upriver bright Chinook	Yes	Not	3.5	3.5	4.5	4.5	16.00	4.0	3.0	7.00	23.00	27.50	2
Eastbank /Wenatchee River Hatchery programs	Wenatchee River	Yes	Not	3.0	3.5	4.0	3.5	14.00	4.0	3.0	7.00	21.00	25.00	3
Okanogan River natural run	Okanogan River natural-origin	Yes	Not	2.0	4.0	4.5	4.0	14.50	4.0	3.0	7.00	21.50	24.50	4
Wenatchee River natural run	Wenatchee River natural-origin	Yes	Not	2.0	4.0	4.3	4.0	14.25	4.0	3.0	7.00	21.25	24.25	5
Wells Hatchery (and Carlton Rearing pond) —Columbia River	Methow River /Okanogan River	Yes	Not	3.0	3.0	3.0	3.0	12.00	4.0	3.0	7.00	19.00	23.00	6
Chelan Falls Hatchery—Columbia River	Columbia River	Yes	Not	3.0	3.0	3.0	3.0	12.00	4.0	3.0	7.00	19.00	23.00	6
Methow River natural run	Methow River natural-origin	Yes	Not	1.0	4.0	4.5	4.0	13.50	4.0	3.0	7.00	20.50	22.50	8
Entiat NFH	Entiat River	Yes	Not	2.0	3.0	3.0	3.0	11.00	4.0	1.0	5.00	16.00	17.00	9
Snake River fall—Lyons Ferry and Nez Perce Hatchery programs	Lower Snake River fall Chinook	No	Threat-ened	1.0	1.0	0.5	2.5	5.00	2.0	1.0	3.00	8.00	9.00	10

Sockeye Salmon Donors

Four Sockeye Salmon and three kokanee donors were reviewed (table 5; appendix B, table B7). Three Sockeye Salmon populations were in the UCR ESU and not ESA listed. Redfish Lake Sockeye Salmon (Springfield Hatchery on the Salmon River, Idaho), located outside the UCR ESU and listed as endangered under the ESA, were not further considered for reintroduction to the UCR. Three native kokanee populations in the UCR were reviewed as donors because of the potential presence of an anadromous life history trait. Chain Lake kokanee were considered genetically unique, divergent from other populations (Kassler and others, 2010) and with low abundance/viability. Therefore, they were excluded from further consideration as a viable donor.

The abundance/viability attribute was given a weight of 2×, owing to the importance of donor availability to a reintroduction program. Abundance/viability rankings ranged from 1.0 to 4.0 for the remaining donor sources (table 5). The highest-ranked donor for abundance/viability was the Okanogan River, natural-origin Sockeye Salmon (4.0), which is considered sustainable and has harvest. These fish could be collected at Wells Dam or using purse seines at the mouth of the Okanogan River. This was followed by the Lake Wenatchee population (ranking of 3.3), the Lake Roosevelt native kokanee (ranking of 3.0), and the Penticton Hatchery (Okanogan River, Sockeye Salmon) that received a ranking of 2.0 because it does not meet escapement goals. Arrow Lakes kokanee (which are a composite of multiple populations) received a ranking of 1.0 because of high demographic risk to the source population.

The native kokanee from Lake Roosevelt were considered the best ancestry/genetic match, and were ranked 4.5, with the assumption that anadromous life history behaviors still exist. The Okanogan River, natural-origin Sockeye Salmon was considered a good ancestry/genetic match (ranking of 4.0), followed by Lake Wenatchee (ranking of 3.0) and Penticton Hatchery (Okanogan River sourced Sockeye Salmon, ranking of 3.0).

Many donors received similar ranks for local adaptation. Lake Roosevelt kokanee received a ranking of 4.5, the highest local adaptation rank, followed by the Okanogan River natural-origin Sockeye Salmon and the Penticton Hatchery (Okanogan River Sockeye Salmon), which both received rankings of 4.0. Lake Wenatchee and Arrow Lakes kokanee both received rankings of 3.0.

Life history compatibility is an important component of Sockeye Salmon reintroduction and was weighted 2× because successful reintroduction of Sockeye Salmon requires an anadromous life history. The highest life history compatibility matches were given to the Sockeye Salmon donor sources. Lake Wenatchee, Okanogan River natural-origin Sockeye, and Penticton Hatchery (Okanogan River Sockeye Salmon) all received rankings of 4.0. The Lake Roosevelt and Arrow Lakes kokanee received rankings of 3.0 because of their dominant kokanee life history strategy.

Okanogan River natural-origin and Lake Wenatchee Sockeye Salmon both received a genetic risk ranking of 3.0 because of their potential to negatively affect native kokanee populations in Lake Roosevelt (table 5). Arrow Lakes kokanee also was ranked 3.0, because of the potential for hybridization. The Penticton Hatchery (Okanogan River, Sockeye Salmon) was viewed as having a moderate-high genetic risk owing to the higher number of hatchery-origin fish, and received a ranking of 2.0.

The disease risk was given a weight of 1.5× because anadromy can increase the risk of IHNV. The Arrow Lakes and Lake Roosevelt kokanee donors both received a ranking of 3.0. The remaining stocks in consideration were moderate to high risk, and given rankings of 2.0.

Lake Roosevelt native kokanee were considered the best donor for reintroducing anadromous Sockeye Salmon to the region because of their local adaptation, low genetic risk, and low disease risk. However, they are not readily available as a brood source. The second-highest ranked donor was the Okanogan River natural-origin Sockeye Salmon, followed by the Lake Wenatchee Sockeye Salmon and the Penticton Hatchery (Okanogan River) Sockeye Salmon (table 5).

Table 5. Synthesis table for Sockeye Salmon donors.

[Attributes and risk rankings for Sockeye Salmon donors. Highest grand total and weighted grand total scores imply the more suitable donor selection, and were consecutively ranked as the most suitable choice (that is, 1). Weights are assigned to attributes and risks considered more important for species reintroduction**.** **Within UCR:** Within upper Columbia River. **ESA status:** Endangered Species Act status]

Attribute weights (1, 2, or 3)				2.00	1.00	1.00	2.00		1.00	1.50				
				Attributes rank 0–5, low to high					Risk rank 5–0, low to high					
Locality source	Population run designation	Within UCR	ESA status	Abundance/ viability	Ancestry (genetics)	Local adaptation	Life history	Sub-total	Genetic risk to resident species	Disease risk to resident species	Sub-total	Grand total	Weighted grand total	Selection rank
Lake Roosevelt	Native, kokanee	Yes	Not	3.0	4.5	4.5	3.0	15.00	5.0	3.0	8.00	23.00	30.50	1
Okanogan River	Okanogan River Natural-origin, Sockeye	Yes	Not	4.0	4.0	4.0	4.0	16.00	3.0	2.0	5.00	21.00	30.00	2
Lake Wenatchee	Wenatchee River Sockeye/ kokanee	Yes	Not	3.3	3.0	3.0	4.0	13.25	3.0	2.0	5.00	18.25	26.50	3
Penticton Hatchery	Okanogan River Sockeye	Yes	Not	2.0	3.0	4.0	4.0	13.00	2.0	2.0	4.00	17.00	24.00	4
Arrow Lakes	Arrow Lakes kokanee	Yes	Not	1.0	3.0	3.0	3.0	10.00	3.0	3.0	6.00	16.00	21.50	5
Snake River programs—Springfield Hatchery - Salmon River	Redfish Lake Sockeye	No	Endan-gered	1.0	1.0	2.0	2.0	6.00	2.0	2.0	4.00	10.00	14.00	6
Chain Lake	Native, kokanee	Yes	Not	0.0	1.0	1.0	1.0	3.00	4.0	3.0	7.00	10.00	12.50	7

Coho Salmon Donors

Five Coho Salmon donors were identified (table 6; appendix B, table B8). Two of these are considered to be in the UCR ESU, coming from the Methow River and Wenatchee River populations. However, the historical broodstock for the Methow and Wenatchee River populations has been predominantly from a lower Columbia River source, the Little White Salmon NFH. As of 2006, all the broodstock for these programs have been derived, respectively, from hatchery- and natural-origin sources from the Wenatchee and Methow Rivers (Galbreath and others, 2014). The three remaining donors are from outside the UCR ESU, including the Yakima River, Thompson Basin, and Lapwai Creek sources.

The abundance/viability attribute was given a weighting factor of 2×, owing to the importance of availability for a reintroduction program. The Methow and Wenatchee River Coho Salmon runs both received moderate abundance/viability rankings of 3.0. The other donor sources outside of UCR ESU were ranked 2.0 or lower.

All the donor sources received a low ancestry/genetic match ranking of 1.0.

The local adaptation attribute received a weight of 2× recognizing the success of nearby donors. In the UCR ESU, the Methow and Wenatchee Rivers Coho Salmon runs both received local adaptation rankings of 3.0, and the donors outside of the UCR ESU received rankings of 2.0.

The life history compatibility attribute received a weight of 1.5× to emphasize fish that can migrate longer distances and might be in better condition at the reintroduction location. Thompson Basin Coho Salmon received the highest life history compatibility ranking of 3.5, owing to their long migration distances. However, this population is located outside the ESU. The Methow and Wenatchee Rivers Coho Salmon runs received life history rankings of 3.0, followed by the Yakima River Coho Salmon from Prosser Dam (2.3), and the Clearwater River Coho Salmon (2.0).

Coho Salmon donors from the Methow, Wentachee, and Yakima Rivers received genetic risk rankings of 4.0 (table 6). Shuswap/Thompson and Lapawai donor sources were viewed as having the highest risk and received a score of 2.0. The disease risk was given a weighting factor of 0.5× because Coho Salmon have less overall disease concern among existing populations and lower potential for “new” introduction. Wenatchee River, Yakima River, and Thompson Basin Coho Salmon runs all received low disease risk rankings of 5.0. Methow and Clearwater River Coho Salmon runs were considered a moderate-to-low disease risk and received rankings of 4.0. These localities have slightly higher disease risk because they have a high IHNV infection pressure and are some of the few places where IHNV-infected Coho Salmon have occurred.

Using the decision support framework and weighted rankings, the highest weighted grand total scores for Coho Salmon were for the Wenatchee River run from the LNFH, and the Methow River run from the Winthrop Hatchery.

Table 6. Synthesis table for Coho Salmon donors.

[Attributes and risk rankings for Coho Salmon donors. Highest grand total and weighted grand total scores imply the more suitable donor selection, and were consecutively ranked as the most suitable choice (that is, 1). Weights are assigned to attributes and risks considered more important for species reintroduction**. Within UCR:** Within upper Columbia River. **ESA status:** Endangered Species Act status. **Abbreviation:** NFH, National Fish Hatchery]

Attribute weights (1, 2, or 3)				2.00	1.00	2.00	1.50		1.00	0.5				
				Attributes rank 0–5, low to high					Risk rank 5–0, low to high					
Locality source	Population run designation	Within UCR	ESA status	Abundance/ viability	Ancestry (genetics)	Local adaptation	Life history	Sub-total	Genetic risk to resident species	Disease risk to resident species	Sub-total	Grand total	Weighted grand total	Selection rank
Leavenworth NFH (Yakama Nation Coho)	Wenatchee River	Yes	Not	3.0	1.0	3.0	3.0	10.00	4.0	5.0	9.0	19.00	24.00	1
Winthrop NFH (Yakama Nation Coho)	Methow River	Yes	Not	3.0	1.0	3.0	3.0	10.00	4.0	4.0	8.0	18.00	23.50	2
Prosser Dam	Yakima River	No	Not	2.0	1.0	2.0	2.3	7.25	4.0	5.0	9.0	16.25	18.88	3
Shuswap/Thompson	Thompson Basin	No	Not	1.5	1.0	2.0	3.5	8.00	2.0	5.0	7.0	15.00	17.75	4
Lapawai Creek	Clearwater River	No	Not	1.0	1.0	2.0	2.0	6.00	2.0	4.0	6.0	12.00	14.00	5

Ecological Impacts

Competition for Food and Space

Workshop participants identified Redband Trout, triploid Rainbow Trout, kokanee, and Burbot as the primary competitors of introduced salmonids. Mean location risk scores indicated little variation between various life stages and hatchery origin of kokanee, Redband Trout, and Rainbow Trout (range, 2.7–2.8). However, Redband Trout had relatively high competition risks in tributaries (4.0), whereas kokanee (5.0) and Rainbow Trout (5.0) had higher competition risks in main-stem habitats. Burbot had a relatively small competition risk with introduced juvenile salmonids in reservoir (2.0) and main-stem (1.0) habitats (appendix B, table B9).

Redband Trout (*Oncorhynchus mykiss gairdneri*)

Adult competition score = 2.7; *Juvenile competition score* = 2.8

The Columbia River Redband Trout is one of three recognized subspecies of Rainbow Trout. They are endemic to the Columbia River and its tributaries in Oregon, Washington, Montana, and Idaho. In the Deschutes River, Oregon, anadromous steelhead spawn 9–10 weeks earlier and in deeper parts of the river than Redband Trout, leading the authors to conclude that they were reproductively isolated from Redband Trout (Zimmerman and Reeves, 2000). This isolation could lead to differences in the distribution of rearing juveniles (Zimmerman and Reeves, 2002). However, in the Yakima River Basin, larger hatchery steelhead juveniles were agnostic toward, behaviorally dominated, and reduced the growth of wild Rainbow Trout (Pearsons and others, 1999). In the Lemhi River, Idaho, resident Rainbow Trout abundance decreased and Rainbow Trout were possibly outcompeted by introduced hatchery steelhead (Bjornn, 1978). Many populations of sympatric resident Rainbow Trout exist alongside anadromous salmonid populations including steelhead. Native populations seem to coexist with spatial and temporal segregation of spawning and rearing populations in the Walla Walla River Basin, Washington (Narum and others, 2004). However, adverse effects to resident trout have been noted after introduction of hatchery steelhead. These negative impacts seem to be associated with hatchery introductions. The removal of a barrier and subsequent recolonization by Coho Salmon did not influence the growth or survival of resident Coastal Cutthroat Trout (*O. clarkii*) in the Cedar River, Washington (Buehrens and others, 2014). Introduced Rainbow Trout upstream of Grand Coulee Dam, Washington, did not seem to be prey-limited, owing to the large mean size (>1.0 mm) of *Daphnia* (Baldwin and Polacek, 2002). More recent data indicate similarly large mean sizes of 1.5 mm for *D. pulex*, and 1.1 mm for *D. retrocurva*.

Kokanee (*Oncorhynchus nerka*)

Natural adult competition score = 2.7; *Wild juvenile competition score* = 2.7; *Hatchery juvenile competition score* = 2.7

Kokanee are a landlocked form of Sockeye Salmon that average about 22.9–30.5 cm (9–12 in.) in length but can grow upward of 50 cm (20 in.) when food is abundant. In Lake Roosevelt, mature wild kokanee usually range from 51 to 64 cm (20–24 in.; Wolvert and McLellan, 2017). Kokanee typically are planktivorous and can have large stunted populations when food is limited (Martinez and Wiltzius, 1995). Sympatric populations coexist with anadromous salmonids, particularly Sockeye. Sympatric populations of kokanee and Sockeye Salmon are genetically different in the Shuswap River, British Columbia, suggesting that fish size sorts spawning aggregations (Wood and Foote, 1990), as is the case with many sympatric populations (for example, Zimmerman and Reeves, 2000). In Lake Ozette, Washington, consumption demands by juvenile Sockeye Salmon, juvenile kokanee, and adult kokanee could all be accommodated by about 1 percent of the *Daphnia* production (Beauchamp and others, 1995). In Lake Ozette, predation is more likely to limit Sockeye smolt production than competition between Sockeye and kokanee. *Daphnia* size continues to average greater than 1 mm in Lake Roosevelt for several species (*D. pulex* and *retrocurva*) (Kain and others, 2017). Depending on the timing of out migrants, Lake Roosevelt might need to support juvenile Sockeye and juvenile summer/fall Chinook Salmon, which also rely heavily on *Daphnia* (Rondorf and others, 1990; Haskell and others, 2017). Bioenergetics studies estimating consumption in Merwin, Yale, and Swift Reservoirs, Washington, reported that a surplus *Daphnia* production could support introduced juvenile summer/fall Chinook Salmon in addition to existing natural kokanee (Sorel and others, 2016a). A similar result was projected for kokanee and Sockeye Salmon in Lake Sutherland, Washington, after the removal of the Elwha Dam (Hansen and others, 2016).

Currently, the Spokane Tribal Hatchery annually releases 100,000 triploid kokanee into Lake Roosevelt (Peone, 2015). Some kokanee naturally spawn in Lake Roosevelt, but not enough is known about their spawning locations to obtain sufficient numbers of sexually mature adults to satisfy egg-take requirements for hatchery production.

Although current and past data summaries indicated ample food resources, the consumptive demand of additional planktivores in Lake Roosevelt is unknown. Based on the size of *Daphnia* in Lake Roosevelt (>1.7 mm during all seasons), Baldwin and Polacek (2002) inferred that food for kokanee was not limited and, therefore, although kokanee have shared resources, they do not compete with other planktivores in Lake Roosevelt. Current research in the lower Columbia River indicates that the addition of nonnative planktivores such as juvenile American Shad (*Alosa sapidissima*) and the mysid shrimp (*Neomysi*s *mercedis*) to reservoir food webs has reduced the mean size and biomass of *Daphnia* available to emigrating fall Chinook Salmon (Haskell and others, 2013). If competition for food between introduced juvenile anadromous salmonids and native kokanee in Lake Roosevelt is a priority concern for managers, then a quantitative bioenergetics study should be considered.

Triploid Rainbow Trout

Juvenile competition score = 2.7

The Spokane Tribal Hatchery and WDFW Sheman Creek Hatchery annually release about 500,000 triploid Rainbow Trout into Lake Roosevelt (Peone, 2015; Kain and others, 2017). In Rufus Woods Lake, where triploid Rainbow Trout are raised for aquaculture in net pens, some triploid Rainbow Trout are released intentionally and some escape from net pens (Keleher and Cross, 2016). Triploid Rainbow Trout stomachs (n=409) collected from fish captured in gill nets and creel surveys indicated no piscivory with fish primarily consuming *Daphnia*, copepods, ostracods, dipterans, snails, and arthropods (Richards and others, 2011). Stable isotope analysis could provide a broader analysis of otherwise undetected piscivory by triploid Rainbow Trout across varying habitats, seasonal and diel time periods, and consumer sizes.

Burbot (*Lota lota*)

Competition score = 1.0

Although there is little information on Columbia River Burbot, they are an important fish to the UCUT. Although Burbot are ESA-listed in the Kootenai River system, Burbot abundance in Lake Roosevelt increased from 2003 to 2011 and remained stable from 2012 to 2015 (Golder, 2017). Burbot generally are piscivorous, but the first foods of young Burbot are pelagic food items such as phytoplankton and zooplankton (Hardy and others, 2008). Therefore, in limnetic parts of rivers and reservoirs, Burbot likely have shared resources with planktivorous fishes. First feeding Burbot can consume items as small as 200–300 µm. Larger Burbot are unlikely to compete with juvenile salmon because they predominately consume fish (38 percent), isopods (35 percent), and insects (11 percent; Polacek and others, 2006). Spatial differences in Burbot diet also have been noted, though no information exists for first feeding Burbot. Polacek and others (2006) speculate that Burbot growth and condition factor were limited by invertebrate and forage fish productivity in Lake Roosevelt.

Predator-Prey Relationships

Overall, workshop participants identified Smallmouth Bass, Walleye, and Northern Pike as the greatest predation risks to juvenile salmon (predation score range, 4.7–2.9). White Sturgeon, Redband Trout, Burbot, and Northern Pikeminnow (predation score range, 2.9–2.2) also were identified as potential predators of juvenile salmon, but with a lower relative predation risk. Finally, Brown Trout, Brook Trout, Yellow Perch, triploid Rainbow Trout, and Largemouth Bass also were identified as potential predators of juvenile salmon, but with relatively low predation risks. Only White Sturgeon was identified as a predation risk to adult salmon (appendix B, table B10). Although not identified by workshop participants, Sculpin greater than 100 mm can be important predators of juvenile salmonids.

Smallmouth Bass (*Micropterus dolomieu*)

Predation score = 4.7

Smallmouth Bass have a high abundance and wide distribution throughout Lake Roosevelt, including larger tributary, main-stem, and reservoir habitat. The group assumed that Smallmouth Bass would pose a substantial and perhaps the greatest predation risk to juvenile salmon of all piscivores; however, there was some uncertainty regarding the extent of spatial and temporal overlap between smallmouth bass and juvenile anadromous salmonids. Predation of subyearling Chinook Salmon can begin when Smallmouth Bass are about 150 mm (Fritts and Pearsons, 2004). As with other predators, predation by Smallmouth Bass is greatest when juvenile salmon are nearshore and as temperatures begin to warm in spring

Walleye (*Sander vitreus*)

Predation score = 4.0

Nonnative Walleye have a wide distribution throughout the Columbia Basin where they are both an important game fish and predator of juvenile salmonids. In the lower Columbia River, juvenile salmon accounted for 14 percent of Walleye diets (Poe and others, 1991; Rieman and others, 1991). In particular, Walleye mostly prey on subyearling Chinook Salmon in August when their distributions overlapped in reservoirs. However, unlike Northern Pikeminnow that tended to consume salmonids in tailrace reaches, Walleye tended to consume salmonids in middle to lower reaches (Vigg and others, 1991). However, Walleye in Lake Roosevelt and Rufus Woods consume salmonids throughout the entire area.

Walleye are abundant and have a wide distribution throughout much of the upper Columbia Basin. They are abundant in Rufus Woods Lake and Lake Roosevelt, and they are increasing upstream of Little Falls Dam on the Spokane River. They also are found throughout the Kettle River upstream to Barstow, Washington. Because Walleye are the primary predator of kokanee and Rainbow Trout in Lake Roosevelt (Baldwin and Polacek, 2002), they likely would prey heavily on introduced juvenile salmonids. The heaviest predation of juvenile salmonids was from 3- to 4-year-old Walleye in Lake Roosevelt (Baldwin and Polacek, 2002; Stroud and others, 2010). Walleye consumed about 10–15 percent of hatchery-released kokanee in Lake Washington and 7.3 percent of hatchery-released Rainbow Trout (Baldwin and others, 2003). A bioenergetics study on the Sanpoil Arm noted that Walleye and Smallmouth Bass consumed 94.7 percent of the outmigrating kokanee fry, 40.1 percent of the kokanee yearlings planted, 24.0 percent of the age 1 outmigrating Redband Trout, and 27.4 percent of the age 2 and age 3 outmigrating Redband Trout (Stroud and others, 2010).

Northern Pike (*Esox Lucius*)

Predation score = 2.9

Nonnative Northern Pike are a recent introduction to the upper Columbia River and pose a substantial predation risk to juvenile salmon. They consume large quantities of trout and salmon (Jepsen and others, 1998) and have already led to population declines of native Bull Trout (*Salvelinus confluentus*) and Westslope Cutthroat Trout (*O. clarkii lewisi*) in the upper Columbia Basin (Muhlfeld and others, 2008). In Coeur d'Alene Lake, Idaho, Northern Pike also have been implicated in the decline of Westslope Cutthroat Trout (Walrath and others, 2015). Northern Pike distribution in the upper Columbia River is expanding rapidly and aggressive removal programs are already in place (Holly McLellan, Confederated Tribes of the Colville Reservation, oral commun., August 16, 2016). However, they have not expanded their distribution downstream into Rufus Woods Lake (Benjamin Cross, Confederated Tribes of the Colville Reservation, oral commun., August 16, 2016). In the Susitna River, Alaska, where Northern Pike were introduced in the 1950s, they consume a substantial biomass of juvenile salmon that could lead to the collapse of salmon runs in some tributaries (Sepulveda and others, 2015). The greatest predation risk may be to juvenile Chinook and Coho Salmon that rear in vegetated, slow- moving river reaches along shorelines (Sepulveda and others, 2013).

White Sturgeon (*Acipenser transmontanus*)

Predation score = 2.2

Although White Sturgeon populations downstream of Bonneville Dam are relatively robust, many impounded reaches in the Columbia Basin have had poor recruitment (Muir and others, 2000). White Sturgeon populations in the Transboundary Reach and the Arrow Reservoir reaches have been adversely affected by lack of recruitment since the early 1980s. Currently, little if any recruitment of upper Columbia River White Sturgeon have placed this population at severe risk of extinction (Hildebrand and Parsley, 2013). Hatchery fish currently supplement aging wild populations.

White Sturgeon historically relied on spawning runs of adult salmon for food. Historically, large salmon runs were an abundant food supply that were seasonally important to the over-winter survival and fecundity of White Surgeon. With anadromous runs now gone, large White Sturgeon stage at the mouths of tributaries to consume spawning Rainbow Trout and kokanee, and their eggs (Hildebrand and Parsley, 2013). With much of the historical habitat of White Sturgeon fragmented from impoundment, dam tailraces have become important feeding areas for adults (Hildebrand and Parsley, 2013).

Young White Sturgeon also are important components of food webs. In free-flowing reaches downstream of Bonneville Dam, White Sturgeon primarily consume *Corophium* spp. and various life stages of dipterans (Muir and others, 2000). White Sturgeon transition from feeding on invertebrates to fish at 60–80 cm, but fish become the primary prey at 80 cm (Muir and others, 1986).

Redband Trout (*Oncorhynchus mykiss gairdneri*)

Predation score = 2.0

Juvenile salmon can face substantial predation pressure from resident trout and juveniles of other anadromous fishes. In Lake Washington, juvenile Sockeye Salmon are consumed by steelhead smolts (Beauchamp, 1995) and by resident Cutthroat Trout *O. clarkii* (Nowak and others, 2004). In the Cedar River, Washington, resident Cutthroat Trout consume one-third of Chinook Salmon smolts, and larger Rainbow Trout consume many Sockeye Salmon fry (Tabor and others, 2012). Rainbow Trout also are known to consume salmon eggs (Eastman, 1996; Meka and others, 2003).

Burbot (*Lota lota*)

Predation score = 2.0

Burbot can prey on eggs and all stages of juvenile salmon. They can focus on hatchery releases of juvenile salmon and on spawning kokanee. In Lake Roosevelt, the distribution of Burbot changes seasonally from deeper benthic habitats in winter and spring to nearshore habitats in summer and fall (Polacek and others, 2006). These shifts generally are associated with increases in the percentage of fish in the diet of Burbot. Subyearling Chinook Salmon, which rear in nearshore areas, might be more susceptible to Burbot predation.

Northern Pikeminnow (*Ptychocheilus oregonensis*)

Predation score = 1.3

Northern pikeminnow are substantial predators of juvenile salmon in the lower Columbia River, with mean consumption rates as high as 2.0 salmon per day (Vigg and others, 1991). Northern Pikeminnow generally are piscivorous when greater than 250 mm, but had the highest predation rates when greater than 450 mm. The highest salmonid predation rates were in July in the McNary Dam Tailrace. The total loss of juvenile salmon to predation was estimated at 2.7 million, with Northern Pikeminnow accounting for 78 percent of this loss (Rieman and others, 1991). However, the loss of juvenile salmon to Northern Pikeminnow is considerably less in unimpounded reaches of the Columbia River (Tabor and others, 1993).

Although Northern Pikeminnow historically were abundant in the river section now impounded by Lake Roosevelt, recent surveys indicated that they comprise less than 5 percent of the gill net catch. The completion of Grand Coulee Dam indirectly resulted in declines of native cyprinids (Suckers, Northern Pikeminnow, and Redside Shiners) by providing suitable habitat for Walleye, Yellow Perch, and Smallmouth Bass that were subsequently introduced. Small numbers of Northern Pikeminnow collected for stomach analysis indicated mostly empty stomachs in Lake Roosevelt (Baldwin and others, 2003). Larger populations exist in parts of the upper Columbia River and Long Lake on the Spokane River, Washington, where Pikeminnow comprise nearly 50 percent of the biomass of offshore sampling (Osborne and others, 2003). During 2010–12, native Peamouth, Redside Shiners, and Northern Pikeminnow comprised 91percent of screw trap catch in the Kettle River (Knudson and Nichols, 2015). Generally, populations in the middle and lower parts of Lake Roosevelt are low (about 3 percent of catch from Fall Walleye Index Netting [FWIN] surveys), with greater populations in the upper part and tributaries of Lake Roosevelt (Knudson and Nichols, 2015). Stable isotope studies would provide information on the feeding ontogeny and degree of piscivory on salmon-like prey compared to alternative forage fishes.

Brown Trout (*Salmo trutta*)

Predation score = 1.0

Nonnative Brown Trout can be piscivorous as they grow. Small Brown Trout could prey on salmon eggs and parr. Their distribution is limited and they are rarely caught in standardized sampling throughout Lake Roosevelt and its tributaries, with the exception of the Colville River downstream of Meyers Falls and the tailrace of Little Falls Dam at the upstream end of the Spokane River arm (Knudson and Nichols, 2015). Brown Trout are known to inhabit parts of the Spokane River drainage upstream of Little Falls Dam and Rufus Woods Lake, and there is some natural reproduction in the Nespelem River.

Brook Trout (*Salvelinus fontinalis*)

Predation score = 1.0

Like Brown Trout, Brook Trout have ontogenetic changes in their diet and can become piscivorous as they grow. Like Brown Trout, much of their predation risk to introduced juvenile salmonid also will likely be in tributary habitats where cooler water temperatures are closer to their thermal optimum. However, standardized surveys throughout Lake Roosevelt rarely find Brook Trout (Knudson and Nichols, 2015). Although they are found in tributary surveys, their abundance is relatively low.

Levin and others (2002) reported higher survival and predicted higher population growth rate of juvenile salmon in remote wilderness streams without Brook Trout. Although the mechanisms are unclear, the authors conclude that Brook Trout consume eggs and fry; they also may out-compete juveniles. In Lake Independence, California, nonnative Brook Trout were a substantial predator of Lahontan Cutthroat Trout (*0. clarkii henshawi*) fry in the single spawning tributary. Ongoing removal programs using electrofishing have increased the number and size range of juveniles and have led to overall population growth (Scoppettone and others, 2012). Macneale and others (2010) reported that co-occurring Brook Trout and juvenile Chinook Salmon did not compete for food based on interspecific interactions, but larger fish generally beat out smaller ones in Summit Creek, Idaho. However, later in summer, Chinook Salmon juveniles displaced larger Brook Trout.

Yellow Perch (*Perca flavescens*)

Predation score = 1.0

Nonnative Yellow Perch are known piscivores, but their gape size likely limits their predation of salmonids to fry and small parr. Yellow Perch are present throughout the shallow areas of Lake Roosevelt. They are present in Rufus Woods, but are not abundant in Lake Roosevelt. They are not an important sport fish, but are the fourth most abundant fish collected in littoral fish sampling surveys (boat electrofishing, seine netting, and fyke netting) after Walleye, Lake Whitefish, and Smallmouth Bass. Yellow perch are abundant in Lake Spokane—a Spokane River reservoir upstream of Little Falls Dam (Osborne and others, 2003).

Triploid Rainbow Trout (*Oncorhynchus mykiss*)

Predation score = 0.7

Triploid Rainbow Trout might prey on eggs of spawning fish in tributaries. Larger Rainbow Trout could prey on fry, parr, and smolts. Habitat overlap with reintroduced salmonids probably will be moderate to high depending on introduction location.

Largemouth Bass (*Micropterus salmoides*)

Predation score = 0.3

Predation by nonnative Largemouth Bass on juvenile salmon generally is lower than Smallmouth Bass, owing to the more restricted distribution of Largemouth Bass. Largemouth Bass are restricted to warm water temperatures and have limited access to juvenile salmon in spring and early summer. In the upper Columbia Basin, the distribution of Largemouth Bass is limited to a few tributary mouths, and they rarely are encountered (Knudson and Nichols, 2015). They are present in Lake Spokane, although their abundance is uncertain. In Lake Washington, Washington, predation of Largemouth Bass on juvenile Chinook, Coho, and Sockeye Salmon is low overall (Tabor and others, 2007).

Reintroduction Strategies

A conceptual design of a decision support framework for selection of a reintroduction strategy (fig. 3) was developed for managers and decision makers to better understand the interplay between reintroduction program goals, release strategies, and donor selection. There was a general consensus that more specific information on release locations and program goals was needed to select appropriate release strategies and numbers. Furthermore, these choices also would be influenced by the donor selection. Thus, the difficulty lies in which decision is made first, with the understanding that there is an interplay among them all. Without that context, a few case studies of other successful species reintroduction strategies are provided within the discussion to inform this study. Additionally, examples of how the decision support process for the reintroduction strategy could inform release strategy selections are provided for each species in the discussion.

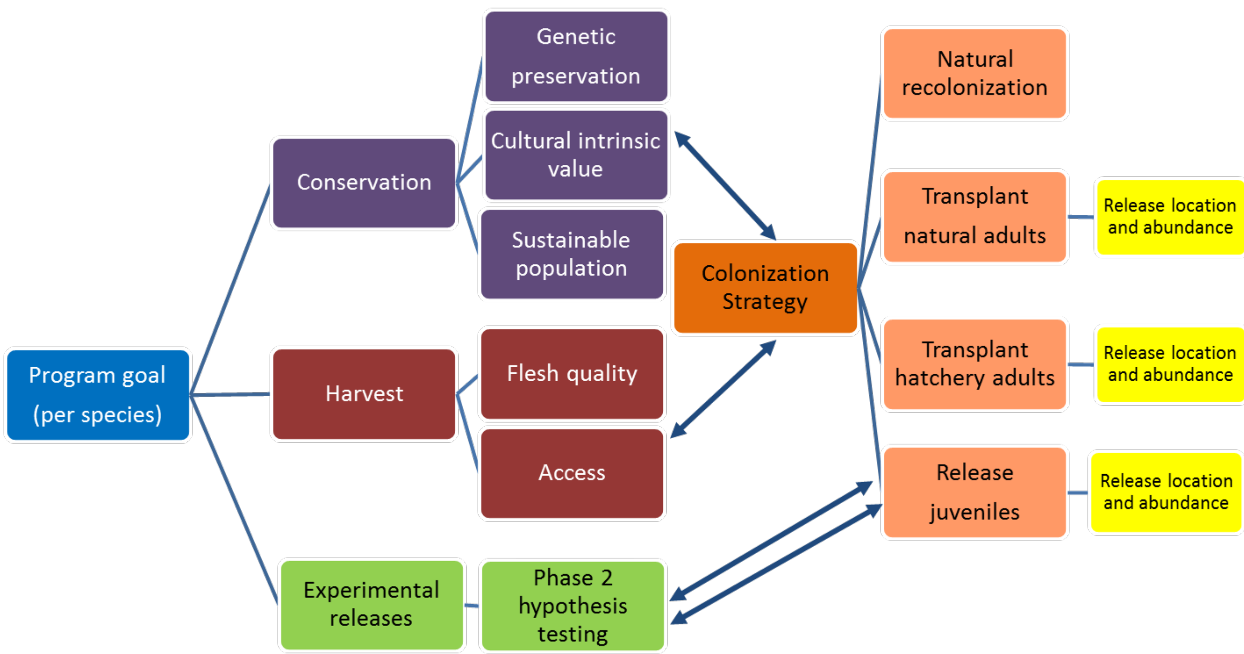

Figure 3. Conceptual diagram of a decision support framework for selection of a reintroduction strategy.

The four reintroduction release strategies considered included: (1) natural recolonization, (2) transplant of natural-origin adults, (3) transplant of hatchery-origin adults, and (4) hatchery juvenile releases. Each strategy has benefits, risks, and constraints, as well as uncertainties associated with it, and can vary by species. Given that the current geographic area is blocked without passage, an active colonization strategy will be necessary. However, if passage was restored and natural recolonization was a viable strategy, there are some considerations associated with this strategy. The benefits include fish that are naturally reaching the reintroduction, and spawning habitats likely are predisposed for life history compatibility (that is, migration distance and timing) and local adaptation. Furthermore, from an evolutionary perspective, natural selection will act on spawning, egg incubation, and early life stages of naturally produced progeny. These natural progeny also have time to acclimate and acquire environmental cues that may help with homing compared to transplanted juveniles. The risks include pathogen introduction and genetic hybridization with resident fish (that is, kokanee and Rainbow Trout). These risks also would be associated with transplanting natural-origin and hatchery-origin adults.

However, some screening can avoid sources with known pathogen occurrences in an active transplant release strategy. An additional constraint associated with transplanting adults involves artificial selection of individuals into the reintroduction site. Benefits for hatchery juvenile releases include low pathogen risks owing to biosecurity programs and, in the short-term, low genetic risk to resident conspecifics. A constraint associated with hatchery juvenile releases includes less or no acclimatization time in natural spawning and rearing areas that may impact the ability of adults to home back to suitable spawning areas and may increase adult straying rates. An additional constraint is that hatchery juveniles have experienced a different natural selection regime than natural-origin rearing juveniles (that is domestication) and may reduce survival and fitness. Experimental releases and monitoring could reduce uncertainty by informing managers on habitat use (that is, stream compared to reservoir), growth performance, species interactions (that is, predation and competition), and survival.

Understanding the factors that influence the ability of reintroduction programs to produce adults that successfully immigrate, spawn, and produce successful, out-migrating offspring is critical and warrants bi-lateral discussion. It is well documented (Connor and others, 2013; Anderson and others, 2014; Galbreath and others 2014; Fast and others 2015) that juvenile salmon and steelhead released into under-seeded habitats can reach the sea, return to freshwater, home to release points, and spawn and produce out-migrating offspring, provided the following conditions are present:

1. The targeted habitat is suitable for production,
2. The reintroduced stock evolved under habitat conditions similar to the targeted habitat,
3. The in-river environments are not lethal, and
4. Passage facilities at dams are functional during seaward migration and adult return.

The latter point here is important for the UCR reintroduction region and will need to be addressed in either infrastructure or management actions for the long-term viability of a reintroduction program. Successful reintroduction programs can still occur even if all these conditions are not yet established; however, extra emphasis may be needed on other management considerations (that is, trap and haul procedures and donor choice).

The four potential reintroduction strategies were ranked based on their probability of success in the short and long terms for Rufus Woods Lake and Lake Roosevelt for each of the reintroduced salmonids. We assumed that fish passage would not be available for short-term (<5-year) considerations, but could be available for long term (>5-year) considerations. Natural recolonization was not considered for the short term in Rufus Woods Lake.

Workshop participants prioritized the reintroduction of natural-origin, summer and fall Chinook Salmon adults first, followed by hatchery-origin adults, and hatchery juveniles last (subyearlings and smolts). In the short term, no other release strategies were prioritized for other species in Rufus Woods Lake. For long-term strategies in Rufus Woods Lake (assumption of volitional passage), natural recolonization was prioritized as the highest reintroduction strategy for all species along with hatchery juvenile releases for summer/fall Chinook Salmon. In considering steelhead in Rufus Woods Lake in the long term, the conservation of Redband Trout genetic integrity was a high priority. Thus, reintroduction of known natural-origin anadromous returns from Redband Trout adults also was considered a high priority, followed by releasing hatchery smolts (Redband Trout broodstock). For summer and fall Chinook Salmon in Rufus Woods Lake in the long term, releasing juvenile hatchery-origin subyearlings and smolts also was considered a high priority equal to the natural recolonization strategy, whereas releasing both natural- and hatchery-origin adults became a low priority. For the remaining species (spring Chinook Salmon, Sockeye Salmon, and Coho Salmon), release strategies were not developed in the workshop, as questions remained about availability and suitability of habitat for these species in Rufus Woods Lake.

We did not consider natural colonization a viable short-term option for reintroduction upstream of Grand Coulee Dam. In considering the most likely strategy to succeed, reintroduction of natural-origin adults received the highest priority for summer and fall Chinook Salmon, Sockeye Salmon, and steelhead (if known-origin adults). For spring Chinook Salmon, reintroducing hatchery-origin adults was considered the most likely release strategy to succeed, but ESA listings would need to be considered. Release of hatchery-origin adults was considered the second-highest priority release strategy for summer and fall Chinook and Sockeye Salmon. It was not considered for steelhead. Experimental releases of hatchery juveniles also were considered for summer Chinook Salmon, Sockeye Salmon, and steelhead. Coho Salmon reintroduction release strategies were not considered likely to succeed. However, if Coho Salmon were deemed as a Tribal cultural priority, reintroduction strategies would be further considered. In the long term, with the assumption of volitional passage, natural recolonization was not considered as a likely strategy to succeed on its own. However, the advantage of a natural recolonization strategy is that it removes the human element of deciding which fish goes where, and allows for natural selection; therefore, it is a critical component of reintroduction if conservation is a program goal. A successful long-term recolonization strategy likely would require a combination of release strategies, including volitional passage and supplementation with hatchery adults and juveniles. This likely would apply to all reintroduced species and would follow the same priority pattern considered downstream of Grand Coulee Dam.

Discussion

Donor Sources

Steelhead Donors

Upper Columbia River Redband Trout were identified as the steelhead donor with the lowest genetic risk to Redband Trout. We considered Redband Trout as a donor because steelhead life history traits might be retained in resident trout populations (Holecek and Scarnecchia, 2013). Tagging data suggest that Sanpoil River Redband Trout may express anadromy. For example, Sanpoil River Redband Trout tagged in 2012 and 2013 moved upstream through Rock Island and Wells Dam fish ladders in spring 2015 (Jones and McLellan, 2017), consistent with the migration timing of adult steelhead. Additionally, Passive Integrated Transponder tags from wild juvenile Redband Trout in the Sanpoil River have been detected in the Columbia River Estuary on the tern colony at East Sand Island (Jones and McLellan, 2017).

Redband Trout have a wide distribution in the UCR. Therefore, interactions with introduced steelhead are likely and could lead to interbreeding of life history types (Zimmerman and Reeves, 2000; Christie and others, 2011). Sympatric steelhead and Redband Trout populations likely are more resilient because they have multiple life history strategies within a population. Interbreeding between anadromous and resident fish can buffer populations from environmental impacts, promote gene flow, and decrease the effects of inbreeding depression (Kostow, 2003, Christie and others, 2011). Interbreeding between hatchery and wild populations can lower reproductive success (Araki and others, 2009; Christie and others, 2014). Therefore, steelhead donors that are genetically related to resident fish may help maintain local adaptations and reduce the effects of outbreeding depression.

Redband Trout collected in Lake Roosevelt tributaries and the Spokane River have high levels of genetic diversity, represent several genetically distinct populations, and are subject to minimal introgression with hatchery coastal Rainbow Trout (Spokane and Goldendale strains) and Redband Trout (Phalon Lake strain; Powell and Faler, 2002; Small and others, 2007; Young and others, 2008; Small and others, 2013; Jones and others, 2016; Small and others, 2016a, 2016b). Admixture with hatchery Rainbow Trout in Lake Roosevelt tributaries and the Spokane River Basin generally is limited. For example, hatchery Rainbow Trout have been introduced in the Sanpoil River where three Redband Trout life histories occur—fluvial, fluvial-adfluvial, and lacustrine-adfluvial. Genetic analysis of these life histories indicates minimal admixture with hatchery Rainbow Trout (Jones and others, 2016). Furthermore, in samples from 20 tributaries and 3 main-stem reaches of the Spokane River, Redband Trout admixture with hatchery coastal Rainbow Trout was suspected in the lower Little Spokane River and Buck, Marshall, Deep, and Dartford Creeks, and with non-native Westslope Cutthroat Trout in Nehchen Creek (Small and others, 2007). Nevertheless, Small and others (2007) concluded that genetic impacts of hatchery Rainbow Trout on native Redband Trout were less than expected. Genetic assignment tests on Redband Trout from Lake Roosevelt suggest that Redband Trout migrate throughout Lake Roosevelt but originate from tributaries as far as 161 km (100 mi) away (Small and others, 2016a). Lake Roosevelt may serve as a conduit for gene exchange among Redband Trout populations (Small and others, 2016a, 2016b), which could have implications for steelhead reintroductions. Therefore, resident Redband Trout donors could be used to establish anadromous populations.

However, resident Redband Trout might not establish anadromous populations. Another, strategy could be to reestablish historical interactions between resident and anadromous populations using anadromous steelhead donors. However, the time frame for evaluation of this strategy is unknown. This strategy also would require approval from the National Oceanic and Atmospheric Administration because steelhead are ESA-listed as threatened and, therefore, introducing them to areas beyond their current distribution requires additional regulatory considerations. Multiple reintroduction strategies and donors for geographic locations where resident Redband Trout occur also might be appropriate.

Chinook Salmon Donors

Spring Chinook and summer/fall Chinook Salmon donors from the UCR had low levels of genetic risk, and could be suitable for reintroduction. Pathogen risk and donor attribute rankings of Chinook Salmon in the donor synthesis tables will facilitate donor selection. In considering Spring Chinook Salmon donors, the program goal (for example, conservation or harvest) also will be important because Spring Chinook Salmon have the additional consideration of ESA-listed fish.

The CJH had the highest selection rank for spring Chinook Salmon and is not ESA listed, as broodstock originated from the LNFH. This donor ranked highest primarily by the high availability rank and low genetic and pathogen risks. The genetic risk of this stock is that it could stray to downstream extant populations. The LNFH spring Chinook Salmon have a low stray rate (Cooper and others, 2006), and by 2019, the CTCR will have a better understanding of what the stray rate is for the new program at CJH. If CJH spring Chinook Salmon have a high stray rate then, their genetic risk score could change considerably. Although the other attribute scores were lower ranking than many of the other donors, particularly for Spring Chinook Salmon, some can be offset potentially through management practices (Paquet and others, 2011). Furthermore, Warnock and others (2016) observed that Carson hatchery-origin fish were genetically similar to Wenatchee River natural-origin Spring Chinook Salmon.

The CJH also was the highest-ranked donor source for the summer/fall Chinook Salmon. This program uses a high proportion of natural-origin broodstock from the Okanogan River and has been meeting the Hatchery Scientific Review Group targets for percent hatchery-origin spawners (pHOS) and proportionate natural influence (PNI), which should improve productivity of the natural-origin spawners. However, it was noted that fall Chinook Salmon in the Hanford Reach has had record high escapement numbers for 3 consecutive years (2013, 2014, and 2015; Richards and Pearsons, 2016) and abundance may have been under-ranked in the donor synthesis table (table 4) of the Hanford Reach upriver bright Chinook Salmon. An additional consideration would be to add a donor source for collection at Priest Rapids Hatchery of natural- and hatchery-origin summer/fall Chinook Salmon, which may have surplus fish available. Another factor not assessed in this risk assessment that could affect the decision in choosing between these two stocks is flesh quality. It was noted that summer Chinook Salmon arrive earlier and have higher flesh quality in the terminal fishing areas than Hanford Reach upriver bright, and, therefore, may be more desirable to Tribal fishermen.

Hatchery management practices can influence the genetics of wild fish (Campton, 1995). Adaptation to captivity can occur in a single generation (Christie and others, 2012). Therefore, supplementation programs may benefit from natural-origin broodstock sources that live in the wild (Hess and others, 2012). In Columbia River tributaries, hatchery-origin spring Chinook Salmon releases have a minimal effect on the genetic diversity of non-target natural-origin populations, suggesting low levels of straying and introgression (Narum and others, 2008; Matala and others, 2012; Van Doornik and others, 2013). Indeed, straying of spring Chinook Salmon from the Cle Elum Supplementation and Research Facility into non-target systems was negligible (Fast and others, 2015). Interestingly, these fish had different morphometric and life history traits than natural-origin fish (Fast and others, 2015).

Hatchery-origin Chinook Salmon that spawn in the wild have varying reproductive success (Williamson and others, 2010; Hess and others, 2012; Anderson and others, 2013; Sard and others, 2015). Williamson and others (2010) reported that hatchery-origin fish produced fewer progeny than natural-origin fish. Hatchery-origin males had lower (but not significantly different) reproductive success than natural-origin males, but females did not have these differences (Anderson and others, 2013; Sard and others, 2015). Although Hess and others (2012) noted that hatchery-origin males had significantly lower reproductive success overall, there was no difference between hatchery- and natural-origin fish that reproduced. The reproductive success of hatchery-origin females was variable, but was not significantly different from natural-origin females. There is evidence that transplanted hatchery- and natural-origin adult Chinook Salmon can contribute to juvenile production in historical habitats (Evans and others, 2015; Sard and others, 2015), as in the active transport and haul release strategy that was used for reintroduction of Chinook Salmon upstream of Cougar Dam on the South Fork of the McKenzie River, Oregon. Other studies of transport and haul strategies upstream of dams indicate success in contributing to natural salmon production for Chinook Salmon, particularly if downstream passage is available (Evans and others, 2015). Although many studies had varying and sometimes inconclusive results on reproductive differences and ultimately fitness for hatchery- and natural-origin fish, most recommend using natural-origin fish if they are available near the reintroduction area (Anderson and others, 2014; Evans and others, 2015; Fast and others, 2015; Sard and others, 2015).

Sockeye Salmon Donors

Lake Roosevelt kokanee was identified as the Sockeye Salmon donor that posed the lowest genetic risk and had the highest selection rank. Lake Roosevelt kokanee apparently have some Sockeye Salmon life history traits (Holly McLellan, Confederated Tribes of the Colville Reservation, oral commun., August 16, 2017). For example, adults have higher growth rates than other kokanee populations, and some kokanee downstream of Chief Joseph Dam are detected in the Columbia River Estuary. This suggests that some kokanee have migratory behavior, as observed in other kokanee populations in British Columbia that reverted to anadromy (Godbout and others, 2011). Seaward migration of kokanee also has been observed in Skaha Lake, British Columbia (Richard Bussanich, Okanagan Nation Alliance, oral commun., January 5, 2017), where Sockeye Salmon were reintroduced. Interestingly, reintroduction of Sockeye Salmon into Skaha Lake has led to hybridization with kokanee (Veale and Russello, 2016). Veale and Russello (2016) reported that hybrids represented 15 percent of age-0 fish, were intermediate in size, and had reduced fitness for traits associated with anadromous and freshwater life histories. Hybridization generally occurs through male kokanee associating with spawning Sockeye Salmon (Foote and Larkin, 1988).

Upper Columbia River kokanee have high genetic diversity and represent genetically distinct populations (Kassler and others, 2010). Lake Roosevelt and Sanpoil River kokanee have little genetic variation, but these stocks were more similar to each other than to other kokanee populations. The Chain and Christina Lakes (British Columbia) populations are distinct from other populations. The Chain Lake population is very small and likely cannot support any meaningful reintroduction efforts. Most unmarked kokanee surveyed from Lake Roosevelt were assigned back to the Lake Roosevelt reporting group (Kassler and McLellan, 2013; Kassler and McLellan, 2014; Kassler and others, 2016). However, numerous kokanee were assigned back to the Lake Whatcom hatchery and the Arrow Lakes, British Columbia, reporting groups. Otolith analysis indicated that some individuals from Lake Roosevelt assigned back to the Lake Whatcom Hatchery reporting group immigrated from Lake Pend Oreille (Wolvert and McLellan, 2015). This suggests that Lake Roosevelt may serve as a conduit for gene exchange among kokanee populations. Furthermore, assignment of individuals back to the Arrow Lakes reporting group suggests that some kokanee downstream of Keenlyside Dam migrate to Lake Roosevelt.

Iwamoto and others (2012) identified contemporary genetically distinct Sockeye Salmon populations in Lake Wenatchee, Okanogan River, and Redfish Lake, and four historical groups were identified. Each contemporary group likely aligned with a historical group, suggesting that one of the historical groups might be extirpated. Iwamoto and others (2012) also suggested that the extirpated group may have originated in headwater lakes of the Columbia River.

The Okanogan River natural-origin Sockeye Salmon population had a slightly lower rank than Lake Roosevelt kokanee in terms of their weighted grand total score (table 5). Their abundance has been high in recent years and they are available for capture in Priest Rapids and Wells Dam fish ladders. Sockeye Salmon (presumably both Wenatchee and Okanogan donors) also are found in the Chief Joseph Dam fish ladder, although in smaller numbers (Kassler and others, 2017 a, 2017b). There is considerable uncertainty regarding the success and timeline for reprogramming kokanee into Sockeye Salmon. However, landlocked *O. nerka* populations impounded for 90 years by dams on the Alouette and Coquitlam Rivers, British Columbia (Godbout and others, 2011), reverted to an anadromous life history. If the genetic risks of introgression with the extant kokanee population are deemed acceptable (score = 3, moderate), the reintroduction scenario using Okanogan River Sockeye Salmon could be considered. Furthermore, the use of Sockeye Salmon for a donor source over a kokanee population will emphasize the existing anadromous life history behavior and may reduce the potential for residualization.

Coho Salmon Donors

Coho Salmon donors were identified as having an equal and relatively low level of genetic risk. The donor sources with the nearest geographic proximity (Wenatchee and Methow Rivers) had the highest selection rankings with very similar scores (table 6). These donor sources, located in the UCR ESU, had been established from lower Columbia River broodstock. Interior Columbia River Coho Salmon were considered extirpated in the 1980s (Galbreath and others, 2014). In recent years, Tribal programs have reintroduced hatchery-origin Coho Salmon, and within 3–5 years have natural-origin spawning occurring (Galbreath and others, 2014). Reintroduction programs have been established by the Yakama Nation in the Yakima River, and in the Methow and Wenatchee Rivers, and also by the Nez Perce Tribe in the Clearwater River. The common approach among all these programs was initiation with acclimation and release of out-of-basin lower Columbia River (LCR) smolts, and transition to production of smolts from adults returning in-basin to develop a localized stock.

The Yakima River Coho Salmon reintroduction broodstock also originated from LCR stock and has now transitioned entirely to Yakima River hatchery- and natural-origin broodstock. Additionally, hundreds of redds are observed annually and a portion of the adult return is naturally spawned fish. In an experimental study to determine negative effects of Coho Salmon on ESA-listed spring Chinook Salmon, marked Coho Salmon were released where there were high densities of Chinook Salmon fry. Of more than 2,000 smolts recaptured downstream, only two fish contained *Oncorhynchus* spp. upon stomach content examination, and post release predation on spring Chinook Salmon was deemed insignificant (Dunnigan, 1999). To expand the area into which Coho Salmon would establish themselves, temporary acclimation facilities were used in tributary streams as well as releasing juvenile parr and allowing for overwintering in the streams before out-migration. Data for these approaches suggested that returning adults showed high homing fidelity to their release streams (Yakama Nation, 2011). The Yakima Basin Coho Salmon Master Plan calls for a conservation hatchery in tributary streams with an annual escapement goal of 3,500 natural-origin fish to the upper Yakima Basin, which, if consistently achieved, will phase out the supplementation program.

The Methow River program began with LCR smolts for rearing and release from Winthrop NFH. However, emphasis switched from this program to the Wenatchee River with the Leavenworth NFH. As of 2003 and 2006, all broodstock production comes from mid-Columbia River for Wenatchee and Methow River runs, respectively for the Yakama Nation reintroduction program. The Yakama Nation Fisheries program also has investigated potential impacts and interactions with these programs to ESA-listed spring Chinook Salmon and steelhead, and concluded that little or no negative impact has resulted (Galbreath and others, 2014).

Although Coho Salmon donors are not likely related to the historical ancestry of Coho Salmon in the UCR, there is little genetic risk associated with a reintroduction program. Furthermore, pathogen and ecological risks to other salmonid species also seem negligible. In considering the successful reintroduction programs by the Yakama Nation, it seems reasonable to think that similar procedures could be used in the UCR.

Ecological Impacts

Competition for Food and Space

In the workshops, we identified Redband Trout, kokanee, and triploid Rainbow Trout, as the primary competitors of reintroduced salmonids. Competition for space likely will occur in tributary habitats, whereas competition for food is more likely to occur in reservoir habitats. In particular, competition between Redband Trout and reintroduced salmonids is more likely in tributary habitats, whereas competition between reintroduced salmonids and kokanee would occur in reservoir habitats. Sockeye Salmon are the only species that are likely to spend an entire year feeding in Lake Roosevelt, potentially competing with kokanee and Redband Trout for zooplankton. Other smolts and transient parr may feed for days to months while migrating through the reservoirs. Estimating the prey demand for a hypothesized population of Sockeye Salmon relative to other fish that consume zooplankton, although not estimated as part of this risk assessment, would characterize the rearing capacity for both resident and introduced salmonids.

Quantifying Zooplankton Production

Current data suggest that food is not limiting to planktivores in Lake Roosevelt; however, there is no published information quantifying the consumptive demand of the primary competitors identified in the workshops. In John Day Reservoir, a comparison of *Daphnia* production to consumption rates of juvenile American Shad (*Alosa sapidissima*) indicated that the nonnative planktivore could consume as much as 83 percent of the existing zooplankton production (Haskell and others, 2013). Clarke and Bennett (2007) used a similar approach to quantify *Daphnia* production in Lake Pend Oreille, Idaho, and concluded that increases in kokanee abundance probably would be constrained by *Daphnia* abundance. Similar approaches incorporating the proposed number, species, and life stage of introduced salmonids need to be used to fully assess the ability of existing food webs to accommodate anadromy (for example, Hansen and others, 2016; Sorel and others, 2016a). Existing long- term datasets of *Daphnia* densities could be used to compare expected consumptive demands to *Daphnia* production estimates.

Effects of Reintroduction on Nutrient Balances

The Spokane Tribe has a long-term dataset of limnological parameters from Lake Roosevelt, but there is a need for macro analysis to develop forward-looking predictive models incorporating operations and biological changes resulting from reintroduction. For example there seems to be little concern for how reintroduction might affect nutrient balances in Lake Roosevelt or tributary habitats. Further analyses could simulate the effect of differing run sizes of anadromous salmonids on nutrient loads given adult run sizes. Similar analyses were recently done for nonnative American Shad using historical and current run sizes of Pacific Salmon, American Shad run sizes, juvenile population estimates from dam indices, and a long-term nutrient monitoring site downstream of McNary Dam (Haskell, 2017). These analyses indicated that the nutrient balances are a product of existing nutrient loads, reservoir retention times, adult run sizes, and the spatial extent of spawning. Although the introduction of anadromous salmonids upstream of Grand Coulee Dam is likely to result in a net import of nitrogen and phosphorus that could stimulate productivity, it also could result in a net export during some years (West and others, 2010). Using long term-nutrient databases, projected run sizes of anadromous fish, and species-specific nutrient concentrations, nutrient flux estimates from reintroduction of anadromy could be achieved and then related to existing nutrient balances.

Unintentional Introduction of Nonnative Invertebrates

Although not identified in workshops as species of interest, the potential effects of unintentional introductions of nonnative invertebrates from downstream should be a concern. In the lower Columbia River reservoirs, upstream movements of nonnative and historically estuarine invertebrates have largely followed the footprint of impoundment. For example, the Siberian prawn, *Exopalaemon modestus*, originally introduced in the Columbia River Estuary through barge traffic, expanded its range upstream, and is now an important component of reservoir food webs as predator and prey (Haskell and others, 2006; Erhardt and Tiffan, 2016). Similarly, the estuarine mysid, *Neomysis mercedis*, has extended its range into lower Columbia and Snake River reservoirs (Haskell and Stanford, 2006) and has become abundant. The calanoid copepod, *Pseudodiaptomus forebesi*, was introduced in the Columbia River Estuary, has expanded its range upstream, and now dominates the plankton community in lower Columbia River reservoirs (Emerson and others, 2015). Other examples of range expansion include the Asian clam, *Corbicula fluminea*, and the amphipod, *Corophium* spp. Before fish passage infrastructure is emplaced, UCUT might want to gain a better understanding of the potential risk of upstream colonization by nonnative invertebrates in Lake Roosevelt and upstream reservoirs.

Functional Response Trials

Functional response models are a fundamental framework used to examine prey consumption as a function of prey density. Functional response model development could be an important tool to examine potential interactions between juvenile salmon and resident species of interest. Although three primary types of functional response are recognized, species of interest for competition likely have Type-II responses. Both kokanee (Koski and Johnson, 2002) and fall Chinook Salmon (Haskell and others, *In Press*) have a Type-II response with changes in *Daphnia* density. However, kokanee may have a greater ability to exploit *Daphnia* at densities greater than 10/L—well within the range of *Daphnia* reported in Lake Roosevelt (fig. 4). A comparative functional response approach is warranted to assess potential competition between anadromous salmonids and resident taxa with shared prey. Functional response experiments can be done in controlled laboratories and, therefore, do not require large field crews. Feeding trials can simulate the range of life stages and conditions in the wild (light, water temperature, and prey densities). These approaches also have been used to assess the effect of nonnatives on native consumption rates of shared prey (Dick and others, 2013).

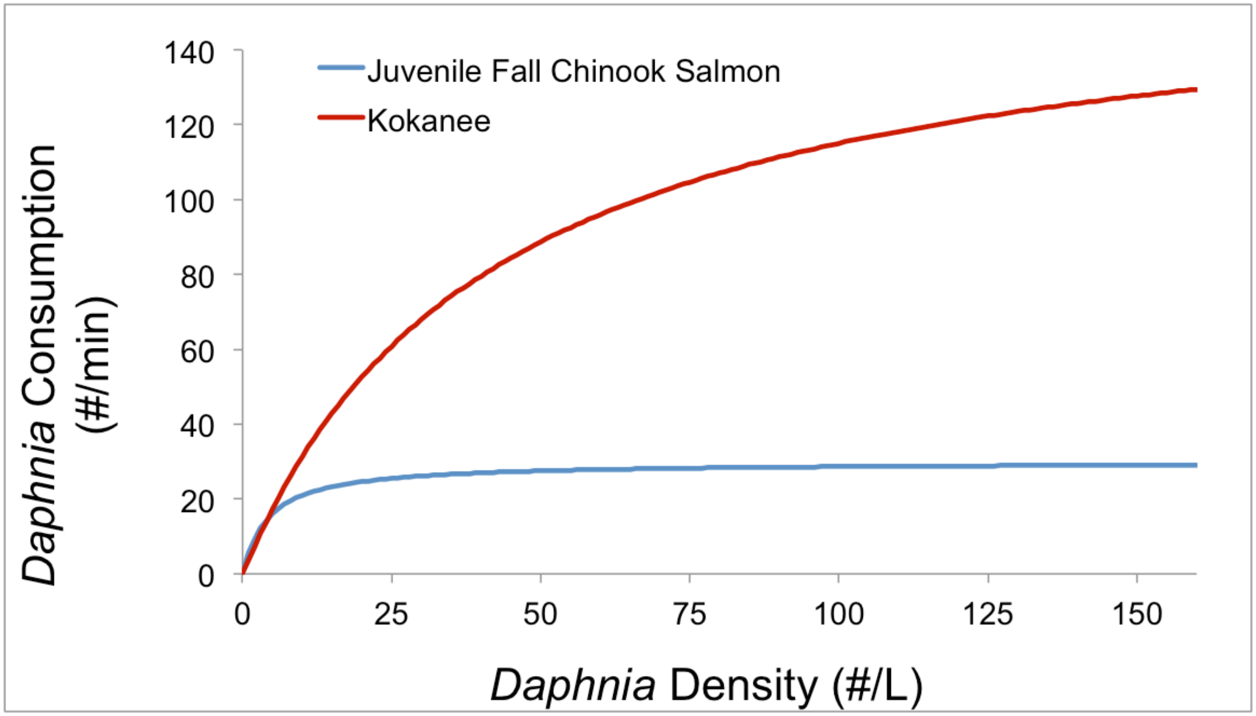

Figure 4. Functional response curves for kokanee (Koski and Johnson, 2002) and juvenile fall Chinook Salmon (Haskell and others, *In Press*). #/min, number per minute; #/L, number per liter.

Predator Prey Relationship

Predation risk to introduced juvenile salmon probably will be high overall, but will vary greatly depending on spatial and temporal overlap with potential predators. Stable isotope analysis would inform feeding ontogeny and degree of piscivory on salmon-like prey compared to alternative forage fishes. This type of analysis is especially useful for piscivores that have high numbers of empty stomachs from regurgitation and rapid digestion (for example, Northern Pikeminnow during summer). Stable isotopes also could provide a better overall assessment of fish that are consuming juvenile salmonids and could be coupled with past and new diet studies to estimate the overall consumption demand on resident and future anadromous salmonids, as was done in Lake Merwin, Washington (Sorel and others, 2016b).

This synthesis is limited by lack of knowledge about the seasonal timing, tributary specific whereabouts, life-stage, and number of salmonids introduced in a given scenario. Given these constraints, we developed overall scores for reintroduction. Future work identifying potential release scenarios could incorporate the scores reported in the tables. This synthesis identified the species posing the greatest relative predation risks to reintroduced salmon. The UCUT could build on this work by estimating the populations of the major predators and respective predation rates on juvenile salmonids in tributary, main-stem, and reservoir habitats. Two primary information pieces are missing to evaluate predation: (1) population data on potential predators and prey and the consumption rate of the predators, and (2) the number and timing of juvenile salmon to be introduced. Future work is needed to quantify populations of the primary predators and competitors identified in this report. Given populations of these fishes, an overall consumptive demand could be developed for the primary predators and their prey. Experimental releases of juvenile salmon could be used to estimate survival through various reservoir reaches. If survival is high, then predation might not be a major limiting factor requiring further study. If survival is low, then studies could further investigate survival bottlenecks including predation.

We identified Smallmouth Bass, Walleye, and Northern Pike as the primary predators of juvenile salmon in Lake Roosevelt and its tributaries. Unfortunately, few formal studies document the population sizes, size structures, and consumption rates of these predators. However, in the lower Columbia River, Rieman and others (1991) did an analysis of juvenile salmonid predation loss in John Day Reservoir and estimated 2.7 million salmonids were consumed annually. Of the mean total, 78 percent were consumed by Northern Pikeminnow, 12 percent by Walleyes, and 9 percent by Smallmouth Bass. Overall, 14 percent of all juvenile salmonids were consumed and predation was highest for Chinook salmon juveniles during July and August—presumably, subyearlings. The risk of predation to juvenile salmonids could be estimated based on estimated juvenile salmonid numbers, life history type, and the predator population sizes of Smallmouth Bass and Walleye in Lake Roosevelt.

Although we did not capture it in our analysis, the size relationship between predator and prey are important considerations regarding predation estimates of introduced salmonids. In the lower Yakima River, Washington, Fritts and Pearsons (2004) reported that 42.9 percent of salmonids were consumed by Smallmouth Bass ranging from 150 to 199 mm fork length (FL), 69.6 percent of salmonids were consumed by Smallmouth Bass less than 250 mm FL, and 83.6 percent of salmonids were consumed by Smallmouth Bass less than 300 mm FL. As expected, small Smallmouth Bass were more numerous but they also consumed more salmonids per capita (Fritts and Pearsons, 2006). Therefore, size-specific consumption rates are necessary to fully assess predation risk to juvenile salmonids from Smallmouth Bass. In contrast, intermediate and large-sized Northern Pikeminnow (>400 mm FL) consumed more salmonids than smaller Northern Pikeminnow (Rieman and Beamesderfer, 1990). The prey-to-predator size ratio is greater for nonnative Smallmouth Bass than for native Northern Pikeminnow owing to differences in gape size and behavior.

Fritts and Pearsons (2004) estimated that Smallmouth Bass annually consumed more than 200,000 juvenile fall Chinook and about 3,000 juvenile Spring Chinook in the Yakima River, Washington. Of the fall Chinook consumed, an estimated 85 percent were wild. Thus, the smaller size of juvenile fall Chinook relative to other salmon life histories and the smaller size of wild fish relative to hatchery reared fish make them most susceptible to Smallmouth Bass predation. These findings are relevant to managers attempting reintroduction of anadromous salmon upstream of Grand Coulee through hatchery releases of juvenile fall Chinook Salmon. In addition to predator-prey sizes, thermal regimes and degree of habitat overlap also will dictate which species and life stages are the most vulnerable to predation (Beauchamp and others, 2007).

A Geospatial Approach for Ecological Risk Assessment

Estimating the risks that reintroduced salmonids will face or the threats they might pose to native resident fishes could be further understood using a spatially explicit (geographic information system [GIS]) approach that facilitates a reach-by-reach examination of potential interactions. Fortunately, GIS and National Hydrography Dataset Plus are ideally suited for this task because stream reaches have a unique identifier and can be viewed in medium (1:100,000) or fine (1:24,000) resolution. Overlaying known or hypothesized fish locations will enable the identification of potential conflicts and risks at different life stages for a target species. Conflict codes can be generated under multiple reintroduction scenarios or management objectives, enabling better planning and risk assessment. Such an approach could be implemented for the entire project area or in focal reaches where pilot reintroduction efforts might occur.

Reintroduction Strategies

In further addressing reintroduction release strategies, a discussion and examples of how to apply the decision support framework (fig. 2) to the donor species are provided to emphasize some of the primary considerations. For steelhead reintroduction, conservation was the primary goal, and conservation of Redband Trout genetic integrity was identified as a priority. A secondary goal was some Tribal harvest in the future. Using Redband Trout as a donor source poses the least risk to existing fish; however, reestablishment of anadromy is uncertain. If volitional passage is restored, natural recolonization strategies would require extensive efficacy monitoring. If passage is restored, then the blocked area also is open to natural recolonization by downstream populations of mixed hatchery- and natural-origin fish. Furthermore, straying is common among steelhead, and can occur at higher rates in hatchery-origin populations than in natural-origin populations (Keefer and Caudill, 2014). Extensive monitoring and management of mixing of steelhead populations will be a consideration if passage is restored in the future.

In considering the reintroduction release strategies, the framework developed by Pearsons and Hopley (1999) to address uncertainty could be helpful. Ultimately, managers and policy makers will consider stakeholder (Tribal and managers) values to decide if scientific uncertainty, risk management, and risk containment warrant acceptance of a strategy. For steelhead reintroduction, it is uncertain if Redband Trout will adapt to an anadromous life history. This uncertainty would be weighed against the risk of potential loss of genetic integrity using other potential donor sources (that is, hatchery- or natural-origin steelhead) and pathogen introductions. Risk containment could range from some monitoring of Redband Trout for anadromous behaviors to intensive monitoring to minimize interactions of reintroduced donors with native Redband Trout to minimize inbreeding and genetic mixing. There is uncertainty whether Redband Trout will establish an anadromous life history with volitional passage, and there is risk of genetic mixing of other donor sources with Redband Trout. Containment risk is high for this strategy because Redband Trout are widely distributed in the UCR and interactions are likely. However, if fish passage is established, risks will be harder to manage. An alternate release strategy might be considered if either the uncertainty associated with establishment of an anadromous run is too high or if harvest was the program goal. In this scenario, transplanting of hatchery- or natural-origin adults or hatchery juveniles could be considered.

For steelhead reintroduction considering donor sources other than the Redband Trout, the natural-origin runs were ranked lower because of high demographic risk to the source populations; thus, transplanting natural-origin adults from these populations may not be a viable option to consider. The Eastbank Hatchery/ Wenatchee River Hatchery programs ranked the second highest and would be a viable option in years that those populations have an excess of hatchery fish requiring management actions for removal to meet pHOS objectives. Pathogen risks were considered equal and high among all the non-native donor sources. Transplanting hatchery-origin adults and juveniles have the risk of hybridization and loss of genetic integrity. Furthermore, with unknown downstream passage abilities, the chance of residualization and spawning with native Redband Trout exists. There are many uncertainties about all these reintroduction strategies (as discussed in section, "Uncertainty in Risk Assessment"), and thus the risks and benefits will need to be thoroughly weighed with stakeholder values and resource management priorities.

The program goals discussed for Spring Chinook Salmon reintroduction were conservation and harvest, but would have additional policy and management considerations (Dunham and others, 2016). Program goals would directly influence donor selection under this consideration. For example, if conservation is the program goal, then ESA-listed fish would be emphasized, but if harvest is the primary goal, then non-ESA listed fish would be emphasized. Furthermore, if harvest is the goal, flesh quality, access, and the extent to which non-ESA listed fish will impact downstream fisheries would be considered. Additionally, experimental releases may be considered to further inform knowledge gaps and uncertainties associated with the reintroduction.

The CJH source was ranked as the most suitable selection within the donor synthesis table for Spring Chinook Salmon. If the program goal was for harvest and experimental release, this would be a suitable choice. Uncertainty with this selection would be the potential effect of stray rate to downstream extant species and uncertainty regarding survival through the reintroduction area. Using the CJH source minimizes the pathogen risks, which were considered low, as well as the demographic risk, also considered low. However, if conservation and natural spawning are objectives, then the CJH and LNFH broodstock sources may not be good choices. These are highly domesticated stocks that have a long history of concrete-to-concrete performance with little evidence of natural reproduction. The Carson/LNFH stock was released for decades in the Entiat and Methow Rivers without effective segregation from the wild population and did not result in viable populations (Casey Baldwin, Confederated Tribes of the Colville Reservation, written commun., May 26, 2017). Likewise, this stock has access to spawning and rearing areas in Icicle Creek and the entire Wenatchee River Basin, but it homes very efficiently back to the LNFH broodstock ladder. Other risk minimization strategies would include broodstock management and harvest management (Paquet and others, 2011; Anderson and others, 2014). Risk containment strategies would be continued monitoring for pathogens, strays into downstream extant populations, harvest management, and continued broodstock management. Survival of juveniles and downstream passage will ultimately be considerations for any reintroduction release strategy in the UCR.

If conservation was the program goal for spring Chinook Salmon, then emphasis would be placed on using ESA-listed fish to establish a sustainable natural population. Use of these fish would require additional consultation with Federal agencies and the proper permits, potentially an Endangered Species Act section 10(j) designation could be obtained for experimental releases for a reintroduction program (Dunham and others, 2016). This also would require an extensive monitoring plan and mitigating the potential for any adverse impacts on downstream ESA-listed fish. Benefits could be an increase in the number of naturally spawning fish in an ESU population, reestablishing occupancy in historical habitat, increased geographic diversity and spatial structure, and promoting ecological and evolutionary processes for local adaptation and diverse life histories (Anderson and others, 2014). The order of release strategy prioritization would be natural recolonization if passage was available, transplanting of natural-origin adults, followed by hatchery-origin adults from ESA listed programs (that is, Winthrop and Eastbank Hatcheries), and juvenile hatchery releases. In the absence of volitional passage, one consideration for surplus fish or broodstock source would be to use natural or ESA-listed hatchery fish that volunteer to the CJH ladder (or other collection location developed in the tailrace of CJH). These fish have downstream source populations (Methow, Entiat, and Wenatchee Rivers), but have shown the propensity to migrate to Chief Joseph Dam and could increase the success rate of their offspring for migrating further upstream.

For summer/fall Chinook Salmon, all viable donor sources are not ESA listed, and the genetic and pathogen risks were the same (low to moderate) among the top choices. The selection ranks primarily were driven by availability. Program goals discussed were harvest, conservation, and the establishment of a sustainable population. Release strategies similar to those applied to spring Chinook Salmon would be applied to summer/fall Chinook Salmon; however, risks to downstream populations would be considered lower.

Reintroduction release strategies for Sockeye Salmon emphasize using native kokanee from Lake Roosevelt, with program goals including harvest and conservation. As with the native Redband Trout, there is some uncertainty associated with whether Lake Roosevelt kokanee will establish an anadromous run, and whether hybridization with anadromous Sockeye Salmon would alter the native kokanee genetic integrity and reduce fitness. There is some concern that Lake Roosevelt kokanee may not be abundant and available as a broodstock source for an anadromous life history trait. This source was still ranked the highest considering the other donor attributes and risks (table 5), but only by a slim margin compared to Okanogan River Sockeye Salmon. Under a conservation program goal, risk minimization strategies would include using only Lake Roosevelt kokanee as a donor source, maintaining the lowest genetic and pathogen risks. Another consideration would be native kokanee that may overlap with Sockeye Salmon populations and the potential for hybridization to reduce fitness of the Sockeye Salmon population. Risk containment would consist of monitoring for evidence of anadromous life history traits (that is, outmigrating juveniles and genetic similarity in Sockeye Salmon from sources outside the reintroduction region), and maintaining or increasing abundance through harvest management to increase broodstock availability.

Alternatively, if the reintroduction program goal and priority is to establish a Sockeye Salmon population with harvest, the Okanogan River natural-origin source could be the best donor choice. The uncertainty associated with this release strategy would again be hybridization with the native kokanee and potential for reduced fitness and loss of genetic integrity of native kokanee, and increased pathogen introductions. Risk minimization strategies would include minimizing overlap with native kokanee where hybridization may occur. A phased approach over time using multiple release strategies and donors also may be appropriate considering the program goals if the benefits are considered greater than the risks and constraints.

Coho Salmon program goals discussed were harvest and conservation. Based on the success of other Coho Salmon reintroduction programs, there seem to be more benefits and less risks associated with this species. In considering reintroduction strategies, availability of donor source may drive release strategy. Reintroduction programs established by the Yakama Nation with juvenile hatchery releases have proved successful (Galbreath and others, 2014). Recently, Liermann and others (2017) documented successful transplanting of hatchery-origin adult Coho Salmon in tributary streams in the Elwha River Basin leading to immediate spawning and smolt out-migrants per kilometer comparable to other Coho Salmon populations in the Pacific Northwest. Natural recolonization also has been documented through detection of juvenile productivity in two tributaries and smolt out-migrants in the main stem in the White Salmon River Basin, Washington (Jezorek and Hardiman, 2017). There is still uncertainty about overall capacity and habitat availability, and potential for ecological concerns with other reintroduced species and native Redband Trout. Experimental releases in which knowledge gaps and uncertainty can be reduced could be considered. Another consideration for Coho Salmon is that their flesh quality may not be as good as that of some other species once they reach the terminal areas far upstream from the ocean (similar to fall Chinook Salmon). The UCUT and other fish managers likely will consider the harvest objectives and cultural value of this species. Coho Salmon may still have cultural and intrinsic value as an important species to the Tribe and the ecosystem, but they may be lower on the priority list for harvest in the terminal area when compared to Spring Chinook, Sockeye, and Summer Chinook Salmon.

For all the reintroduction species, a series of potential release strategies will need to be considered in which the potential risks and critical uncertainties will be identified (for example, reservoir survival, density-dependent competition, etc.) for each species reintroduction strategy and location. Other important considerations include habitat availability, species interactions, biotic resistance, density dependence, and productivity of reservoirs and tributaries. Planning and deliberate implementation for successful reintroduction programs can reduce many of the risks associated with reintroduction.

Experimental releases may be a way to reduce uncertainty about many of the reintroduction release strategies; however, reversibility (mitigation) of these actions and impacts need to be considered. This is especially true for the Redband Trout and native kokanee populations. Well-designed experimental releases for hypothesis testing and monitoring will increase our understanding of ecological impacts of reintroduction on resident fish—in particular, conspecific donors with kokanee and resident Redband Trout to potentially reduce the loss of genetic diversity and fitness. Phased approaches, using single or multiple donor sources, multiple release strategies (transplanting juveniles and (or) adults) and locations, as well as management practices, will all influence the success of the reintroduction program and inform an adaptive management approach. Unanticipated adverse impacts of management actions should be considered, as well as establishment of acceptable impacts to native fish and downstream conspecifics (Pearsons, 2008). Furthermore, an adequate monitoring program should be designed to detect such impacts. However, it is difficult to scientifically detect—in a timely manner through abundance monitoring—small impacts that may be important to managers (Ham and Pearsons, 2001; Pearsons, 2008). As connectivity is reestablished, the risk of movement and expansion of invasive species (upstream and downstream) also will need to be considered.

Uncertainty in Risk Assessment

We recognize that there are uncertainties associated with the risk-assessment methodology applied herein that could potentially bias our findings. Nevertheless, the attributes and risk categories used in this assessment have been considered as important and valuable components of reintroduction assessments (Pearsons and Hopley, 1999; Anderson and others, 2014; Houde and others, 2015; Warnock and others, 2016). Here, we identify several potential uncertainties and biases that may be associated with the risk-assessment methodology. Subjective rankings and expert opinions from regional biologists can potentially introduce bias (Pearsons, 2008). However the use of subjective rankings and expert opinions for risk-assessment procedures has been established (Pearsons and Hopley, 1999; Pearsons and others, 2012) and provides a rapid way to do a risk assessment that is repeatable and transparent, and can be updated with new information. Although preliminary tables for genetic risk, competition, and predation (tables B3, B9, and B10) included uncertainty scores with subjective rankings, the donor source tables (B4–B8) did not include an uncertainty score, as it was difficult to assign uncertainty (that is, variability) to each attribute that could be summarized into one grand and (or) weighted total score. Instead, median scores were used to capture the central tendency of the regional and technical experts. However, some variation did exist, implying some uncertainty about final ranking values, which is not implicitly captured in the synthesis tables. This happened when regional experts differed in opinions (perhaps based on local knowledge or perceived value of resource) or in their interpretation of the underlying assumptions with a particular attribute. Furthermore, we recognize that some attribute categories could be correlated or considered redundant, resulting in the unintentional overemphasis of some attributes. Although the attribute definitions were different, some attributes had similar assumptions. For example, geographic proximity could imply likeliness for more similar ancestry/genetics, local adaptation, and compatible life history strategies for nearby donor sources.

It is important to consider the potential for unintended outcomes associated with reintroduction efforts (Pearsons, 2008), as introduced species may behave in novel or unexpected ways in a new environment. Residualization is one such unintended outcome. Residualism may be permanent in that migratory species may abandon migration altogether and stay in freshwater habitats for the remainder of their existence. Temporary residualization can occur when a migratory species temporarily delays seaward migration to remain in freshwater for some period of time (for example, over winter) before completing migration at a later date. If reintroduced species permanently residualized in Rufus Woods Lake or Lake Roosevelt, they may pose ecological and genetic risks to resident species. For example, residualized steelhead, because of their relatively larger size, could prey on smaller juvenile salmon and steelhead as well as eggs of spawning fish in tributaries (Beauchamp, 1995; Eastman, 1996; Meka and others, 2003). This could increase the mortality of the native Redband Trout and kokanee. Additionally, returning adult steelhead and Sockeye Salmon could hybridize with native Redband Trout and kokanee, as well as with conspecifics. Interbreeding between residualized and returning anadromous adults could increase the hybridization burden (for example, fitness reduction) on native populations relative to the hybridization burden imposed by returning anadromous adults only. Therefore, using Redband Trout and kokanee donor sources for reintroduction could alleviate negative genetic effects that could result from interbreeding with residualized individuals.

Permanent residualization of anadromous salmonids is not a common occurrence (there are very few published reports) at a population level, but it has occurred in lakes in Washington, Idaho, and California (Romer and Monzyk, 2014; Perales and others, 2015). The best known example is the establishment of naturally reproducing populations of Chinook Salmon, Coho Salmon, and steelhead in the Great Lakes following their introduction in 1967 and where environmental conditions are favorable (Peck and others, 1999). In Quartzville Creek and Green Peter Reservoir in Oregon, an adfluvial life history form of Chinook Salmon was documented following their reintroduction upstream of a high-head dam in this upper Willamette River Basin system (Romer and Monzyk, 2014). Alternate life history forms are more likely to result from temporary residualization caused when artificial barriers prevent migration between freshwater and saltwater habitats (Quinn and Meyers, 2004) or from migratory delay (Connor and others, 2005). Temporary residualization may not necessarily mean that fish will complete their migration to the ocean once they resume downstream movement. Landlocked Coho Salmon emancipated from Riffe Lake into the Cowlitz River downstream of the lake failed to emigrate seaward, which may have been owing to a combination of environmental cues and fish physiological status (Kock and others, 2011). Whether either form of residualization will occur in fish reintroduced upstream of Chief Joseph and Grand Coulee Dams is difficult to say. Given the size of Rufus Woods Lake and Lake Roosevelt, combined with large-scale lentic habitats, smolts may have difficulty navigating to potential downstream passage options within the normal smolt migration window. However, the relatively high flow rates through these reservoirs may provide the migratory cues anadromous fish need to successfully emigrate through them, thus minimizing the incidence of residualization. Residualization or delayed migration of any species under consideration would add to the complexity and challenges associated with monitoring, research, and reintroduction.

Summary

There are many aspects of reintroducing salmonids into the upper Columbia River (UCR) not covered in this report. Establishment of a successful reintroduction program is complex, and an adaptive management approach would be beneficial. The U.S. Geological Survey (USGS) did not focus on economic costs or risks, program goals, or priorities associated with salmonid reintroduction to the UCR, but recognized that these factors will influence management decisions. A consideration not addressed in this report was the process in which Tribal leader preferences may be established concerning first foods, harvest, and reestablishing cultural practices around salmon, and how these preferences will influence program goals for reintroduced species. This process might take into consideration flesh quality, access, species preference, prioritization for harvest, and restoration of cultural practices.

This risk assessment is an initial first step to better understand reintroduction risks and donor selection. There are still many unknowns (for example, reservoir survival, fish passage, density-dependent competition, habitat suitability, etc.) to be considered in moving forward. Studies targeting areas where insufficient data or critical uncertainties remain would be prudent. These may include studies to determine the habitat availability and suitability, potential production capacity of reintroduction areas, survival, and fish passage investigations.

The USGS has provided a process and framework for selecting donor species. The framework developed in this report could and should be modified as new information (such as donor availability, compatibility, and pathogen risks) becomes available, and the tables could be reevaluated and updated. The framework provided for decision support for reintroduction release strategies also can be modified as program goals and priorities are established.

Acknowledgments

We thank the members of the Upper Columbia United Tribes (UCUT) work group for hosting two workshops in Spokane, Washington, and for providing invaluable input to the risk assessment. Bret Nine has been very helpful in contract administration of this project for the UCUT workgroup. All the workshop attendees listed in appendix C provided input to the risk assessment. In particular, Casey Baldwin provided detailed comments that greatly improved the final risk assessment report. We also thank the following UCUT members for their review comments and local knowledge input: Conor Giorgi, Holly McLellan, Jason McLellan, and Bret Nine. We thank the following reviewers who provided insightful and helpful comments: Dave Beauchamp, Joseph Anderson, Don Ratliff, and Jason Dunham. We also thank our colleagues from the Western Fisheries Research Center for assistance in proposal development: Noah Adams, Ken Tiffan, John Plumb, and Russ Perry. We thank the U.S. Geological Survey Priority Landscapes project for providing financial assistance toward completion of this project.

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Glossary

Broodstock Adult fish used by hatcheries to propagate the next generation of fish (Hatchery Scientific Review Group, 2009).

Conservation program A conservation program may be designed to prevent extinction, preserve the genetic diversity of the population, and (or) provide a demographic safety net (Hatchery Scientific Review Group, 2009).

Distinct Population Segment (DPS) A listable entity under the Endangered Species Act (ESA) that meets tests of discreteness and significance according to U.S. Fish and Wildlife Service and National Oceanic and Atmospheric Administration fisheries policy. A population is considered distinct (and hence a "species" for purposes of conservation under the ESA) if it is discrete from and significant to the remainder of its species (based on factors such as physical, behavioral, or genetic characteristics), it occupies an unusual or unique ecological setting, or its loss would represent a significant gap in species range (National Oceanic and Atmospheric Administration, 2015).

Evolutionary Significant Unit (ESU) An evolutionary significant unit is a Pacific Salmon population or group of populations that is (1) substantially reproductively isolated from other conspecific populations, and (2) represents an important component of the evolutionary legacy of the species (National Oceanic and Atmospheric Administration, 2015).

Genogroup Within a single species of pathogen, a group of genetically similar pathogen strains or types.

Hatchery-origin fish Fish that were spawned or reared in a hatchery and can be associated with a hatchery program.

Hatchery-origin spawners (HOS) Hatchery-origin fish that spawn in the wild (Hatchery Scientific Review Group, 2009).

Harvest program A harvest program is designed primarily to provide recreational, Tribal, and (or) commercial harvest opportunities. Harvest programs should be designed to meet well-defined goals (for example, specific harvest levels) without causing adverse impacts to naturally spawning populations (Hatchery Scientific Review Group, 2009).

Natural-origin fish Fish that were spawned and reared in the wild regardless of parental origin (National Oceanic and Atmospheric Administration, 2015).

Natural-origin spawners (NOS) Natural-origin fish that spawn in the wild (Hatchery Scientific Review Group, 2009).

Pathogen Microbial organism known to cause disease in fish.

Pathogen burden For any given pathogen, the amount of free microbe in the environment capable of infecting fish.

Percent hatchery origin spawners (pHOS) The mean proportion of natural spawners in a watershed or stream composed of hatchery-origin adults. pHOS = (HOS/HOS + NOS).

Appendix A. Resident Fish Species List

Table A1. Common names of species currently or historically present upstream of Chief Joseph Dam including tributaries, northeastern Washington.

Species	Native/non-native
Chinook Salmon	Native
Sockeye Salmon	Native
Coho Salmon	Native
Steelhead	Native
Pacific Lamprey	Native
White Sturgeon	Native
Mountain Whitefish	Native
Westslope Cutthroat Trout	Native
Redband Rainbow Trout	Native
Kokanee	Native
Bull Trout	Native
Pygmy Whitefish	Native
Burbot	Native
Chiselmouth	Native
Peamouth	Native
Northern Pikeminnow	Native
Longnose Dace	Native
Speckled Dace	Native
Redside Shiner	Native
Longnose Sucker	Native
Bridgelip Sucker	Native
Largescale Sucker	Native
Prickly Sculpin	Native
Mottled Sculpin	Native
Slimy Sculpin	Native
Shorthead Sculpin	Native
Torrent Sculpin	Native
Leopard Dace (documented in Canada, rare)	Native
Lake Chub (tributaries of the Kettle River, very rare)	Native
Kokanee (Whatcom hatchery stock)	Non-native
Rainbow Trout (Coastal hatchery stock)	Non-native
Goldfish	Non-native
Carp	Non-native
Tench	Non-native
Brown Bullhead	Non-native
Black Bullhead	Non-native

Species	Native/non-native
Yellow Bullhead	Non-native
Channel Catfish	Non-native
Northern Pike	Non-native
Lake Whitefish	Non-native
Brown Trout	Non-native
Brook Trout	Non-native
Lake Trout	Non-native
Tiger Trout	Non-native
Pumpkinseed	Non-native
Bluegill	Non-native
Smallmouth Bass	Non-native
Largemouth Bass	Non-native
Black Crappie	Non-native
Yellow Perch	Non-native
Walleye	Non-native
Threespine Stickleback	Non-native
Brook Stickleback (Fivespine)	Non-native
Grass Pickerel (Redfin)	Non-native
Tiger Muskellunge	Non-native
Green Sunfish (tributaries near Kettle Falls)	Non-native
Fathead Minnow (Turnbull/CCT Lakes)	Non-native
Golden Shiner (Twin Lakes)	Non-native

Appendix B. Risk Assessment Tables

Table B1. Resident fish species of interest and their geographic location by life stage, population status, and disease/pathogen burden risk.

[See table B2 for complete scientific names of pathogens. **Life stage abbreviations:** a, adult; ALL, all life stages; e, eggs; f, fry; s, smolts; SA, spawning adults; Tribs, tributaries; Lg, large; Sm, small. **Abundance ranks:** 0 = extirpated, 1 = low, 3 = moderate, 5 = high. Trend ranks: 0 = extirpated, 1 = decreasing, 3 = steady, 5 = increasing. **Distribution ranks:** 0 = extirpated, 1 = rare, 3 = narrow/limited, 5 = wide. **Disease/pathogen ranks:** LOW = pathogens are widespread in both residents and donor regions, effective control measures exist; MED = pathogens are detected in both resident and donor regions, control measures have limited success; HIGH = one or more pathogen is either not detected in donor region or no effective control measure exists; NA = not applicable: UNK = unknown. **Other abbreviations:** IHNV, Infectious hematopoietic necrosis virus; IPNV, infectious pancreatic necrosis virus; LFD, Little Falls Dam; LR, Lake Roosevelt; RW, Rufus Woods; VHSV, viral hemorrhagic septicemia virus; WSIV, White Sturgeon iridovirus]

Species	Native or non-native?	Geographic location use by life stage				Population status (rank 0–5)			Disease/pathogen concerns			Primary locations
		Tribs (Lg)	Tribs (Sm)	Main stem	Reser-voir	Abun-dance	Trend	Distri-bution	Primary pathogen burden	Species specific high risk pathogens	Relative risk (low to high)	
Chinook Salmon	Native	SA/e,f,s	SA/e,f,s	SA	ALL	0	0	0	NA	*R. salmonin-arum*, IHNV	NA	Historical— Pend Oreille River, Kootenay River and tribs, Salmon River and tribs, Columbia River below confluence with Kootenay River and downstream of Lower Arrow Lake, Spokane River, Little Spokane River, lower Hangman (Latah) Creek, Sanpoil River, and lower Colville River and Kettle River.
Chinook Salmon	Non-native	SA/e,f,s	SA/e,f,s	SA	ALL	1	1	1	NA	*R. salmonin-arum*, IHNV	MED	Some in RW (Carson hatchery-origin stock).
Sockeye Salmon	Native	SA	SA	ALL	ALL	0	0	0	NA	IHNV	NA	Historical- Upper Arrow, Lower Arrow, Whatshan and Slocan Lakes in British Columbia and tribs.
Coho Salmon	Native	ALL	ALL	ALL	ALL	0	0	0	*R. salmonin-arum, A. salmonicida, C. shasta*	*R. salmonin-arum, A. salmonicida, C. shasta*	NA	Historical—lower Spokane River, Little Spokane River, and lower Hangman (Latah) Creek, Sanpoil River, and lower Hall Creek.

Species	Native or non-native?	Geographic location use by life stage				Population status (rank 0–5)			Disease/pathogen concerns			Primary locations
		Tribs (Lg)	Tribs (Sm)	Main stem	Reser-voir	Abun-dance	Trend	Distri-bution	Primary pathogen burden	Species specific high risk pathogens	Relative risk (low to high)	
Steelhead	Native	ALL	ALL	ALL	ALL	0	0	0	NA	IHNV	NA	Historical— lower Spokane River, Little Spokane River, lower Hangman (Latah) Creek, Sanpoil River, lower Colville River, Kettle River, Pend Oreille River downstream of Metaline Falls, Salmon River and tribs, and lower Kootenai River.
Pacific Lamprey	Native	ALL	ALL	ALL	ALL	0	0	0	NA	*A. salmonicida*, *R. salmonin-arum*	NA	Historical—found in same places as salmon and steelhead before dam construction.
White Sturgeon (wild)	Native	NONE	NONE	ALL	ALL	3	1	3	NA	WSIV	HIGH	Upper one-third of LR from Gifford upstream.
White Sturgeon (hatchery)	Hatchery -origin	NONE	NONE	ALL	ALL	3	5	3	NA	WSIV	HIGH	Upper one-third of LR from Gifford upstream and upper Columbia River.
Burbot	Native	ALL	a	ALL	ALL	4	4	5	NA	*Y. ruckeri*, *A. salmonicida*, IHNV, VHSV?	MED	LR, RW.
Redband Trout	Native	ALL	a	ALL	ALL	3	3	4	*M. cerebralis, R. salmonin-arum, C. shasta, M. cerebralis, F. psychrophil-um*, *Y. ruckeri*	*M. cerebralis*, IHNV	HIGH	Widely distributed in LR and Spokane River and its tribs, isolated population in Hangman (Latah) Creek, in Sanpoil River, limited in RW.
Kokanee	Native	SA	SA	ALL	ALL	2	5	4	IHNV	IHNV	HIGH	Limited to lower/mid reservoir LR in RW outmigrants from LR. Genetically distinct population in Little Spokane River watershed, Chain Lakes.

Species	Native or non-native?	Geographic location use by life stage				Population status (rank 0–5)			Disease/pathogen concerns			Primary locations
		Tribs (Lg)	Tribs (Sm)	Main stem	Reser-voir	Abun-dance	Trend	Distri-bution	Primary pathogen burden	Species specific high risk pathogens	Relative risk (low to high)	
Northern Pikeminnow	Native	ALL	NONE	ALL	ALL	3	3	4	*R. salmonin-arum*	unknown	UNK	Less abundant in LR, Spokane River upstream of LFD, RW.
Bull trout	Native	NONE	NONE	a	a	1	3	1	*R. salmonin-arum*, *M. cerebralis*	*M. cerebralis*	MED	RW, rare.
Kokanee (Whatcom strain)	Hatchery -origin	SA	NONE	a	a	1	3	3	IHNV	IHNV	HIGH	LR, RW.
Rainbow Trout (coastal strain)- triploids	Hatchery -origin	a	NONE	a	a	4	3	4	NA	IHNV	HIGH	LR, RW.
Northern Pike	Non-native	ALL	NONE	ALL	ALL	2	5	3	NA	*Y. ruckeri*	LOW	Not yet in RW; In Spokane R upstream of LFD, and Long Lake (Lake Spokane), Kettle River, and Colville River.
Walleye	Non-native	ALL	NONE	ALL	ALL	5	4	5	NA	*F. columnare*	LOW	LR, Spokane River (spawning)
Smallmouth Bass	Non-native	ALL	NONE	ALL	ALL	5	5	5	NA	VHSV 4b	LOW	LR, RW, and Spokane River.
Largemouth Bass	Non-native	ALL	NONE	NONE	ALL	1	3	2	NA	VHSV 4b	LOW	Spokane River in impounded reaches (Long Lake, upstream of Nine Mile Falls Dam)
Lake Whitefish	Non-native	NONE	NONE	ALL	ALL	4	3	4	NA	VHSV 4b, *R. salmonin-arum*	LOW	LR (most abundant), RW.
Brook Trout	Non-native	ALL	ALL	None	None	1	3	3	NA	IPNV, *M. cerebralis*, *A. salmonicida*,	MED	Tribs to LR.

Table B2. Pathogens of management concern in the Columbia River Basin, northeastern Washington.

[The microbe name, disease caused, and host species with known disease impacts are listed. Infectious hematopoietic necrosis (IHN) virus has three lines because there are three lineages of virus that have species-specific virulence, which are indicated within brackets. The two important risk assessment criteria, risk of introduction and management strategies, are listed with the greatest risk values highlighted in gray]

Microbe	Disease in fish	Reginal species with known disease burdens	Risk Assessment: Introduction risk if absent — Present/absent in resident region	Risk Assessment: Management risk if avoidance is only strategy available — Management
Flavobacterium psychrophilum	Bacterial Coldwater Disease	Bull Trout, Sockeye Salmon/kokanee, Chinook Salmon, steelhead/Rainbow Trout, Coho Salmon	Present	Avoidance, antibiotics
Myxobolus cerebralis	Whirling Disease	Sockeye/kokanee, steelhead/Rainbow Trout, Coho Salmon	Present	Avoidance
Renibacterium salmoninarum	Bacterial Kidney Disease	Bull Trout, Sockeye Salmon/kokanee, Chinook Salmon, steelhead/Rainbow Trout, Coho Salmon	Present	Avoidance, antibiotics
Ceratonova shasta	Ceratomyxomatosis	Coho Salmon, steelhead/Rainbow Trout, Chinook Salmon	Present	Avoidance
Flavobacterium columnaris	Columnaris	Chinook Salmon	Present	Avoidance, antibiotics
Aeromonas salmonicida	Furunculosis	Sockeye Salmon/kokanee, Chinook Salmon, steelhead/Rainbow Trout, Coho Salmon	Present	Avoidance, antibiotics
Infectious Hematopoietic Necrosis Virus [UP group]	IHN	Sockeye Salmon/kokanee [UP group viruses]	Present	Avoidance
Infectious Hematopoietic Necrosis Virus [UC group]	IHN	Chinook Salmon [UC group viruses]	Absent	Avoidance
Infectious Hematopoietic Necrosis Virus [M genogroup]	IHN	steelhead/Rainbow Trout [M group viruses]	Absent	Avoidance
*Yersinia rucker*i	Enteric Redmouth	steelhead/Rainbow Trout	Present	Avoidance, antibiotics, vaccine

Table B3. Genetic risks to resident fish species.

[**Abbreviations:** SOC, Sockeye Salmon; CHK, Chinook Salmon; COH, Coho Salmon; STH, steelhead; UNK, unknown]

Interacting Species	Introduced anadromous salmonids				Factors contributing to increased genetic risk (0=none, 1=low,… 5=high)				Overall impact (0–5) (low to high)	Uncertainty Rank (0–5) (low to high)
	SOC	CHK	COH	STH	Donor stock	Existing assemblage	Reintroduction strategy	Fitness decline with hatchery stock		
Lake Roosevelt kokanee	X				5	3	5	UNK	3	4
Chain Lake kokanee	X				5	3	5	UNK	3	4
Sockeye (downstream)	X				2	2	5	UNK	2	3
Native Redband Trout				X	5	5	5	4	4	5
Steelhead (downstream)				X	4	4	5	4	3	4
Spring Chinook (downstream)		X			4	4	5	3	3	4
Fall/summer Chinook (downstream)		X			3	3	5	3	2	3
Coho Salmon (downstream)			X		3	3	5	4	2	4

Factors contributing to increased risk:

1. Donor stock choice
   a. Genetic relationship with populations in basin
   b. Genetic change with hatchery practices (loss of diversity, inbreeding, domestication selection)
   c. Is donor stock from segregated or integrated hatchery?
   d. Number of generations the stock has been artificially propagated
2. Existing assemblage (likeliness of interaction and hybridization)
   a. Native Redband Trout awaiting steelhead
   b. Native kokanee awaiting Sockeye Salmon
   c. Downstream anadromous conspecifics
3. Reintroduction strategy
   a. Natural recolonization, transplantation, or hatchery release

Table B4. Risk assessment table for steelhead donors.

[**Rank 0–5:** AV, Abundance/viability; AG, Ancestry/genetics; LA, Local adaptation; and LH, Life history compatibility. Rank values are median scores from workshop 2 participants. **Abbreviations:** ESA, Endangered Species Act; ESU, Evolutionarily Significant Unit; fpp, fish per pound; IHNV, infectious hematopoietic necrosis virus; NFH, National Fish Hatchery; pHOS, percent hatchery-origin spawners; rkm, river kilometer; tribs, tributaries; UCR, upper Columbia River]

Source/ population	Management history	Broodstock	Program purpose	Availability and production for use (constraints if known)	ESA/ ESU	Rank 0–5 (low to high)				Disease/ pathogen concerns	Other notes (for example, origin, history, etc.)
						AV	AG	LA	LH		
Eastbank Hatchery—Wenatchee and Chiwawa Rivers, and Nason Creek, summer steelhead	Release as many as 400,000 smolts to Nason Creek, upper Wenatchee River and Chiwawa River acclimation site, acclimated at Chiwawa River site only if it does not interfere with spring Chinook production. Some incubation and rearing at Chelan Falls Hatchery.	From Wenatchee River at Dryden and Tumwater Dams, hatchery origin.	Integrated conservation/ harvest program (segregated harvest as well).	Conservation fisheries to remove excess hatchery fish; could be surplus fish available, depending on escapement and pHOS. Dryden and Tumwater Dams are potential collection sites.	Threat-ened UCR ESU	3.0	3.0	3.0	3.0	IHNV	Substantial adult straying outside of basin, likely due to hatchery practices-early rearing occurs at Eastbank and Chelan Hatcheries on non-Wenatchee water sources. Effectiveness of hatchery fish spawning in wild unknown; may reduce steelhead productivity. Risk of reducing genetic diversity for natural spawners.
Wells Hatchery—Columbia, Methow, and Twisp Rivers, —summer steelhead	Releases about 320,000 smolts in Equal proportions to Twisp and Chewuch Rivers, and upper Methow River. Mixed hatchery- and natural-origin; however, the run is dominated by hatchery-origin fish.	Hatchery dominant/ natural origin mix. Adults collected at Wells Dam and Hatchery (Methow River, Twisp River) for run-at-large.	Integrated conservation/ harvest program (segregated harvest as well).	Conservation fishery to Remove excess hatchery fish; surplus depending on escapement and pHOS. High risk of reducing genetic diversity due to history of domestication.	Threat-ened UCR ESU	3.0	2.0	3.0	3.0	IHNV	Effectiveness of hatchery fish spawning in wild is unknown; may factor in reducing steelhead productivity. Historical summer steelhead abundance in Methow River estimated at about 3,600 fish

Source/ population	Management history	Broodstock	Program purpose	Availability and production for use (constraints if known)	ESA/ ESU	Rank 0–5 (low to high) AV	AG	LA	LH	Disease/ pathogen concerns	Other notes (for example, origin, history, etc.)
Omak Creek Hatchery–Okanogan and Similkameen Rivers, summer steelhead	Program in transition from Wells Dam/ Omak Creek to 100% Okanogan. Release smolts in Okanogan River and tribs. Egg incubation/rearing at Wells Hatchery. ~20,000 juvenile summer steelhead released in Omak Creek. Fish are acclimated in Omak Creek or are scatter-planted in the watershed.	Broodstock is collected at Omak Creek and the Okanogan River. The past program collected at Wells Dam. Likely a mix of hatchery and natural origin.	Integrated conservation and harvest program	Very small population and limited ability to collect surplus hatchery fish in the Okanogan watershed. Risk of reducing genetic diversity for natural spawners.	Threat-ened UCR	1.0	2.5	4.0	3.0	IHNV	The effectiveness of hatchery fish spawning in the wild compared to naturally produced spawners is unknown at this time and may be a major factor in reducing steelhead productivity. Currently, and for the past 20+ years, most steelhead spawning in the wild are hatchery fish.
Winthrop Hatchery—Methow River, summer steelhead	About 100,000 Summer steelhead smolts released from Winthrop NFH of Wells Hatchery broodstock.	Run-at-large Wells Dam broodstock—mixed hatchery natural-origin.	Mitigation program integrated harvest, conservation; some segregated harvest.	Conservation fisheries to remove excess hatchery fish so surplus fish available in future, depending on escapement and pHOS. High risk of reducing Genetic diversity for natural spawners due to history of domestication.	Threat-ened UCR	3.0	2.0	3.0	3.0	IHNV	The effectiveness of hatchery fish spawning in the wild compared to naturally produced spawners is unknown at this time and may be a major factor in reducing steelhead productivity. Currently, and for the past 20+ years, most steelhead spawning in the wild are hatchery fish.
Wenatchee, Methow, Okanogan, Entiat Rivers—natural-origin summer steelhead			Sustainable natural population	High demographic risk. Not a primary contributing population to the resource. No fish collection facilities.	Threat-ened UCR	1.0	3.5	4.0	4.0	IHNV	Wenatchee River strongest of the weak.

Source/ population	Management history	Broodstock	Program purpose	Availability and production for use (constraints if known)	ESA/ ESU	Rank 0–5 (low to high)				Disease/ pathogen concerns	Other notes (for example, origin, history, etc.)
						AV	AG	LA	LH		
Lake Roosevelt/ Sanpoil River/ upper Columbia River tribs/Spokane River and tribs, Redband Trout		Native resident	Conservation	Low abundance, return to anadromous runs will be slow, and only for conservation (no harvest) for a long time. Evidence of anadromy life history behaviors.	Threat-ened UCR	3.0	5.0	5.0	5.0	IHNV	Closely related to UCR Steelhead - genetics. Evidence of anadromous life history trait present (PIT-tag evidence out migrating). Sanpoil River may have availability and in tributaries.
Wells/Ringold Hatchery—Columbia River lower-middle main-stem summer steelhead	The Ringold steelhead program began 1963 using Skamania brood stock. In 1998, after UCR steelhead listed, the broodstock changed to Wells source.	Hatchery primarily Skamania broodstock. In 1998, the broodstock source changed to Wells stock.	Segregated—harvest	Not recommended for use. Wells Hatchery sends their overflow to Ringold just to meet legal obligations.	Threat-ened UCR	1.0	1.0	1.0	1.0	IHNV	A max of 180,000 4–5 fpp yearlings released per year, about 6 months acclimation in Ringold Spring water, released in Spring Creek, enter Columbia River at rkm 567 (downstream of Hanford Reach). Release is volitional, mid-April–early May.

Table B5. Risk assessment table for spring Chinook Salmon donors.

[**Rank 0–5:** AV, Abundance/viability; AG, Ancestry/genetics; LA, Local adaptation; and LH, Life history compatibility. Rank values are median scores from workshop 2 participants. **Abbreviations:** BKD, Bacterial Kidney Disease; CJH, Chief Joseph Hatchery; ESA, Endangered Species Act; ESU, Evolutionarily Significant Unit; ICTRT, Interior Columbia Technical Recovery Team; IHNV, infectious hematopoietic necrosis virus; LNFH, Leavenworth National Fish Hatchery; NA, not applicable; NFH, National Fish Hatchery; UCR, upper Columbia River; WNFH, Wenatchee National Fish Hatchery]

Source/ population	Management history	Broodstock	Program purpose	Availability and production for use (constraints if known)	ESA/ ESU	Rank 0–5 (low to high)				Disease/ pathogen concerns	Other notes (for example, origin, history, etc.)
						AV	AG	LA	LH		
Eastbank / Wenatchee River Hatchery programs—Wenatchee River spring Chinook	Mitigation program. Fish spawning and incubation at Eastbank Hatchery. Acclimation ponds at Chiwawa and other sites. Yearlings released in the Chiwawa River.	Spawning adults (adult captured broodstock) Wenatchee Basin and Chiwawa River and Tumwater Dam.	Integrated—Conservation/ harvest/ hatchery return.	Surplus Chiwawa hatchery adults may be available at Tumwater Dam.	Endan-gered/ UCR	3.0	3.0	3.0	2.0	IHNV	Wenatchee are more pure UCR genetic stock than Methow. Methow is closer and WNFH is giving eggs (200,000) to CJH for the Endangered Species Act section 10(j) program. re-introduction in Okanagan. Success of the Chiwawa Hatchery and natural-origin spring Chinook is unknown.
Wenatchee River natural Origin spring Chinook	Natural-origin run.	Natural-origin three extant populations—Wenatchee, Methow, and Entiat Rivers (one extinct—Okanogan).	Natural sustainable population.	Primary population. Demographic risk is high —low abundance and productivity. Potential poor response to ocean conditions, bottleneck not replacing themselves.	Endan-gered/ UCR	1.0	4.0	3.0	3.5	IHNV	The Wenatchee population is classified by the ICTRT as “Very Large”; the population has been classified as Primary.
Methow Hatchery—Methow River spring Chinook	Methow composite – hatchery—broodstock from Methow hatchery, Twisp and Chewuch Rivers, and Wells Dam.	Broodstock from Methow Hatchery, Twisp and Chewuch Rivers, and Wells Dam. Data indicate That 93 percent is of hatchery-origin.	Integrated—Conservation/ harvest.	Population diversity likely reduced due to habitat degradation, harvest, and out-of-basin stock (Carson) from Winthrop NFH. BKD can be problematic. Demographic risk is likely high in most years.	Endan-gered/ UCR	2.0	2.5	3.0	2.0	IHNV	The Methow population is classified by the ICTRT as “Very Large”; the population has been classified as Primary. Juvenile fish are acclimated at the Twisp, Methow, and Chewuch acclimation sites. Closer geographically than others.

Source/ population	Management history	Broodstock	Program purpose	Availability and production for use (constraints if known)	ESA/ ESU	Rank 0–5 (low to high) AV	AG	LA	LH	Disease/ pathogen concerns	Other notes (for example, origin, history, etc.)
Winthrop Hatchery—Methow River spring Chinook	Currently used by CTCR for the Okanogan stocking. Also released into The Methow River. Used as safety net for the Methow River Hatchery.	Composite (hatchery/ natural-origin) —Methow. Historic Carson lineage.	Integrated—Conservation/ harvest.	Carson stock used prior to 2003, with Methow R origin stock from 1999. May have hatchery surplus. BKD a reoccurring problem.	Endan-gered/ UCR	3.0	2.0	3.0	3.0	IHNV BKD	ICTRT has classified the Methow River spring Chinook as “Very Large”; the population classified as Primary.
Methow River—Natural-origin	Natural-origin run.		Natural sustainable population.	Collection of natural run of river may be difficult.	Endan-gered/ UCR	1.0	4.0	3.0	3.0	IHNV	ICTRT has classified the Methow River spring Chinook as “Very Large”; the population classified as Primary.
Winthrop / Chief Joseph Hatcheries/ 10J program–Okanogan River spring Chinook	Endangered Species Act section 10(j) program. Okanogan spring Chinook considered extirpated—Reintroduction program	Transfer of eggs from Winthrop Hatchery for production at CHJ Hatchery and release in Okanogan River.	Conservation—Integrated.	Surplus may be available. Otherwise, none available in Okanogan; collection of brood not permitted in Phase 1.	Endan-gered/ UCR.	1.0	2.0	3.0	2.0	NA	Potential surplus of fish.
Leavenworth NFH—spring Chinook	Self-sustaining segregated hatchery population of Carson stock, adapted to Wenatchee system. Juveniles released in Icicle Creek. Terminal fishery	Adult return "volunteers" to hatchery—Carson stock origin-adapted to Wenatchee River system, including Icicle Creek.	Segregated—Harvest.	Carson stock origin (out of ESU). BKD. Surplus available in some years.	Not ESA listed. Out of ESU.	3.0	1.0	2.0	1.0	*R. Salmonin-arum*, IHNV, BKD	Adapted to Wenatchee system. Warnock and others (2016) noted that there was a close genetic relationship between Carson stock and the Wenatchee River natural run stock - surrogate for UCR ESU fish.
Chief Joseph Hatchery–Lower Columbia River spring Chinook	Fish releases in Columbia and Okanogan Rivers, Omak Creek, and Salmon Creek	Adults returning to Leavenworth and Methow Rivers (Okanogan) —Carson Hatchery. origin stock	Segregated harvest only from concrete to concrete.	Leavenworth River fish-have Carson Hatchery origin stock in them. Surplus fish likely.	Not ESA listed. Out of ESU.	4.0	1.0	2.0	1.0	NA	Carson fish produced at LNFH for many generations. They are out of ESU Program also at CJH for segregated harvest—Similkameen River (satellite hatchery) in Wenatchee Basin. Warnock and Others (2016) noted a close Genetic relationship between Carson stock and Wenatchee River natural run surrogate for UCR ESU fish.

Table B6. Risk assessment table for summer/fall Chinook Salmon donors.

[**Rank 0–5:** AV, Abundance/viability; AG, Ancestry/genetics; LA, Local adaptation; and LH, Life history compatibility. Rank values are median scores from workshop 2 participants. **Abbreviations:** BKD, Bacterial Kidney Disease; CJD, Chief Joseph Dam; ENFH, Entiat National Fish Hatchery; ESA, Endangered Species Act; ESU, Evolutionarily Significant Unit; GCD, Grand Coulee Dam; IHNV, infectious hematopoietic necrosis virus; NA, not applicable; NFH, National Fish Hatchery; PNI, proportionate natural influence UCR, upper Columbia River]

Source/ population	Management history	Broodstock	Program purpose	Availability and production for use (constraints if known)	ESA/ ESU	Rank 0– (low to high)				Disease/ pathogen concerns	Other notes (for example, origin, history, etc.)
						AV	AG	LA	LH		
Wenatchee River—Natural origin	Natural run	Natural-origin.	Natural sustainable population.	Could be collected at Dryden or Tumwater Dams. Generally no surplus to support a large-scale reintroduction.	Not ESA listed. UCR	2.0	4.0	4.3	4.0	NA	Genetically similar to all other populations in the UCR.
Eastbank Hatchery / Wenatchee program Wenatchee River summer Chinook	Wenatchee River summer-fall—Have been propagated in the Wenatchee River since the late 1980s and are a mixture of native summer Chinook and returning hatchery fish.	Broodstock collected at Dryden and Tumwater Dams, nearly 100-percent Natural origin. Reared in Dryden Pond.	Integrated—Conservation/ harvest.	Numerous fish with *Saprolegnia* sp. (fungus) observed in Dryden Pond. Managers indicate frequent and shortly before release. BKD common.	Not ESA listed. UCR	3.0	3.5	4.0	3.5	BKD, *Saproleg-nia* sp.	
Methow River—Natural-origin	Natural run	Natural-origin.	Natural sustainable population/ harvest	No collection facilities; does not meet escapement objectives. High demographic risk.	Not ESA listed. UCR	1.0	4.0	4.5	4.0	NA	Disagreement on genetic similarity to UCR stocks, more similar to Wenatchee River stocks.
Wells Hatchery—Methow River/ Okanogan River summer Chinook	Long history of hatchery propagation with mixed brood stock acclimation and release at Carlton Pond.	Collected at Wells,Methow and Okanogan composite with stray fish from Wenatchee and unmarked hatchery fish.	Integrated—Sustainable population/ segregated harvest	Long history of domestication, less desirable than one of the tributary programs that have high PNI.	Not ESA listed. UCR	3.0	3.0	3.0	3.0	BKD	Hatchery population not associated with a "wild" stock. Need more information about overall summer/fall Chinook population above Rocky Reach Dam. Are main-stem spawners genetically distinct?

Source/ population	Management history	Broodstock	Program purpose	Availability and production for use (constraints if known)	ESA/ ESU	Rank 0– (low to high) AV	AG	LA	LH	Disease/ pathogen concerns	Other notes (for example, origin, history, etc.)
Okanogan River—Natural-origin	Natural run	History mixed-composite hatchery- and natural-origin Methow and Okanogan Rivers adults	Natural sustainable population/ harvest	Collection of natural run-of-river may be difficult.	Not ESA listed. UCR	1.0	4.0	4.5	4.0	NA	No strong differences between any of the UCR stocks or their counterparts from the pre-hatchery era (Hillman and others, 2015).
Chief Joseph Hatchery—(Okanogan River) summer Chinook	Similkameen has been going since the late 1980s, but the rest of the program began in 2013.	Two programs, One is integrated and uses wild brood from the Okanogan. The other is segregated using first-generation returns from the integrated program.	Integrated harvest and conservation/ segregated harvest	Surplus hatchery fish typically available. Use integrated surplus first; it may be more desirable because they have wild parents.	Not ESA listed. UCR	5.0	3.8	4.5	4.0	BKD	Need more information about overall summer/fall Chinook population above Rocky Reach Dam. Are main-stem spawners genetically distinct?
Chelan Falls Hatchery—Columbia River	Previously was Turtle Rock production but moved to Chelan Falls to enhance terminal fishery and reduce straying.	Wells Fish Hatchery.	Integrated—Harvest	No local brood collection facility.	Not ESA listed. UCR	3.0	1.0	3.0	3.0	NA	Not part of a population.
Entiat NFH—Entiat River summer Chinook	Entiat River summer Chinook—likely descendants from hatchery releases from ENFH in 1941 and 1976 and were not native to the Entiat River.	Eggs from Wells Hatchery.	Segregated—Harvest	Returning adults are not desired in the Entiat because it is not considered a historical population and because of possible competition with spring Chinook (red superimposition and juvenile rearing). Potential for source Stock if adult collection. facilities were added to ENFH.	Not ESA listed. UCR	2.0	3.0	3.0	3.0	NA	Small stock, broodstock are Mixed from Wells Dam, not clear if wild returns from the hatchery spawners could be used for reintroduction. Unsure of robustness of any of these populations. Entiat River—low abundance, stabilizing population.

Source/ population	Management history	Broodstock	Program purpose	Availability and production for use (constraints if known)	ESA/ ESU	Rank 0– (low to high)				Disease/ pathogen concerns	Other notes (for example, origin, history, etc.)
						AV	AG	LA	LH		
Hanford Reach upriver bright Columbia River Fall—Priest Rapids and Ringold Hatcheries	The Columbia River upriver bright stock is defined as wild and hatchery fall Chinook originating upstream of McNary Dam	Wild/hatchery fall chinook upstream of McNary Dam.	Conservation and harvest	Adult collection Potential at Ringold is limited. The history of avian predation and disease also inhibits salmon production. Continued use of the Ringold facilities would Require extensive renovations. BKD is a reoccurring problem.	Not ESA listed. UCR	3.5	3.5	4.5	4.5	IHNV, BKD	High abundance and productivity, but they are genetically similar to integrated hatchery fish. Harvest quality concerns? Flesh quality may be low above CJD and GCD. Hanford Reach upriver brights currently are not in decline; they are classified as strong and healthy (Hatchery Scientific Review Group, 2009).
Lyons Ferry/ Nez Perce Hatchery programs—Lower Snake River Fall Chinook	Spawning escapement natural- and hatchery-origin adults. Hatchery adults from eggs or juveniles produced at Lyons Ferry reared and released in Snake River, or from four propagation programs in Clearwater River.	Natural—Hatchery-origin Snake River Basin.	Conservation and harvest	Do not recommend for Use; out of ESU.	Threat-ened Snake River ESU. .	1.0	1.0	0.5	2.5	IHNV	Less genetic resemblance than other donors, Warnock and others, 2016. The four programs in Clearwater are Lyons Ferry Hatchery, Fall Chinook Acclimation Ponds Program, Nez Perce Tribal Hatchery, and Oxbow Hatchery fall-run Chinook hatchery.

Table B7. Risk assessment table for Sockeye Salmon donors.

[**Rank 0–5:** AV, Abundance/viability; AG, Ancestry/genetics; LA, Local adaptation; and LH, Life history compatibility. Rank values are median scores from workshop 2 participants. **Abbreviations:** CPUD, Chelan County Public Utility District; CTCR, Confederated Tribes of the Colville Reservation; ESA, Endangered Species Act; ESU, Evolutionarily Significant Unit; IHNV, infectious hematopoeitic necrosis virus; NA, not applicable; UCR, upper Columbia River; WDFW, Washington Department of Fish and Wildlife]

Source/ population	Management history	Broodstock	Program purpose	Availability and production for use (constraints if known)	ESA/ ESU	Rank 0–5 (low to high) AV	AG	LA	LH	Disease/ pathogen concerns	Other notes (for example, origin, history, etc.)
Chain Lake Native kokanee			Harvest, sustainable population	Genetic analysis by WDFW indicates Chain Lake kokanee divergent from wild and hatchery populations. May represent a unique kokanee population. Unknown anadromous life history traits	Not ESA listed. UCR	0.0	1.0	1.0	1.0	NA	Unknown—whether anadromy life history traits still present
Lake Roosevelt Native kokanee			Harvest, sustainable population	Unknown anadromous life history traits	Not ESA listed. UCR	3.0	4.5	4.5	3.0	NA	Unknown—whether anadromy life history traits still present
Lake Wenatchee—Wenatchee Sockeye/ kokanee	One of two viable Sockeye populations in Columbia River. Terminal fisheries after 24,000 sockeye passed Tumwater Dam. CPUD funded Net pen program was abandoned because lack of success.	No hatchery program. Composite–natural/ hatchery origin collected at Tumwater Dam of run At large (only wild used).	Harvest, sustainable population	Readily available at Tumwater Dam or as part of the composite at Priest Rapids Dam.	Not ESA listed. UCR	3.3	3.0	3.0	4.0	IHNV	Seem to have preference for finer substrate (Conor. Giorgi, Spokane Tribe of Indians, written commun., August 16, 2016).
Arrow Lakes—kokanee	In the late 1980s and early 1990s, upper and lower Arrow tributaries supported between 600,000 800,000 kokanee Salmon spawners, But numbers Declined steadily through 1990s to low of 97,000 in1997.	Mixed heritage from many locations; hatchery fish.	Harvest, sustainable population	Not likely that the Canadian sockeye-kokanee are closely related—not recommended to use. Mixed heritage from many location movements	Not ESA listed. UCR	2.5	4.0	4.0	3.0	IHNV	Not likely that the Canadian sockeye kokanee are closely related—not recommended to use. Mixed heritage from many location movements. May be nutrient limited ongoing fertilization project. Score was moved to a 3 in workshop 2 for ancestry.

Source/ population	Management history	Broodstock	Program purpose	Availability and production for use (constraints if known)	ESA/ ESU	Rank 0–5 (low to high)				Disease/ pathogen concerns	Other notes (for example, origin, history, etc.)
						AV	AG	LA	LH		
Okanogan River—Natural origin Sockeye			Harvest, sustainable population	In the last decade, it generally exceeds escapement objectives, but that objective is scheduled for re-calculation. It would be relatively easy to obtain many adults for transplant or broodstock from Wells Dam or the CTCR purse seine at the mouth of the Okanogan River.	Not ESA listed. UCR	4.0	4.0	4.0	4.0	IHNV	Run timing into the Columbia River for both populations overlaps and occurs from early June to mid-July.
Penticton Hatchery—Okanogan River Sockeye	Spawn adults, incubate eggs, and rear fish to be released into Okanogan River system, including Skaha Lake, as many as 5 million fry	Wild and Hatchery fish seined from the spawning grounds upstream of Osoyoos.	Harvest, sustainable population	Same as the natural run, but they are not externally marked so it would not be practical to try to extract only hatchery fish	Not ESA listed. UCR	3.0	3.0	4.0	4.0	IHNV	Not meeting escapement goals, so availability was adjusted to a 2 in final synthesis table
Springfield Hatchery, Snake River programs—Redfish Lake Sockeye	Captive broodstock program began in 1991 to protect remnant population.	Broodstock From Sawtooth Basin and Redfish Lake or Sawtooth Hatchery	Conservation/ stainable population	Out of basin source. Potential disease risk from infectious hematopoietic necrosis virus. Cannot afford the demographic cost. Low out of basin survival.	ESA listed. Out of ESU Snake River Sockeye	1.0	1.0	2.0	2.0	IHNV	

Table B8. Risk assessment table for Coho Salmon donors.

[**Rank 0–5:** AV, Abundance/viability; AG, Ancestry/genetics; LA, Local adaptation; and LH, Life history compatibility. Rank values are median scores from workshop 2 participants. **Abbreviations:** ESA, Endangered Species Act; ESU, Evolutionarily Significant Unit; IHNV, infectious hematopoeitic necrosis virus; LCR, lower Columbia River, MCR, middle Columbia River; NA, not applicable; NFH, National Fish Hatchery; UCR, upper Columbia River]

Source/ population	Management history	Broodstock	Program purpose	Availability and production for use (constraints if known)	ESA/ ESU	Rank 0–5 (low to high)				Disease/ pathogen concerns	Other notes (for example, origin, history, etc.)
						AV	AG	LA	LH		
Winthrop Hatchery (Yakama Coho) —Methow River run	The Yakama Nation reintroduction program releases juvenile hatchery Coho in Methow River, broodstock was LCR-Little White Salmon/ Willard NFH.	Broodstock for Methow River currently hatchery- and natural-origin from MCR.	Natural sustainable population—broodstock and reintroduction for eventual harvest.	Hatchery stock is established, natural production phases outplant juveniles in Methow, Chewuc, and Twisp Rivers, and Wolf Creek. May not be locally adapted. In UCR, but historical out of basin broodstock.	Not ESA listed. UCR	3.0	1.0	3.0	3.0	NA	Historically, about 23,000–31,000 Coho spawned in Methow River subbasin (Hatchery Scientific Review Group, 2009). It was thought the basin supported more Coho than spring Chinook or steelhead.
Leavenworth Hatcheries—Wenatchee River run	Egg incubation may occur at Peshastin incubation facility or at the Entiat NFH. About 1.1 million Fish released yearly To Wenatchee River and Nason, Coulter, Beaver, and Icicle Creeks.	Broodstock collected at Dryden and Tumwater Dams or Leavenworth NFH. Spawning at Entiat NFH. Mixed hatchery- and natural-origin.	Broodstock development—towards natural run sustainable population.	Four-phase reintroduction includes two broodstock development phases with two natural production phases. Juveniles reared out-of-basin and smolts acclimated and released in basin.	Not ESA listed. UCR	3.0	1.0	3.0	3.0	IHNV	Spawn in main-stem Wenatchee River (Cashmere to Lake Wenatchee); Little Wenatchee River; and Nason,Beaver, Icicle, Peshastin, Mission, and Chiwaukum Creeks. Return mid-Sept to late Nov. Spawning October–December. Yearling migrate out March–April.
Prosser Dam—In-river Adult Coho—Yakima River run	Yakima subbasin—The Naches and upper Yakima are not managed as separate populations.	Yakima subbasin—Adults used For broodstock—collection does not differentiate between upper Yakima and Naches components.	Natural sustainable population.	Naturalized Yakima Coho not part of any ESU.	Not ESA listed	2.0	1.0	2.0	2.3	NA	Kreeger and McNeil (1993) and Yakima Subbasin Plan (Yakama Nation, 1990), estimate historical run of 44,000–100,000. Recent program, as many as 700,000 smolts are acclimated and released from ponds on Naches River, and on upper Yakima River.

Source/ population	Management history	Broodstock	Program purpose	Availability and production for use (constraints if known)	ESA/ ESU	Rank 0–5 (low to high)				Disease/ pathogen concerns	Other notes (for example, origin, history, etc.)
						AV	AG	LA	LH		
Shuswap/ Thompson Basin Coho					Not ESA listed. Out of basin. .	1.5	1.0	2.0	3.5	NA	Might be a great match in terms Of migration characteristics (distance from the ocean) and Since extirpated and no adjacent downstream populations, may be acceptable to use out of basin/outside Columbia River?
Lapawai Creek—Clearwater River	Coho salmon officially declared extirpated from Clearwater River in 1986. In 1994, the Nez Perce Tribe Clearwater Coho Restoration Project was initiated.	In fall, returning adult collected at Dworshak and Kooskia NFHs and Lapwai Creek for spawning at Kooskia NFH. About 300,000 juveniles are incubated, hatched, and reared at Dworshak and Kooskia.	Integrated—Sustainable population/ harvest		Not ESA listed. Out of basin.	1.0	1.0	2.0	3.0	IHNV	

Table B9. Ecological Impacts—Competition for Food and Space

Resident taxa	Introduced salmonid				Life stage of introduced	Competition risk with resident	Location and intensity of interaction Rank (0,1,2...5) (low to high)			Mean location risk	Overall negative impact (decrease in fitness) rank (0–5) (low to high)	Uncertainty rank (0–5) (low to high)
	Sockeye	Chinook	Coho	Steelhead			Trib-utaries	Main-stem	Reser-voir			
Adult Redband Trout	X	X	X	X	Fry, parr, smolt, adult	Food, space, behavior	4.0	2.0	2.0	2.7	3.0	4.0
Juvenile Redband Trout	X	X	X	X	Fry, parr, smolt	Food, behavior	4.0	2.5	2.0	2.8	3.0	4.5
Adult kokanee (natural)	X				Fry, parr, smolt, adult	Food, space	1.0	2.0	5.0	2.7	3.0	4.0
Juvenile kokanee (natural)	X	X	X	X	Fry, parr, smolt	Food	1.0	2.0	5.0	2.7	2.0	3.0
Juvenile Kokanee (hatchery)	X	X	X	X	Fry, parr, smolt	Food	1.0	2.0	5.0	2.7	2.0	3.0
Juvenile Rainbow Trout (hatchery)	X	X	X	X	Fry, parr, smolt	Food	1.0	2.0	5.0	2.7	2.0	3.0
Burbot	X	X	X	X	Fry, parr, smolt	Food	0.0	1.0	2.0	1.0	1.5	4.0

Table B10. Ecological Impacts—Predator Prey Relationships

[**Abbreviations:** NA, Not available]

Predator taxa	Prey taxa				Prey life stage	Risk to introduced salmonid	Location and intensity of predation rank (0–5) (low to high)			Mean location risk	Uncertainty rank (0–5) (low to high)
	Sockeye	Chinook	Coho	Steelhead			Trib-utaries	Main-stem	Reser-voir		
Adult steelhead	X	X	X	X	Fry, parr, smolt	Predation	1.0	1.0	1.0	1.0	NA
White Sturgeon	X	X	X	X	Eggs, fry, parr, smolt, adults	Predation	0.0	4.5	2.0	2.2	3.0
Redband Trout	X	X	X	X	Eggs, fry, parr	Predation	2.0	2.0	2.0	2.0	4.0
Kokanee (Natural)	X	X	X	X	Fry	Predation	0.0	0.0	0.0	0.0	4.0
Burbot	X	X	X	X	Eggs, fry, parr, smolt	Predation	1.0	2.0	3.0	2.0	3.0
Northern Pikeminnow	X	X	X	X	Eggs, fry, parr, smolt	Predation	1.0	1.5	1.5	1.3	1.0
Northern Pike	X	X	X	X	Fry, parr, smolt	Predation	1.0	3.3	4.5	2.9	1.0
Triploid Rainbow Trout	X	X	X	X	Eggs, fry, parr, smolt	Predation	0.0	1.0	1.0	0.7	1.0
Smallmouth Bass	X	X	X	X	Fry, parr, smolt	Predation	4.0	5.0	5.0	4.7	1.0
Largemouth Bass	X	X	X	X	Fry, parr, smolt	Predation	0.0	0.5	0.5	0.3	1.0
Yellow Perch	X	X	X	X	Fry, parr	Predation	1.0	1.0	1.0	1.0	2.0
Walleye	X	X	X	X	Fry, parr, smolt	Predation	2.0	5.0	5.0	4.0	1.0
Brown Trout	X	X	X	X	Eggs, fry, parr, smolt	Predation	1.0	1.0	1.0	1.0	1.0
Brook Trout	X	X	X	X	Eggs, fry, parr	Predation	3.0	0.0	0.0	1.0	1.0

Appendix C. Attendee List for Workshops

Table C1. Attendee list for workshop 1 held in Spokane, Washington, August 15–17, 2016.

Name	Organization
Casey Baldwin	Confederated Tribes of the Colville Reservation
Thomas Biladeau	Coeur d'Alene Tribe
Rachel Breyta	United States Geological Survey
Pat Connolly	United States Geological Survey
Jeremey Cram	Washington Department of Fish and Wildlife
Benjamin Cross	Confederated Tribes of the Colville Reservation
Conor Giorgi	Spokane Tribe
Jill Hardiman	United States Geological Survey
Craig Haskell	United States Geological Survey
James Hatten	United States Geological Survey
Elliot Kittel	Spokane Tribe
Holly McLellan	Confederated Tribes of the Colville Reservation
Jason McLellan	Confederated Tribes of the Colville Reservation
Bret Nine	Confederated Tribes of the Colville Reservation
Carl Ostberg	United States Geological Survey
Jill Phillips	Confederated Tribes of the Colville Reservation
Kirk Truscott	Confederated Tribes of the Colville Reservation
Angelo Vitale	Coeur d'Alene Tribe
Will Warnock	Columbia River Intertribal Fish Commission (Canada)
Howie Wright	Okanagan Nation
Michael Zimmer	Okanagan Nation

Table C2. Attendee list for workshop 2 held in Spokane, Washington, January 4–5, 2017.

Name	Organization
Casey Baldwin	Confederated Tribes of the Colville Reservation
Thomas Biladeau	Coeur d'Alene Tribe
Rachel Breyta	United States Geological Survey
Richard Bussanich	Okanagan Nation
Pat Connolly	United States Geological Survey
Benjamin Cross	Confederated Tribes of the Colville Reservation
Christopher Donley	Washington Department of Fish and Wildlife
Conor Giorgi	Spokane Tribe
Jill Hardiman	United States Geological Survey
Craig Haskell	United States Geological Survey
James Hatten	United States Geological Survey
Holly McLellan	Confederated Tribes of the Colville Reservation
Jason McLellan	Confederated Tribes of the Colville Reservation
Bret Nine	Confederated Tribes of the Colville Reservation
Randy Osborne	Washington Department of Fish and Wildlife
Carl Ostberg	United States Geological Survey
John Sirois	Upper Columbia United Tribes

Publishing support provided by the U.S. Geological Survey
Science Publishing Network, Tacoma Publishing Service Center

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Hardiman and others—Risk Assessment for Reintroduction of Anadromous Salmonid, Chief Joseph and Grand Coulee Dams, Washington—Open-File Report 2017–1113

ISSN 2331-1258 (online)
https://doi.org/10.3133/ofr20171113