



INDEPENDENT SCIENTIFIC REVIEW PANEL

2018 Research Project Status Review for the Columbia River Basin Fish and Wildlife Program and 2017 Research Plan

ISRP 2018-8 SEPTEMBER 28, 2018



Cover design by Eric Schrepel, Technical and Web Data Specialist, and cover photo by Tony Grover, Fish and Wildlife Division Director



Independent Scientific Review Panel

for the Northwest Power & Conservation Council

851 SW 6th Avenue, Suite 1100

Portland, Oregon 97204

www.nwcouncil.org/fw/isrp

ISRP Members

Stanley Gregory, Ph.D., Professor Emeritus of Fisheries at Oregon State University

David Heller, M.S., Aquatic Habitat Management and Restoration Consultant, formerly Fisheries Program Leader for the Pacific Northwest Region, USDA Forest Service

Wayne Hubert, Ph.D., Fisheries Consultant and Professor Emeritus at the University of Wyoming, Department of Zoology and Physiology

R. Scott Lutz, Ph.D., Associate Professor of Wildlife Ecology, University of Wisconsin

Alec Maule, Ph.D., Consulting Fisheries Scientist, formerly head of the Ecology and Environmental Physiology Section, United States Geological Survey, Columbia River Research Laboratory

Robert J. Naiman, Ph.D., Emeritus Professor of Aquatic and Fishery Sciences at University of Washington

Greg Ruggerone, Ph.D., Fisheries Scientist for Natural Resources Consultants

Steve Schroder, Ph.D., Fisheries Consultant and former Fisheries Research Scientist at the Washington Department of Fish and Wildlife

Carl Schwarz, Ph.D., Professor of Statistics and Actuarial Science at Simon Fraser University, Canada

Desiree Tullos, Ph.D., P.E., Professor at Oregon State University, Biological and Ecological Engineering Department

Chris C. Wood, Ph.D., former Head of Conservation Biology Section at the Pacific Biological Station, Fisheries and Oceans Canada, Nanaimo, British Columbia, Canada

ISRP Peer Review Group

Kurt Fausch, Ph.D., Emeritus Professor of Fisheries and Aquatic Sciences, Department of Fish, Wildlife, and Conservation Biology at Colorado State University (new ISRP member beginning October 2018)

Katherine Myers, Ph.D., Research Scientist, Aquatic and Fishery Sciences, University of Washington (Retired)

Staff

Erik Merrill, J.D., Manager, Independent Scientific Review, Northwest Power and Conservation Council

ISRP 2018 Research Project Status Review

Contents

Table 1. Projects and Recommendations	iii
I. Executive Summary.....	1
II. Background	6
III. Review Charge and Process	6
IV. Overview of Progress by Research Projects	8
Evaluating Fish and Wildlife Populations.....	10
Evaluating Habitat and the Effectiveness of Restoration Actions	11
Fish Propagation and the Effectiveness of Supplementation.....	12
V. Programmatic Comments.....	14
Introduction	14
Information Sharing	14
Evaluating Fish and Wildlife Populations.....	16
Need for Long-term Monitoring of Complex Ecosystems	16
Predation: Avian and Ecosystem-wide	17
Value of Multiple Molecular Genetics Labs.....	18
Potential to Expand Use of Parental-Based Tags and Genetic Stock Identification for Harvest Monitoring and Other Management Applications	18
Evaluating Habitat and the Effectiveness of Restoration Actions	19
Climate Change	19
Reintroduction of Anadromous Fish to Blocked Areas.....	20
Design of Future Monitoring of Habitat Status and Restoration Effectiveness	21
Fish Propagation and the Effectiveness of Supplementation.....	23
Supplementation	23
Precocious Maturation in Hatchery Reared Yearling Chinook	25
Studies of Relative Reproductive Success (RRS): Synthesizing Results-to-Date.....	26
Literature Cited in Programmatic Section	33
VI. ISRP Comments on Each Project.....	35

Introduction	35
Ocean Research, Monitoring, and Evaluation	35
Avian Predation.....	40
Snake River Fall Chinook Life History.....	42
Fish Tagging Technology Development	45
Reintroduction of Anadromous Fish to Blocked Areas.....	47
Habitat Status and Restoration Effectiveness Research and Monitoring	49
Freshwater Mussels	69
Resident Fish Habitat Enhancement and Passage	71
Fish Genetics, Salmonid Supplementation, and Hatchery Reform	76
Relative Reproductive Success	94
Appendix 1: ISRP Review Questions and Outline for Comments	104
Appendix 2: ISRP Recommendation Terms	105

Table 1. Projects and Recommendations

Click page numbers to jump to reviews

ID	Title	Project Proponent	Meets ISRP Criteria?	Page
Ocean Research, Monitoring, and Evaluation				
199801400	Ocean Survival of Salmonids	National Oceanic and Atmospheric Administration	Yes	35
Avian Predation				
199702400	Avian Predation on Juvenile Salmonids	Oregon State University, Real Time Research	Qualified	40
Snake River Fall Chinook Life History				
200203200	Snake River Fall Chinook Salmon Life History Investigations	Pacific Northwest National Laboratory, University of Washington, US Fish and Wildlife Service (USFWS), US Geological Survey (USGS)	Qualified	42
Fish Tagging Technology Development				
198331900	New Marking and Monitoring Technologies	National Oceanic and Atmospheric Administration	Qualified	45
Reintroduction of Anadromous Fish to Blocked Areas				
201600300	Habitat assessment in blocked areas	Spokane Tribe	N/A ¹	47
Habitat Status and Restoration Effectiveness Research and Monitoring				
201600100	BPA Project Action Effectiveness Monitoring (AEM) Programmatic	Cramer Fish Sciences, Natural Systems Design	Qualified	49
200301700	Integrated Status and Effectiveness Monitoring Program (ISEMP)	National Oceanic and Atmospheric Administration	N/A	54
201100600	Columbia Habitat and Monitoring Program - (CHAMP)			

¹ N/A – not applicable. Four projects are completed or phasing out. The ISRP reviewed these for their results and contributions to the Council’s Program and Research Plan.

ID	Title	Project Proponent	Meets ISRP Criteria?	Page
200900400	Monitoring Recovery Trends in Key Spring Chinook Habitat Variables and Validation of Population Viability Indicators	Columbia River Inter-Tribal Fish Commission (CRITFC)	Qualified	60
200725200	Hyporheic Flow Assessment in Columbia River Tributaries	Umatilla Confederated Tribes (CTUIR)	Qualified	63
200901400	Biomonitoring of Fish Habitat Enhancement	Umatilla Confederated Tribes (CTUIR)	Qualified	66
Freshwater Mussels				
200203700	Freshwater Mussel Research and Restoration	Umatilla Confederated Tribes (CTUIR)	Qualified	69
Resident Fish Habitat Enhancement and Passage				
200811100	Twin Lakes Enhancement	Colville Confederated Tribes	N/A	71
200724600	Restoration of Bull Trout Passage at Albeni Falls Dam	Kalispel Tribe	Qualified	73
Fish Genetics, Salmonid Supplementation, and Hatchery Reform				
200850400	Sturgeon Genetics	Columbia River Inter-Tribal Fish Commission (CRITFC)	Yes	76
200890700	Genetic Assessment of Columbia River Stocks	Columbia River Inter-Tribal Fish Commission (CRITFC)	Yes	79
200900500	Influence of Environment and Landscape on Salmonid Genetics	Columbia River Inter-Tribal Fish Commission (CRITFC)	Yes	82
200900900	Basinwide Supplementation Evaluation	Columbia River Inter-Tribal Fish Commission (CRITFC)	Yes	84
198909600	Genetic Monitoring and Evaluation (M&E) Program for Salmon and Steelhead	National Oceanic and Atmospheric Administration	Qualified	86
199305600	Advance Hatchery Reform Research	National Oceanic and Atmospheric Administration	Yes	89
200203100	Growth Modulation in Salmon Supplementation	National Oceanic and Atmospheric Administration, University of Washington	Yes	91
Relative Reproductive Success (RRS)				
200303900	Monitor and Evaluate (M&E) Reproductive Success and Survival in Wenatchee River	National Oceanic and Atmospheric Administration, Washington Department of Fish and Wildlife (WDFW)	Yes	94
200305400	Evaluate the RRS of Hatchery-Origin and Wild-Origin Steelhead Spawning Naturally in the Hood River	Oregon State University	Yes	96

ID	Title	Project Proponent	Meets ISRP Criteria?	Page
200306300	Natural Reproductive Success and Demographic Effects of Hatchery-Origin Steelhead in Abernathy Creek, Washington	US Fish and Wildlife Service (USFWS)	Qualified	98
201003300	Study Reproductive Success of Hatchery and Natural Origin Steelhead in the Methow	Washington Department of Fish and Wildlife (WDFW)	Yes	101

ISRP 2018 Research Project Status Review

I. Executive Summary

This report provides the Independent Scientific Review Panel's (ISRP) final comments and recommendations on 25 research-focused projects. The review assessed results from each project and ascertained which critical uncertainties in the Council's 2017 Research Plan were being addressed. Ten projects met the ISRP's scientific review criteria. The ISRP believes these ten projects do not need further ISRP review in the upcoming Category Reviews of Fish and Wildlife Projects unless the projects change in scope or propose new methods. Eleven projects met scientific criteria with some qualifications either for clarification or improvement of research approaches. The ISRP expects that the qualifications will be addressed during the upcoming Category Reviews. Four other projects are completed or nearing completion. They were evaluated solely for contributions to the Fish and Wildlife Program (Program) and 2017 Research Plan.

The 25 research projects reviewed fall into three broad categories: (a) fish and wildlife populations; (b) habitat and the effectiveness of restoration actions; and (c) fish propagation and the effectiveness of supplementation. Collectively, these projects address an appropriate diversity of critical uncertainties and are providing valuable results to the Program. We also note that there is collaboration among researchers supported by Bonneville Power Administration (BPA) funds and that the projects are addressing many key uncertainties in the 2017 Research Plan and producing numerous peer-reviewed publications. These publications provide evidence for well-designed studies that advance scientific knowledge while also communicating the findings to others within and beyond the Columbia Basin. The Council and BPA should take pride in the forward thinking and innovative research that they are supporting in the Basin. Opportunities for further progress are summarized below.

Evaluating Fish and Wildlife Populations

Support long-term studies. Due to the large number of environmental factors at play and their inherent variability in complex ecosystems, spatially extensive, long-term studies are required for estimating the effects of factors affecting population processes. Although it is wise to periodically review the objectives of any long-term monitoring plan, decisions to interrupt, modify or terminate long-term studies must be made very carefully. The value of incremental information acquired from each additional year of research can be extremely high, particularly as the frequency of extreme weather events increases.

Support and expand monitoring of salmon survival in the ocean. NOAA Fisheries' Ocean Survival of Salmonids Project ([199801400](#)) will continue to provide critical information into the

future with benefits to the Program growing with each additional year. The project should continue to evolve to address key management questions and existing data gaps (e.g., effects of forage fish abundance on salmon survival).

Evaluate predation at an ecosystem scale and consider density dependent effects. The Avian Predation Project ([199702400](#)) has enabled managers to reduce avian predation on salmonids at key points in the Basin. As management actions are implemented to reduce avian predation and disperse local bird populations, outcomes for both salmonids and avian predators should continue to be monitored by participating agencies. Furthermore, additional research on the impacts of predation should assess the relative impacts of fish, bird, and mammal predation at all stages in salmonid life history and at an ecosystem scale. The critical question to be addressed is whether predation at successive stages is compensatory, depensatory, or additive.

Support and apply advances in molecular genetics. Genetic and pedigree assessment methods are changing rapidly, making it possible to answer questions that seemed intractable only a decade ago. On first consideration, the development of independent molecular genetics laboratories within the Basin may not seem cost effective, but the ISRP believes the partial redundancy confers important benefits like resilience in the face of technical or institutional problems, and greater opportunities for innovation and wider collaboration to advance genetic techniques and software.

Given the recent success of genetic laboratories working cooperatively with others in the Basin, California, British Columbia, and Alaska, it may be time again to examine the potential of using parent-based tagging (PBT) and genetic stock identification (GSI) to identify the origin of salmonids caught in ocean fisheries. The ISRP is uncertain if existing genetic baselines, processing technology and capacity, and sampling infrastructure are adequate yet, or could be expanded sufficiently, to replace or supplement the present role of thermal marks and coded-wire tags in fisheries management. Ideally, an economic analysis should be conducted, informed by independent scientists with expertise in fisheries monitoring.

Evaluating Habitat

Consider climate change in project design and prioritization. Climate change is expected to alter habitat conditions in the Basin from those experienced today. Additionally, substantial changes in land use are projected to occur in the future. Synergistic interactions between these two factors will create new environmental conditions. Project proponents should examine how climate change, coupled with changes in land use, may impact the long-term benefits of their project and provide information on how to ameliorate impacts. Climate and land use changes may determine where restoration is most beneficial and should be considered in prioritization of investments.

Review assessment of reintroduction of anadromous salmon to blocked areas. The Habitat Assessment in Blocked Areas Project ([201600300](#)) provides useful estimates of available habitat and quality, but a more detailed discussion of the limits of the assessment methods is needed. The ISRP recommends that the comprehensive set of Phase 1 documents and results, as well as successive phases, be reviewed by the ISRP and/or ISAB to ensure that the assessment of potential for reintroduction is scientifically sound.

Incorporate lessons learned in plans for habitat status and restoration effectiveness monitoring. Habitat monitoring must be adequate to cover a wide range of spatial and temporal scales. The Columbia Habitat and Monitoring Program (CHaMP, [201100600](#)) used a spatially balanced design to sample a representative snapshot of habitat diversity. A fraction of sites was visited annually to understand changes in habitat from year to year, while remaining sites were visited every three years to assess longer-term trends. The BPA Project Action Effectiveness Monitoring (AEM) Programmatic effort ([201600100](#)) is investigating how fine-grained measurements of habitat at site scales can be combined to assess impacts at a larger spatial scale. The investment in the Integrated Status and Effectiveness Monitoring Program (ISEMP, [200301700](#)) and CHaMP has produced a substantial body of habitat data, methodological advances, analytical tools, and invigorated life-cycle models, which provide a foundation on which to build future monitoring programs. This legacy should be carefully considered when developing the new tributary habitat RME strategy co-led by BPA, Council, and NOAA. The ISRP recommends that design of future monitoring should incorporate many of the 54 monitoring protocols and 800 CHaMP monitoring sites to take advantage of the seven-year database for future trend analysis. One of the innovative organizational aspects of the Integrated Final Report for ISEMP/CHaMP is the concise and informative summaries of the individual sub-projects. The Council and BPA should consider using similar formats for other reports and products.

Review compatibility of methods and support long-term data storage and access. Monitoring at many different spatial and temporal scales (sites, reaches, subbasins, ESUs, or Basin) requires a high degree of coordination in the design of each project so that local monitoring can be integrated with watershed and Basin-wide monitoring. A habitat-monitoring working group (e.g., similar to the Pacific Northwest Aquatic Monitoring Partnership, PNAMP) could be charged with reviewing all habitat monitoring projects to ensure they are compatible, as well as to ensure that data are collected with standardized methods. Additionally, the ISRP recommends that the Program support data repositories to facilitate access to and long-term storage of data from BPA-funded projects.²

² Projects that address this need such as PNAMP, StreamNet, and the Fish Passage Center were not included in this review; in the upcoming Category Review, the ISRP looks forward to reviewing to what extent Program project are satisfying these data collection, storage, and access needs.

Fish Propagation

Improve practices for hatchery supplementation. Eight projects are designed to improve or evaluate hatcheries as a conservation tool for supplementing wild populations. Standard hatchery rearing protocols have been shown to amplify the precocious maturation of Chinook and steelhead as residuals or minijacks that do not migrate to the ocean. Releasing large numbers of fish that become residuals or minijacks has consequences for both fisheries' management and population recovery. First, minijacks represent a potential loss of harvestable adults. Second, misreporting them as smolts in hatchery-release statistics leads to erroneous conclusions about smolt survival and the contribution of hatchery smolts to overall production. Because minijacks typically go unnoticed by hatchery managers, more monitoring is needed to confirm (and convince hatchery personnel) that large numbers are being released. The ISRP encourages the Program to support a comprehensive survey of minijack production in hatcheries that are releasing yearling Chinook juveniles in the Basin, as proposed and initiated in the Growth Modulation in Chinook Salmon Supplementation project ([200203100](#)).

Continue studies of relative reproductive success (RRS). The ISRP compared progress achieved by six research projects investigating the fitness of hatchery-origin fish spawning naturally. Collective results from these projects confirm that hatchery-origin fish, on average, have less reproductive success than natural origin fish when they spawn naturally in the wild (i.e., $RRS < 1$). Experimental research is now underway to distinguish ecological and genetic effects on RRS, and it warrants continued support. Concerns about "carry-over" genetic effects of supplementation on the future productivity and adaptability of wild populations are greatly diminished if reduced RRS is purely an environmental effect. Studies to date indicate that genetic effects are less pronounced in Chinook salmon than steelhead. Many of the projects reviewed are expected to report their most valuable results over the next few years. At that time, an updated synthesis of findings will be especially valuable. The ISRP is reassured that the RRS studies are on track and that proponents are collaborating and sharing information effectively.

Sharing Information

Support publications and conferences. The ISRP strongly encourages the publication of peer-reviewed scientific papers to reliably disseminate research results to those with specific technical skills. On the other hand, newspaper articles, Basin-wide newsletters, TV and podcasts are needed to inform and gain the trust of the broader public. Well-structured conferences are also an efficient way to quickly disseminate key research findings among researchers and stakeholders throughout the Basin. Conferences are effective for directing participants to new sources of information, classifying and prioritizing that information, and initiating communication and establishing new collaborations. Additionally, posting results on web-pages or communicating with local media, such as the Columbia Basin Bulletin, can potentially reach a very broad audience.

Foster communication between researchers and decision makers. Researchers should be encouraged to provide information applicable to management issues throughout the life of a monitoring program, not just at the end. Such communication requires that project proponents understand and agree on the kind of information and the format for reporting that decision makers and managers are willing to accept. More discussion of formats and schedules for delivery of interim information at the outset of future monitoring programs will be useful. The new RME strategy co-led by BPA, Council, and NOAA should include a detailed adaptive management framework with explicit guidance and requirements to ensure that research meets the needs of restoration practitioners and decision makers.

II. Background

Project reviews increase Program accountability and transparency; improve project design, implementation, and overall effectiveness; and facilitate information sharing and adaptive management.

On June 5, 2018, the Northwest Power and Conservation (Council) initiated this Status Review of 25 research projects to evaluate the extent that research helps address critical uncertainties as defined in the [2017 Research Plan](#), as well as how the ongoing research can inform other parts of the Council's Fish and Wildlife Program. The Council identified the 25 projects through a research inventory process that recognized the various levels at which research exists in the Program: some as small components of larger implementation projects and others that primarily focus on research. The 25 projects in this review were identified as being focused *primarily* on research. Each project has the potential for broad applicability and was directed at one or more of the Council's critical research uncertainties.

This status review was designed to address the Council's programmatic recommendation and [decision](#) for research projects evaluated in the 2010-2011 Research, Monitoring and Evaluation and Artificial Production (RME/AP) Category Review. Findings from this Status Review are intended to inform the next Category Review scheduled to occur in late 2018 and early 2019.

III. Review Charge and Process

ISRP reviews are based on criteria provided in the 1996 amendment to the Northwest Power Act that directs the ISRP to review projects for consistency with the Council's Fish and Wildlife Program and to evaluate if projects 1) are based on sound scientific principles, 2) benefit fish and wildlife, 3) have clearly defined objectives and outcomes, and 4) contain provisions for monitoring and evaluation of results. The ISRP is also charged with reviewing the results of Program expenditures.

For this Status Review, the ISRP evaluated the results of the 25 research-focused projects for their progress toward meeting project objectives and addressing critical uncertainties in the Council's [2017 Research Plan](#). In addition to tracking progress, the Status Review is intended to inform the next Category Review by providing guidance on which project or sets of projects could be improved, re-focused, or expanded to better match 2014 Program and 2017 Research Plan needs. Accordingly, the ISRP's project-specific (Section V) and programmatic review comments (Section VI) are framed to provide explicit advice on progress to date and opportunities for improving future research. For instance, at the Program level, the ISRP looked for evidence of productive collaboration, opportunities for synergy, or unneeded redundancy among projects. This is a results-oriented review intended to inform the future direction of the research projects individually and collectively.

The ISRP's review process to develop recommendations and comments followed several steps:

1. **Council request and guidance.** The Council initiated the review process on June 5, 2018 with a [guidance letter](#) to project proponents describing the review process and requesting project summaries and other supporting material by August 13, 2018. The ISRP received all review materials in a timely manner to complete the review.
2. **ISRP individual member reviews.** Each project was initially reviewed by a three- or more-person team, whose members were selected based on expertise and previous experience reviewing the project. Each reviewer provided a preliminary and independent written evaluation of the project, which was then shared for discussion prior to step 3. Individual reviewer's comments and records of discussions are confidential and not available outside of the ISRP review teams.
3. **Project presentations and programmatic discussions.** On August 27 and 28, the proponents presented their projects to the ISRP, Council staff, BPA staff, other proponents, and the public, and they answered questions from the group. The meeting concluded with a brief open dialog on programmatic issues. The [presentations](#) and programmatic discussions were invaluable to the ISRP's understanding of the projects' progress, constraints, and contributions to the Fish and Wildlife Program.
4. **ISRP evaluation meeting and report completion.** On August 29, following the presentations, the full ISRP met to discuss individual comments, develop a consensus recommendation for each project, and ensure consistency across reviews. After the evaluation meeting, individual reviewer comments were synthesized into a consensus statement on each project. All members of the ISRP then evaluated and edited the draft consensus statements and developed programmatic comments to produce this final report.

Next Steps: Council recommendation. This ISRP 2018 Research Project Status Review will help inform Council staff's recommendations for addressing critical research uncertainties in the Program for Council consideration. These recommendations will provide context for the formal review of projects in the Basinwide, Mainstem, and Research Category scheduled to begin in late 2018. Pursuant to the 1996 amendment, the Council must fully consider ISRP recommendations when making its recommendations regarding funding and provide an explanation in writing where its recommendations diverge from those of the ISRP. [Public Comment](#) on the ISRP's Report will be accepted through the close of business on October 24, 2018.

IV. Overview of Progress by Research Projects

Wide-ranging human actions have altered the Columbia River Basin over the past two centuries. Dams erected in the mainstem and numerous tributaries changed the free-flowing river system into a fragmented network with numerous reservoirs. Other actions that substantially altered the Basin include road construction, logging and use of splash dams, dredging, mining, agriculture and grazing, isolation of flood plains and side channels via dikes and levees, urbanization, riparian plants and beaver removals, chemical contaminants originating from both urban and agricultural sources, introduction of non-native species, the annual release of over 100 million hatchery salmonids, and ongoing climate change ([ISAB 2015-1](#)). These and other alterations have often led to significant deleterious impacts on many of the Basin's indigenous fish and wildlife species and have created substantial conservation challenges.

The Bonneville Power Administration (BPA), through the Northwest Power and Conservation Council's (Council) Fish and Wildlife Program, supports research that addresses many of these challenges. Such consistent support, along with formal guidance contained in the Fish and Wildlife Program and the Council's Research Plan, is a positive development that has established regional conservation and mitigation expertise in numerous entities (federal, state, tribal, local, public, and private). These groups commonly partner with university researchers, NGOs, consultants, public utility districts, and among themselves on many projects. Such collaboration expands the topics, methods, and types of research that can be conducted.

Our review of the 25 research projects covered in this report indicates that: (a) collaboration among researchers supported by BPA funds is clearly occurring in many projects, (b) many key uncertainties in the Council's 2017 Research Plan are being addressed, and (c) almost all of the projects have produced numerous peer-reviewed publications describing research results that are useful both within and outside of the Basin. The publication of these articles ensures scientific peer review of methods and data interpretation, and significantly augments the ISRP review process.

Most of the project summary reports provided succinct descriptions of overall goals, typically summarized results obtained across multiple years, and were generally well written and informative. Constraints on length precluded detailed accounts of methods and data analyses. However, these could be found in annual reports and peer-reviewed articles. Taken as a whole, results from many of these projects provide substantial information and guidance to Basin managers.

The 25 projects reviewed fall into three broad categories of research on: (a) the status, trends, and life histories of fish and wildlife populations; (b) the status and trends of fish and wildlife habitat and the effectiveness of restoration actions; and (c) fish propagation and the

effectiveness of supplementation (Table 2). Examples of methods, findings and conclusions reached by a few of the projects in each general research category are briefly highlighted below. For detailed results, interested readers are encouraged to examine annual reports and the peer-reviewed publications originating from each project.

Table 2. General topic areas covered by the 25 research projects reviewed by the ISRP in 2018.

General Topic	Sub-Topic	Project
Evaluating Fish & Wildlife	Evaluating Survival, Migration Rates, Movements Among Habitats, & Growth	New Marking and Monitoring Techniques Ocean Survival of Salmonids Avian Predation on Juvenile Salmonids Snake River Fall Chinook Salmon Life History Investigations ISEMP Restoration of Bull Trout Passage at Albeni Falls Genetic Assessment of Columbia River Salmonid Stocks Basinwide Supplementation Evaluation Freshwater Mussel Research and Restoration
	Measuring the Genetic Diversity of Populations	Sturgeon Genetics Influence of Environment and Landscape on Salmonid Genetics
Evaluating Habitat	Single Factor Effects on Habitat Suitability	Hyporheic Flow Assessment in Columbia River Tributaries Twin Lakes Enhancement
	Habitat Restoration Effects at Different Scales	Monitoring Recovery Trends in Key Spring Chinook Habitat.... Biomonitoring of Fish Habitat Enhancement BPA Action Effectiveness Monitoring ISEMP/CHaMP
Fish Propagation	Improving Hatchery Culture Methods	Advance Hatchery Reform Research Growth Modulation Evaluate the RRS of Hatchery-origin & Wild Steelhead...Hood River Natural RS and Demographic Effects of Hatchery-Origin Steelhead...Abernathy Cr. Basinwide Supplementation Study Study RS of Hatchery and Natural Origin Steelhead in the Methow
	Evaluating the Genetic Effects of Supplementation	Genetic Monitoring and Evaluation Program for Salmon & Steelhead Monitor and Evaluate RRS of Spring Chinook in the Wenatchee Natural RS and Demographic Effects of Hatchery-Origin Steelhead...Abernathy Cr. Basinwide Supplementation Study RS of Hatchery and Natural Origin Steelhead in the Methow

Evaluating Fish and Wildlife Populations

The projects that monitored fish and wildlife populations examined the survival, migration rates, passage, and growth of fishes in the Basin, estuary, ocean plume, and ocean. Several of them also surveyed the genetic diversity of the Basin's fish populations and investigated factors that were responsible for observed patterns. A number of notable results were produced. For example, an enduring need of researchers that track the speed, migratory routes, and survival of juvenile salmon has been to identify the timing and quantity of fish passing over dam spillways. Another comparable need has been to detect juvenile and adult salmonid passage in deep and broad river systems. A PIT tag detection array that can be deployed in dam spillways has recently been developed and is slated to be used at Lower Granite Dam. Additionally, a vertical PIT tag detection barge has been built and is being field tested in the Columbia River below Bonneville Dam. The vertical orientation of the wands makes it possible to detect passage of PIT tagged fish throughout the water column. The capacity to detect PIT tagged fish below Bonneville will provide important abundance, migration speed, and survival information to Basin managers.

Long established monitoring efforts in freshwater habitats and in the Columbia River's estuary and ocean plume consistently provide important information to the Program. A single example of this type of project is the annual survey of oceanographic conditions in the estuary and coastal marine areas. This survey identified a suite of variables that are closely linked to initial marine growth and survival in juvenile salmonids. An early warning system based on these variables is used to predict cohort survival rates and is an important tool for Basin managers. Without this information too, the effectiveness of the Program's freshwater restoration and fish recovery programs would be difficult to assess, as ocean conditions appear to overwhelmingly affect overall survival.

Other research projects in this category have utilized substantial advances in the speed, accuracy, and reduced cost of genetic screening to obtain long-desired genetic information. Parentage-based tagging (PBT) and genetic stock identification (GSI) based on single nucleotide polymorphisms (SNPs), for instance, are now being used to track the harvest of Chinook, sockeye, and steelhead in mainstem fishing areas. Furthermore, PBT is used to follow trends in production, stray rates, the survival, and migratory behavior of individual hatchery populations. Additionally, newly developed genetic tools are annually used to identify and monitor the stock composition, abundance, and run-timing of hatchery- and natural-origin Chinook, sockeye, and steelhead as they pass over Bonneville Dam. Genetic panels containing hundreds of SNPs have similarly been developed for coho, Pacific Lamprey, and white sturgeon. SNP panels in these species have made it possible to perform parentage analyses, identify the origins of unknown fish, ascertain population structure, and examine adaptive genetic variation.

Neutral and adaptive genetic variation in the Basin's Chinook and steelhead populations has also been evaluated. Two factors, temperature and precipitation, were discovered to be the key drivers behind local adaptations in individual steelhead and Chinook populations. An understanding of the broad geographic patterns of neutral and non-neutral genetic variation will be value to regional managers since these trends can be used to guide long-term conservation efforts. Genetic association studies have also taken place to identify genomic regions associated with thermal adaptation, disease resistance, age-at-maturity, run-timing, and anadromy. SNP markers associated with these regions have been identified and are helping researchers validate and monitor genetic variation in fish originating from diverse locations throughout the Basin.

Evaluating Habitat and the Effectiveness of Restoration Actions

No less impressive have been the results produced by habitat monitoring projects. These studies have investigated the effects of individual factors on habitat characteristics at specific sites or examined the combined effects of numerous restoration actions across watersheds and subbasins. For example, one project evaluated the importance of hyporheic flows on habitat suitability for salmonids. Results to date confirm that water temperature is one of the most important limitations on water quality in the Columbia River Basin and that even small amounts of hyporheic exchange can influence channel temperatures throughout an entire year. Floodplain mapping tools, thermal regime assessment methods, and hyporheic modeling results from the project are being used by managers to guide water temperature management and habitat restoration.

Habitat restoration practitioners have long sought to quantify changes in habitat characteristics and biota that arise from single interventions or cumulative effects of numerous activities. Four research projects are making progress toward that goal. Some key findings from two of these efforts, the Action Effectiveness Monitoring (AEM) and CHaMP/ISEMP projects are briefly summarized below. Both projects were implemented to identify restoration opportunities, determine the benefits of restoration actions on habitat variables, and evaluate subsequent trends in the status and abundance of juvenile steelhead and Chinook.

Distinct differences, however, exist in the spatial and temporal scales of the two projects. The AEM project evaluates the effectiveness of restoration actions at specific sites and at a project site or reach scale. Conversely, the CHaMP/ISEMP project was implemented to quantify the aggregated effects of restoration actions throughout entire watersheds or subbasins. The effectiveness of introducing large woody debris (LWD) and restoring fish passage at full barriers was evaluated by the AEM project. Fish abundance in the summer months was compared by using control and treated sites. A full analysis of effects throughout the year is still needed to ascertain if habitat capacity and productivity have increased because of these actions. To date,

the main contribution of this project has been to establish quantitative approaches that can be used to assess the effectiveness of local restoration actions.

Although the CHaMP and ISEMP projects were terminated, their work products will have an enduring influence on how habitat monitoring will be conducted, not only in the Basin, but worldwide. The projects modeled stream habitat across a broad range of spatial scales and related habitat attributes to salmonid abundance. More than 800 sites were monitored over a seven-year period. Data from these locations will provide critical information and act as a foundation for monitoring for years to come. A few of the key products and findings of the projects include: (a) a method to estimate juvenile salmon and steelhead abundance based on the production of benthic algae, (b) the use of the Barker Model to analyze mark-recapture data, (c) using Quantile Regression Forest models to relate fish abundance to habitat, (d) an analyses of the effects and benefits of using beaver dam analogs (BDAs) in a tributary to the John Day River, (e) guidance on how to measure habitat across a wide area—it was discovered that measuring more sites at intermediate levels (e.g., once every 3-years) was more effective than annually sampling fewer sites, and (f) the discovery that some of the most effective improvements in fish abundance and habitat improvements were produced from low-cost projects. The ISRP recommends that future monitoring efforts in the Basin employ many of the monitoring protocols, sampling sites, methodological advances, analytical tools, and life cycle models developed by the CHaMP and ISEMP projects.

Fish Propagation and the Effectiveness of Supplementation

Research projects involving hatchery propagation of salmonids are addressing two important topics: (1) the effects of genetic and environmental factors on in-hatchery growth, maturation rates, and post-release behavior and survival; and (2) the effectiveness of hatcheries as a conservation tool for supplementing natural populations. For example, projects that examine the effects of hatchery conditions on juveniles released from Chinook hatcheries have revealed an under-appreciated problem. In some facilities, substantial numbers of yearling hatchery Chinook were found to be precociously maturing males or minijacks. Depending upon the genetic history of the hatchery stock and whether the hatchery program was integrated or segregated, anywhere from 8% to 71% of the male fish being released were maturing as minijacks. Approaches such as low lipid diets, slowing growth during the fall, and the use of cold surface waters for rearing were found to reduce early maturation rates. Further study is needed to investigate the full extent of this problem. Until some of the techniques and approaches to reduce early maturation can be widely applied, it is likely that millions of minijacks are annually produced from the Basin's Chinook hatcheries.

Several studies also examined the effects of hatchery conditions on juvenile steelhead. In one case, the use of underwater feeders, overhead cover, and low rearing densities are being

evaluated in an attempt to reduce selection for aggressive and surface-oriented juveniles. These behaviors appear to be selected for in steelhead hatcheries that use traditional rearing methods. If heritable, they would be maladaptive in nature. Another study examined the growth trajectories of juvenile steelhead. Two distinct patterns were found. Some hatchery steelhead grow rapidly and become smolts (age-1) after a year of rearing. Others are slower growing and take two years (age-2) to become smolts. Differences in juvenile migration rates, tolerance to saltwater, marine residency, and adult behavior exist between the two smolt types. During different parts of the life cycle, growth and survival advantages will favor one or the other type of smolt. These differences led researchers to examine the benefits of releasing both age-1 and age-2 smolts. Such an evaluation is currently taking place in the Twisp River.

Supplementation or the integration of local wild broodstock into hatchery programs and the subsequent strategy of allowing adults produced from these fish to spawn in nature is widely used in the Basin. However, physiological, behavioral, morphological, and demographic differences between hatchery-origin (HO) and natural-origin (NO) fish have been observed. It is likely that some or most of these changes have reduced the fitness of the HO fish when they are allowed to spawn in nature. A comprehensive set of research projects is taking place in the Basin to evaluate how modifications in broodstock origin, feeding and growth profiles, and the hatchery environment, may reduce the prevalence of inadvertent domestication in cultured salmonids.

Several ongoing studies, for example, are examining the effects of exclusively using local wild fish as broodstock (100% pNOB) in steelhead and spring Chinook. Results from two spring Chinook programs (Yakima River and Johnson Creek) suggest that the relative reproductive success of hatchery adults produced from natural origin parents is comparable to wild counterparts, if the fish spawn in the same locations and during the same time periods. Alternatively, naturally spawning steelhead produced from wild parents tend to have lower reproductive success than wild spawners. A number of causes for the reduced reproductive success of hatchery steelhead were identified. Many are genetic in nature and are caused by selection pressures the fish experience in the hatchery as juveniles. In general, these studies indicate that steelhead appear to be more susceptible to inadvertent hatchery domestication than Chinook, and that the exclusive use of natural-origin broodstock appears to reduce domestication effects, at least in Chinook salmon. However, both genetic and environmental factors were found to influence the reproductive success of hatchery steelhead and Chinook when they spawn in nature. Disentangling the relative importance of these factors remains a daunting challenge but is key to redesigning hatchery operations that can minimize adverse and unintended effects. This task is being addressed by many of the current research efforts taking place in the Basin.

V. Programmatic Comments

Introduction

Many of the Council's critical uncertainties (2017 Research Plan) are being successfully addressed by ongoing research, but a number of gaps and challenges became evident in this review. The following programmatic comments vary in detail and purpose. Primarily, they are meant to flag issues that require attention and to identify topic areas that warrant additional research. In some instances, recommendations for future actions are also offered.

Some programmatic comments are general yet very brief because the short review timeline limited our ability to address the topic as thoroughly as it deserves (e.g., climate change). Some comments are brief because they apply specifically to a single project (e.g., avian predation, salmonid survival in the ocean, or reintroduction of salmonids into the blocked area). Other comments are longer because we have attempted to compare and synthesize results from a number of related projects (e.g., relative reproductive success studies). In each case, the programmatic comments are intended to identify issues and opportunities that will be explored more thoroughly in the upcoming Category Reviews.

Information Sharing

The sharing of information – whether it is project design and location, data analyses, ideas, or general insights – is the heart of effective restoration. Information sharing is identified as a vital element of the current Fish and Wildlife Program and as a cornerstone of adaptive management. A lack of information sharing has been widely recognized as a main reason for restoration failures (Naiman 1992, National Research Council 1996, Naiman et al. 1998).

Information must be shared in many forms because there are diverse and important audiences. For instance, peer-reviewed articles and technical reports provide insights and detailed data analyses to those with specific technical interests and skills, whereas newspaper articles, newsletters, TV, and podcasts inform and gain the trust of the broader public. Conferences and meetings allow engagement across all levels and are especially useful for encouraging learning and for building personal connections and trust between the public, managers, and decision makers.

The Program articulates general measures for the Council to inform and involve the public (including elected officials) through print, electronic, social media, and other means. The Council, in partnership with BPA and other interested parties, is expected to publicly recognize and acknowledge entities providing useful examples of productive partnerships across social and ecological boundaries (e.g., through conferences and annual meetings). As well, the Council

is expected to monitor the success of outreach and involvement efforts directly related to information sharing.

The ISAB's *Review of the 2014 Columbia River Basin Fish and Wildlife Program* ([ISAB 2018-3](#), pages 71-72) states that "while there is strong evidence of the value and success of public engagement and outreach efforts, public engagement also involves costs and benefits, and it may be highly successful in some cases or fail in others." Consequently, cost-effectiveness evaluation of various approaches to public engagement is highly recommended.

The ISRP understands that attending conferences and annual meetings, as well as production of newsletters, are often targets of budget cuts. Nevertheless, the ISRP believes that they have significant scientific and social values. Effective public engagement begins early in the timeline of projects, encourages debate and discussion of alternatives, and includes individuals and groups that may be either positively or negatively affected. In the Columbia Basin, conferences, annual meetings, and newsletters are central to this effort.

This Research Project Status Review provides yet another example of how challenging the sharing of information can be, as well as how much it ultimately benefits the Program. So much high-quality research is being conducted in the Basin that researchers, managers, and stakeholders alike are often overwhelmed by the quantity of information being produced. For instance, managers in diverse parts of the Basin are likely unaware of recent findings from the Grande Ronde study on the impact of widespread riparian plantings on stream temperatures. Finding effective ways to reach a range of interests and technical skills is a major challenge and a fundamental necessity for success.

The ISRP strongly encourages the publication of peer-reviewed scientific papers as a valuable technique to reliably disseminate research results. Even so, most biologists become overwhelmed by the number of scientific papers they ought to read. Indeed, for this review, ISRP members relied heavily on the research narratives and syntheses from the latest annual reports for projects being reviewed because it was often too time consuming to read all the relevant scientific articles and technical reports.

Well-structured conferences are critical as an efficient way to disseminate key research findings in a timely way among researchers and stakeholders throughout the Basin. Conferences are also effective for directing participants to new sources of information, classifying and prioritizing that information, and initiating communication and new collaborations. As well, posting results on web-pages can potentially reach a very broad audience if an effective dissemination plan is in place that includes presentations at scientific and practitioner conferences and interactions with local media.

Evaluating Fish and Wildlife Populations

Need for Long-term Monitoring of Complex Ecosystems

There are a large number of factors in complex ecosystems often with inherently high variability in each factor over space and time. This complexity results in an inability to run designed and replicated experiments to investigate the relative importance of each factor, thereby necessitating spatially extensive and long-term studies for estimating the effects of individual factors. The incremental information acquired from each additional year of work is extremely high, particularly as the frequency of extreme events increases. Therefore, interruptions, modifications, or termination of long-term studies need to be assessed very carefully.

Two examples of long-term studies from the set projects reviewed are NOAA Fisheries Ocean Survival of Salmonids Project ([199801400](#)) and the Columbia River Inter-Tribal Fish Commission's (CRITFC) Grande Ronde Project ([200900400](#)).

NOAA Fisheries' Ocean Survival of Salmonids Project is an example of an excellent long-term monitoring project investigating factors that influence the early ocean distribution, timing, and survival of salmonids. The key finding is that ocean conditions are enormously influential and highly predictive of salmon returns, conditions that can conceal the effects of local restoration actions. These findings are important in the development of life-cycle models that are used to investigate the impact of different proposed management actions (e.g., additional spill or habitat restoration actions) over the entire life cycle and not just during a limited part of the life cycle.

CRITFC's Grande Ronde Project ([200900400](#)) spent over nine years collecting high quality stream habitat and biotic data. The proponents are developing analytical tools needed to quantify status and trends in habitat conditions and fish populations and tools to evaluate the effectiveness of aggregate restoration activities. They found that limiting factors differed among basins (water temperature in the upper Grande Ronde and pool structure for parr in Catherine Creek). Consequently, management strategies for increasing habitat carrying capacity also differed. Their findings are important because they represent the kind of investigations needed to understand the numerous intersections between climate change and restoration actions.

Nevertheless, it is wise to review periodically the objectives of any long-term monitoring plan to see if modifications are required. For example, the Ocean Survival Study provides useful information on the distribution (spatial and temporal) of salmon in the early ocean stages, but recent hypotheses about the impact of predators and alternate prey have not been directly investigated. These impacts could be investigated at relatively small marginal costs to the current program. In addition, survival is measured only indirectly in this project. Now that there

is a good understanding of factors influencing survival as salmonids traverse the hydrosystem (e.g., the impact of flow from Comparative Survival Study), interest is shifting to factors influencing survival below Bonneville Dam. It may be timely to include other types of monitoring (e.g., acoustic techniques similar to arrays formerly used) to provide direct estimates of survival.

Predation: Avian and Ecosystem-wide

The Avian Predation Project ([199702400](#)) has been successful in providing managers with information to manage avian predation on salmonids at key points in the Basin. However, predation should be considered on a larger scale, taking into account the relative impacts of fish, bird and mammal predation at all stages in salmonid life history. The critical question to be addressed is whether predation at successive stages is compensatory, depensatory, or additive. As defined in the ISAB report on predation metrics ([ISAB 2016-1](#)):

“Compensatory mortality occurs when predation mortality at one life stage is offset to some degree by decreased mortality at the same or subsequent life stages. For example, a predator might eat injured or weak fish that would have died before reaching adulthood; therefore, controlling this predator would not result in more adult fish.” (ISAB 2016-1, page 1)

Compensatory mortality is inherent in the general phenomenon of density dependence that is frequently under-appreciated in planning restoration actions ([ISAB 2015-1](#)).

The ISRP suggests that several questions related to system-wide predation should also be addressed:

- What are key bird, fish, and mammal predators and their specific salmonid prey?
- What is the role of alternative prey fish abundance in buffering juvenile salmonids from fish predators, especially in the ocean and estuary?
- Where and when in the salmonid or predator life cycle is management intervention warranted?

Competition for food, habitat, and other needed resources may have similar or even greater impacts than predation on salmonid populations. An important information gap that deserves some research attention, for instance, is an evaluation of the possible competitive interactions between the millions of annually released hatchery fish and naturally produced salmonids (see [ISAB 2011-1, Appendix C.6.](#)). Possible effects of competition in the lower river and estuary between hatchery and natural origin juveniles remains largely unknown. Additionally, competitive interactions between juvenile salmonids and juvenile American shad or other fish species for planktonic food, is another area that could use some focused research. Detecting possible biological impacts due to competition on growth and survival is difficult and may

explain why competition has not been extensively investigated. Nevertheless, increasing our understanding of how competitive interactions affect the Basin's salmonid populations would be a valuable management asset.

Value of Multiple Molecular Genetics Labs

Genotyping, pedigree assessment, and genetic association methods are changing rapidly, making it possible to answer questions that seemed intractable only a decade ago. Currently several federal, state, university, and tribal laboratories have the capability to genotype samples from genetic surveys of Basin fish and wildlife. One could question the value of having multiple laboratories process genetic samples obtained from research projects in the Basin. Wouldn't a single facility be more efficient? The ISRP finds that the present situation of having multiple sites perform genetic analyses is justified. The development of independent, yet cooperative molecular genetics laboratories provide the Program with an important resource. The partial redundancy that exists among the labs offers some resilience in the face of technical or institutional problems. Moreover, reliance on a single laboratory might lead to stagnation of methods in the long term. For instance, gene association studies and the continued enhancement of population-specific genetic baselines by different labs have led to the discovery of new single nucleotide polymorphism (SNPs) markers. These methods and baselines are being shared among the existing labs leading to ever more accurate genetic assignments.

State and federal laboratories have also made it routine practice to archive tissue or DNA samples. The utility and demand for these samples grows as new markers or methods make it possible to refine previous assignments or undertake new studies. Not all individual labs have the space or capacity to be an archival facility. Having in-house expertise to genotype samples also expedites processing and helps to ensure sample integrity. Having multiple laboratories also creates a pool of regional expertise that accelerates the development of new methods and procedures. Finally, many of the laboratories are processing samples from outside the Basin and serving other analytical needs, tasks that provide opportunities for further advancement of genetic techniques and software.

Potential to Expand Use of Parental-Based Tags and Genetic Stock Identification for Harvest Monitoring and Other Management Applications

Given the success of genetic laboratories working cooperatively in the Basin and along with others in California, British Columbia, and Alaska, it may be time to revisit a decade-old idea of using parentage-based tags (PBT) and genetic stock identification (GSI) to identify the origin of ocean-caught salmonids. Currently, billions of hatchery salmonids, predominately chum, pink, and sockeye, annually receive thermal marks (T-marks) in their otoliths. These "biological barcodes" are primarily used by managers to track marine harvest rates. In contrast, harvest

rates on coho and Chinook appear to be based primarily on recoveries of coded-wire tags (CWTs).

The ISRP is uncertain if existing genetic baselines, processing technology and capacity, and sampling infrastructure are adequate, or could be expanded sufficiently, to replace or supplement the present role of T-marks and CWTs for fish identification. Perhaps a combination of methods, T-marks for the billions of hatchery chum and pink salmon, along with GSI and PBT for other species could prove cost-effective. In any case, the pace of advancement in the speed and accuracy of genetic assignments along with reductions in the costs associated with sample processing make it prudent to revisit this question. Ideally, an economic analysis should be conducted to examine the costs and benefits of using various methods of stock identification, alone or in combination.³ Since the goal is to help managers determine the most cost-effective method to assess ocean harvests, the economic analysis should also be informed by independent scientists with expertise in fisheries monitoring.

Evaluating Habitat and the Effectiveness of Restoration Actions

Climate Change

Many projects in this review have relatively short-term time frames and implicitly assume that effects seen today will continue in the future. However, future climate change will alter conditions in the Basin from those experienced today.

Consequently, projects should incorporate information to gauge the impacts of climate change on the system, examine how climate change may impact the long-term benefits or justification for the project, and/or provide information on how to ameliorate the impacts of climate change. For example, the work on minijacks produced by hatcheries shows that the minijack proportion can be influenced by changing the temperature of the water in which the fish are raised. One impact of climate change may be an increase in the temperature of the source-water for hatcheries. Research could project how potential climate change would alter the production of minijacks and impacts on SARs. In another example, the Grand Ronde Project examined the impact of riparian shading on stream temperature and forecasted that an aggressive riparian restoration campaign may be a viable strategy against the impact of climate change on stream temperature.

³ The [Council-led Fish Tagging Forum](#) considered these issues in 2013, but genetic tagging and identification technology has advanced since the Forum review and will continue to advance. The [Pacific Salmon Commission](#) has also considered this issue in recent years.

A number of aspects of climate change need to be considered by project proponents. For example, findings from individual projects may or may not be applicable to other parts of the Basin. In addition, projecting impacts of climate change will often require life-cycle models. Furthermore, climate change may impact where restoration is most beneficial and should be considered in prioritization of investments (e.g., Donley et al. 2012; Catford et al. 2013; Golladay et al. 2016). Finally, climate change cannot be uncoupled from land use change. They act synergistically to affect river conditions. Substantial changes in the Basin's landscape are taking place, and their effects will need to be considered in the future. All these aspects are likely to require technical expertise outside the scope of individual projects. Basin-wide coordination is required to identify individual project results that may be useful in forecasting the effects of climate change or adjusting for climate change. Specific projects can be "flagged" for the attention of a working-group that could then decide if project findings should be applied elsewhere in the Basin. Individual projects also can provide data to the life-cycle modeling groups that are investigating climate change scenarios.

Reintroduction of Anadromous Fish to Blocked Areas

The 2014 Program contains a strategy to investigate the feasibility of reintroducing anadromous fish above Chief Joseph and Grand Coulee dams using a three-phased approach with each successive phase depending on the previous phase:

"Pursue a science-based, phased approach to investigating the reintroduction of anadromous fish above Chief Joseph and Grand Coulee dams including juvenile and adult passage at the dams. The phases shall include:

Phase 1 (to be completed no later than the end of 2016):

- *Evaluate information from passage studies at other blockages and from previous assessments of passage at Grand Coulee and Chief Joseph dams*
- *Investigate habitat availability, suitability and salmon survival potential in habitats above Grand Coulee. This might include selective releases of salmon and steelhead. Investigate the scientific feasibility and possible cost of upstream and downstream passage options for salmon and steelhead. Before funding new investigations, provide the Council with a report for consideration of subsequent work to advance the fish passage planning process." (NPCC 2014-2, pages 84-85)*

At this time, the ISRP has reviewed only one project, which addressed the second objective of Phase 1. The Blocked Area Assessment Project is an important project that provides useful estimates of available habitat and quality, but a more detailed discussion of the limits of the assessment methods is needed. For example, an analysis of the uncertainty in the Intrinsic Potential and Ecosystem Diagnosis and Treatment (EDT) models would be beneficial since they are based on highly uncertain data. In addition, a detailed description is needed of the different

components of Phase 1, including individual objectives, timelines for completion and how the components fit together. The ISRP recommends that the comprehensive set of Phase 1 documents and results, as well as successive phases, be reviewed by the ISRP and/or ISAB to ensure that the assessment of potential for reintroduction is scientifically sound.

Design of Future Monitoring of Habitat Status and Restoration Effectiveness

Monitoring habitat over broad spatial and temporal scales is fundamental for sound management decisions and Program success. Restoration actions can modify habitat at small spatial scales in relatively short periods of time, but climate and land use changes may be modifying habitat at basinwide scales over a much longer term. Consequently, different types of habitat monitoring designs are needed.

Researchers in long-term ecological research programs have recommended “adaptive monitoring” approaches that: (1) address well-defined questions that are specified before the commencement of a monitoring program; (2) are based on rigorous statistical designs; (3) are based on explicit conceptual models of how ecosystems or specific components of ecosystems function; and (4) fulfill a human need for the information (Lindenmayer and Likens 2009). Detection of long-term, cumulative impacts of restoration actions in the Basin, as well as potential stressors in the system like climate and land use change, requires monitoring programs designed to measure habitat and fish and wildlife populations over multiple decades. Monitoring habitat at large spatial and long temporal scales requires a carefully designed probability-based sampling protocol to be able to upscale local habitat measurements to the basin scale. For example, CHaMP used a spatially balanced sampling framework to sample a representative snapshot of habitat diversity. A fraction of sites was visited annually to understand changes in habitat from year to year, while remaining sites were visited every three years to assess longer-term trends.

One of the fundamental characteristics that differentiates the ISEMP and CHaMP programs from the AEM program is the spatial and temporal scales for which they were designed. CHaMP and ISEMP were designed to assess status and trends of habitat and fish populations and benefits of restoration at the scale of entire watersheds or basins. AEM is designed primarily to assess the effectiveness of specific types of restoration actions at the site and project scale and assess whether success of actions differ among geographic areas. Measurements in such different programs have the potential to be complementary rather than mutually exclusive if the linkages and comparability of data are carefully considered in designing future programs.

At local scales, sampling of habitat must be fine-grained. It is not realistic to expect that a Basin-wide program can also provide fine-scale information by itself. Each project will need to incorporate a local-scale monitoring design. Measurement of short-term responses at the project scale by the team that designed and built the projects allows mid-course corrections for

the project to work as designed. These project measurements can be combined to assess impact at a larger spatial-scale. For example, the AEM program takes measurements of habitat (and responses) at the reach or finer scale and combines results from multiple projects. With a well-conceived sampling design, this can provide long-term, local-scale lessons from many projects across diverse geomorphic and ecological conditions.

Unfortunately, there can be a mismatch between the length of time a project is monitored and the ultimate habitat response. Some restoration responses can occur relatively quickly, with immediate impacts, but restoration actions may have a limited “shelf-life.” For instance, adding wood to a system can have immediate effects, but wood eventually degrades or is transported downstream. Other types of restoration, such as riparian planting, require decades for desired outcomes, such as inputs of large wood. Consequently, local monitoring should continue for a substantial period of time or be revisited long after a project is completed to measure longer-term effects. A well-designed habitat monitoring program should be explicit about its spatial and temporal limits as well as provide adequate spatial and temporal information so that it can be used in combination with other sites for analyses of larger geographic areas.

Monitoring programs also need to be flexible to incorporate technological advances (e.g., remote sensing and data mining methods) that may obviate the need for some sampling if a complete census becomes achievable. For example, data loggers to measure stream temperatures may be replaced by remote thermal imaging. With a well-formulated design, such a transition can be handled gracefully without the need to restart the time-series of data.

Monitoring at many different spatial and temporal scales (sites, reaches, subbasins, ESUs, or Basin) requires a high degree of coordination in the design of each project so that local monitoring can be integrated with watershed and basinwide monitoring. A habitat-monitoring working group (e.g., similar to how the Pacific Northwest Aquatic Monitoring Partnership or PNAMP works) could be charged with reviewing all habitat monitoring projects to ensure they are compatible and that data are collected with standardized methods. This working group would also investigate how technological advances could improve data collection.

All issues associated with habitat cannot be anticipated in advance. To enable emerging issues to be investigated, monitoring designs must be clearly described and acquired data must be readily accessible. The ISRP recommends that the Program support data repositories to facilitate access to and long-term storage of data from BPA-funded projects. Projects that address this need, such as PNAMP, StreamNet and the Fish Passage Center, were not included in this review. In the upcoming Category Review, the ISRP looks forward to reviewing to what extent these data collection, storage, and access needs are being met.

The Council recently appointed a technical workgroup to develop a program-focused habitat monitoring and evaluation approach that will meet information needs for guiding habitat actions throughout the basin and document progress in addressing limiting factors for specific

life-stages of anadromous and resident fish. Although the ISEMP and CHaMP projects are now closed, some observations looking back on the multi-year effort may be useful in designing and implementing future, large-scale projects, particularly those that address similar research questions. As summarized in the Executive Summary and Overview of Progress sections of this report, the ISRP recommends that design of future monitoring should incorporate many of the 54 monitoring protocols and 800 CHaMP monitoring sites to take advantage of the seven-year database for future trend analysis. The results of ISEMP and CHaMP can be used for designing future M&E projects and for their long-term data in selecting future monitoring sites. Their analyses of measurement noise and overall variance for 54 different habitat measurements will provide important insights for future programs. The investment in ISEMP and CHaMP has produced a substantial body of habitat data, methodological advances, analytical tools, and invigorated the life cycle models, which provide a foundation on which to build future monitoring programs. This legacy should be carefully considered when developing the new tributary habitat RME strategy co-led by BPA, Council, and NOAA.

A critical challenge for RME projects is providing information that can be directly applied to management issues throughout the life of the project, not just at the end. This requires agreement at the start of the project between the funders and the investigators about the degree of uncertainty that decision makers and managers are willing to accept and the format for reporting. More discussion and agreement on formats and delivery of interim information at the outset of future monitoring programs will be useful. Innovative methods for communicating results and identifying potential applications could greatly enhance the dissemination of monitoring information and improve projects throughout the Basin. The new RME strategy co-led by BPA, Council, and NOAA should include a detailed adaptive management framework with explicit guidance and requirements to ensure research is best designed and communicated to meet the needs of restoration practitioners and decision makers.

Fish Propagation and the Effectiveness of Supplementation

Supplementation

Supplementation is widely used as a conservation tool for fish populations in the Basin. It typically involves collecting local wild fish for hatchery broodstock and allowing adults produced from these “integrated hatcheries” to spawn naturally. However, there are continuing concerns about domestication selection and the effect of physiological, behavioral, morphological, and demographic differences between hatchery-origin (HO) and natural-origin (NO) fish. The Program is supporting a robust research effort to evaluate how modifications in broodstock origin, feeding and growth profiles, and the hatchery environment may reduce the degree of inadvertent domestication in cultured salmonids.

The Hood River Steelhead Project ([200305400](#)), for example, is currently investigating how changes in hatchery rearing environments may reduce the strength of domestication selection faced by juvenile steelhead while reared artificially. Investigators leading this project hypothesize that production of age-1 smolts favors aggressive and surface-oriented juveniles. If these traits are heritable and selected for in the hatchery, then the offspring of hatchery adults spawning in the wild would likely experience high rates of predation. Losses of juveniles due to enhanced aggressiveness and surface orientation would help explain lower reproductive success of hatchery parents in the wild. Underwater feeders, lower rearing densities, and overhead covers in rearing ponds will be tested to see if their application can reduce selection for these traits. Two other projects, Growth Modulation ([200203100](#)) and Advanced Hatchery Reform ([199305600](#)), are developing rearing protocols to create growth patterns in hatchery fish that resemble those of wild juvenile fish. Natural growth profiles help to reduce early maturation in yearling male Chinook salmon. Reduction in the release of precocious parr or minijacks will increase the abundance and productivity of anadromous fish and reduce the ecological impacts that minijacks impose on wild populations in the habitats they share.

The Advanced Hatchery Reform Project is investigating the types of steelhead smolts that should be produced and released from a hatchery. Results from this project indicate that juvenile steelhead exhibit two different growth trajectories. Some become smolts after one year of rearing whereas others grow more slowly and require two years to become smolts. Significant physiological, morphological, and behavioral differences were found to exist between age-1 and age-2 smolts. These differences affected migration rates, tolerance to seawater, ocean residency, and aggressiveness during spawning and may be heritable.

Differences between the traits of age-1 and age-2 steelhead provide each type of smolt with survival and growth advantages at disparate life stages. For instance, age-2 smolts migrate more rapidly and have a higher tolerance to seawater than age-1 smolts. Thus, they likely have higher early marine survival rates. Conversely, age-1 smolts rear longer in the ocean and return as larger more fecund fish. Steelhead hatcheries typically rear and release age-1 smolts. Under this regime, slower growing fish that were likely age-2 smolts may residualize and compete with resident fish for resources. This tendency reduces the production of anadromous fish, and it can also lead to deleterious ecological interactions. Given the benefits and costs of each type of smolt, a strategy of releasing both age-1 and age-2 is being adopted. The early growth patterns of the fish will be used to identify and separate the juveniles soon after ponding so they can be reared separately. The Methow Steelhead Project ([201003300](#)) will evaluate the effects of releasing age-1 and age-2 steelhead smolts on the steelhead population in the Twisp River. This project will also examine the reproductive success of reconditioned kelts (an additional supplementation strategy), comparing their reproductive success to natural kelts and maiden spawners.

Hatchery supplementation is also being used to restore salmon runs in tributaries where the original indigenous populations were extirpated. To facilitate recolonization, broodstock fish

are typically collected from nearby donor populations with adaptations that most closely match those believed to be needed in the new habitat. Once natural recruits begin to return, they are integrated into the hatchery broodstock to promote further adaptation of the new “local” hatchery population to the novel habitat. A number of these recolonization efforts are being evaluated by the Basinwide Supplementation Evaluation Project ([200900900](#)). This project tracks the genetic diversity and reproductive success of transplanted hatchery fish spawning in the novel environment and determines how rapidly the population is adapting to its new natal stream. In aggregate, numerous innovative studies are being conducted to improve the success of hatchery supplementation. Most are just beginning; nevertheless, some results are already leading to refinement of present methods.

Precocious Maturation in Hatchery Reared Yearling Chinook

The inadvertent production of precocious parr or minijacks in Chinook salmon is a persistent problem in some hatcheries where fish are reared and released as yearlings. Unfortunately, standard hatchery rearing protocols often amplify the likelihood of precocious maturation. Early work by NOAA researchers, for instance, showed that rapid juvenile growth during the early fall may trigger precocious maturation (Larsen et al. 2006). Yearling Chinook salmon are often tagged or marked during winter months prior to being released the following spring. Feeding regimes are regularly put in place to get the fish large enough in the fall to accommodate the stress associated with tagging and marking and to enhance post-release survival. Unfortunately, this practice, adopted to increase survival, may exacerbate the production of minijacks. Moreover, it may be difficult to convince hatchery personnel of these unintended consequences because minijacks are not easy to identify at release. Few differences exist between early maturing males and normal smolts in physical appearance and behavior. Chinook minijacks exit their rearing sites at the same time as smolts. Consequently, they typically go unnoticed and are difficult to enumerate or cull.

Releasing large numbers of minijacks has consequences for both fisheries management and population recovery that are underappreciated. Minijacks are not smolts, but they are misreported as smolts in hatchery release statistics. Failure to enumerate substantial numbers of minijacks causes corresponding errors in estimates of SAR, SAS, and R/S, leading to erroneous conclusions about trends in smolt survival and the contribution of hatchery smolts to overall production. Moreover, minijacks represent a substantial loss of anadromous adults that may contribute to harvests and recovery efforts, had they not matured precociously.

Most minijacks emigrate downstream upon release. Some venture as far as the estuary, others enter the mainstem, and a few remain in their natal streams. At these locations they may compete with hatchery and natural origin smolts for food and other resources and possibly attract predators. Thermal barriers and inadequate energy reserves often prevent minijacks from reaching spawning grounds (Beckman et al. 2005). Those that do return may participate in

spawning events but typically have substantially lower reproductive success than their larger anadromous competitors (Schroder et al. 2011, Ford et al. 2012).

Two research projects, Growth Modulation in Chinook Salmon Supplementation ([200203100](#)) and Basinwide Supplementation Evaluation ([200900900](#)), are providing information on the prevalence of minijacks and the genetic and environmental factors responsible for their occurrence. Environmental conditions at hatcheries – including seasonal thermal patterns, water sources (relatively warm ground water vs. cooler surface water), feeding rates, and lipid or energy content in foods – all appear to be important. Clear genetic differences have also been observed. Segregated hatchery programs, for instance, consistently produce fewer minijacks and appear to have higher threshold sizes for precocious maturation.

Because each hatchery is different, a single strategy to reduce early maturation in yearling Chinook will not be effective. Instead, individualized approaches will need to be established for each facility and possibly for each race of Chinook. However, reducing growth during the early fall and using foods with relatively low lipid values appear to be universally useful. A table presented in the narrative of the Growth Modulation Project shows how existing information can be used to predict the probability of minijack maturation at different fork lengths for 10 hatcheries. If this table were expanded to include additional hatchery populations, it could be used more widely as a management tool to reduce minijack production in the Basin.

Understanding the factors affecting precocious maturation and how they might be ameliorated is important for developing, evaluating, and implementing effective rearing and release strategies in the Basin's Chinook hatcheries. We encourage the Program to support a comprehensive survey of hatcheries that are releasing yearling Chinook juveniles in the Basin. This survey would allow additional hatcheries to be included in the predictive table and help to determine the magnitude of minijack releases in the Basin. Continued exploration of possible approaches to reduce early maturity is also encouraged. Treatments to reduce minijack rates should, however, be evaluated to ensure that they do not interfere with the smoltification process. Currently, the Growth Modulation Project is evaluating the effects of existing treatments on smoltification. The demographic consequences of reducing releases of minijacks also needs further investigation. For example, will reducing the number of minijacks increase the number of jacks? Are overall shifts in age at maturity in males and females occurring due to early rearing treatments? In summary, despite all the complexities and questions associated with early maturation, continued research work in this area is of real value to the Program.

Studies of Relative Reproductive Success (RRS): Synthesizing Results-to-Date

A number of projects are designed to test whether hatchery supplementation can make a positive net contribution to the recovery of salmon populations, and to determine how hatcheries should be used as a conservation tool. Relative reproductive success (RRS) is defined

as the ratio of the average number of progeny produced by a hatchery origin (HO) fish relative to that produced by a natural origin (NO) fish spawning naturally in the same environment. If $RRS < 1$, then HO fish produce fewer progeny than their wild counterparts. For comparisons in this discussion, we refer to HO fish spawning in the natural environment as the “F0 generation”, their progeny as the “F1 generation”, and subsequent generations as “F2” and so on.

The ISRP examined progress achieved by six BPA-funded research projects, which collectively comprise ten studies led by five different agencies. Four of the projects target steelhead (Table 3A) and six target stream-type Chinook salmon (Tables 3B and 3C). Results from these projects collectively confirm that even early generation (F1 and F2) HO fish are, on average, less fit than NO fish when they spawn naturally in the wild (i.e., $RRS < 1$). Reduced RRS has been observed in both males and females of both species and in most locations. However, both magnitude and statistical significance of the observed reduction in RRS vary greatly among studies.

Some of the variation among studies can be attributed to differences in statistical power associated with larger samples and longer time series. The studies vary widely in duration, and RRS estimates for the F1 generation are based on time series that range from 1 to 13 brood years. Calculating RRS values from multiple brood years allows estimation of between-year variation and provides more reliable estimates of mean RRS. Not surprisingly, therefore, statistically significant reductions in RRS were detected most often in the studies that examined the most brood years.

A key result from the two NOAA-led projects is that estimates of RRS obtained by assigning and counting juvenile progeny per spawner closely predict those obtained by assigning and counting adult progeny per spawner. This finding suggests that reductions in RRS occur during spawning or early juvenile rearing, not during ocean residence or migration to or from the ocean. Measuring RRS with juvenile progeny instead of adult progeny offers two very important benefits, larger samples (hence more precise estimates of RRS) and earlier results. Accordingly, other recent studies have adopted this strategy.

Having confirmed that HO fish typically exhibit lower fitness in the wild, some of the projects are now testing whether reduced RRS is an environmental effect on early development caused by the hatchery environment or a genetic effect caused domestication selection. If reduced RRS is purely an environmental effect, then there is less concern about genetic effects on the future fitness of wild populations.

To this end, some of the studies monitor physical variables associated with the rearing or spawning environment, as well as differences in suites of biological attributes exhibited by the fish (e.g., size, age at maturity, fecundity, run timing straying, seawater adaptability). These measurements can be used as covariates in statistical models to examine correlations with reproductive success, which in turn, can help to rule out alternative hypotheses about causation.

In Chinook salmon, reduced RRS is strongly associated with ecological mechanisms such as differences in spawning location (primarily in females), which may be a consequence of how and where the hatchery fish were released. In males, reduced RRS may be an effect of growth rate on age at maturation and adult size, which reduces their competitive ability and mating success. Even so, genetic effects on RRS are still evident in at least some studies of Chinook salmon. For example, in the Wenatchee Chinook study, straying of adult progeny (i.e., in the F1 generation) was influenced by the parental pedigree (i.e., the degree of hatchery influence in the F0 generation).

Genetic effects are clearly more pervasive in steelhead than Chinook salmon, likely because the longer duration of juvenile life in freshwater affords greater opportunity for domestication selection during hatchery rearing. Genetic effects are evident in comparisons of RRS among natural spawners whose parents have varying degrees of hatchery influence in their pedigrees (i.e., wild X wild, wild X hatchery, or hatchery X hatchery). Additional evidence for genetic effects comes from studies where a reverse effect on RRS was observed in captivity ($RRS > 1$) versus the wild ($RRS < 1$). Such trade-offs are consistent with genetic adaptation to the captive environment with a concomitant loss of adaptation to the wild.

Disentangling the relative contribution of genetic and environmental effects on reduced fitness of early-generation hatchery fish is important for predicting the long-term (i.e., “carry-over”) effects of hatchery fish spawning in wild populations. Such predictions will pave the way for fisheries management to either implement pragmatic changes in hatchery practices or re-evaluate the goals and use of conservation hatchery programs. At least two studies have examined (Hood Steelhead) or are now examining (Wenatchee Chinook) the persistence of these genetic effects over multiple generations. However, more experimental research seems warranted specifically to distinguish ecological and genetic effects. This knowledge is needed to predict the extent to which hatchery supplementation might limit the ability of small wild salmon and steelhead populations to adapt to changes in their local environments.

Knowing the environmental or genetic mechanisms by which RRS is reduced is also key to redesigning hatchery protocols to avoid adverse consequences. As mentioned previously in programmatic comments on supplementation, some studies are now trying to determine what traits are under selection and what features of the hatchery environment promote selection. For example, the Hood steelhead study is seeking to identify: (1) a suite of genes (perhaps associated boldness and growth rate) that are most subject to selection in a hatchery, and (2) how the hatchery environment could be modified to diminish the expression of these genes, thereby reducing the opportunity for selection. The Methow steelhead study is beginning to field test recommendations (from the Advance Hatchery Reform project) to release steelhead smolts at age-2 rather than age 1 to reduce the prevalence of residual males and minijacks that have adverse consequences for natural populations.

Studies to date have revealed that RRS can be reduced for a variety of different reasons. Because of this complexity, a more detailed conceptual framework is needed to predict how different species or populations will respond to hatchery supplementation and to allow managers to make better case-specific decisions. The ISRP believes that an updated synthesis similar to Christie et al. (2014) is needed to make progress toward such a framework. On the other hand, we also recognize that a general synthesis at this time might be premature, as many of the studies reviewed here will be reporting their most valuable results over the next few years. We compiled the data in Tables 3A-C to help gauge the range of results that are currently available for synthesis and the kind of results that can be expected in the near future. Overall, we are reassured that the RRS studies are on track and that proponents are collaborating and sharing information effectively.

The ISRP suggests that any new effort to synthesize results across the RRS studies should consider the history of hatchery influence prior to and during each study. It seems important to examine how RRS is affected by, other things being equal, (a) the history of the hatchery broodstock in terms of provenance, effective number, previous introgressions or bottlenecks that might have affected its diversity and adaptability; and (b) the management of pNOB, pHOS and PNI in the study populations during the study. It is worth noting that values for pNOB and pHOS appear to vary widely across the studies, although these values are not readily available in the materials provided for our review. It is also interesting that recent studies (e.g., Yakima Chinook) have emphasized the use of all natural broodstock (pNOB=1) and that these studies have reported minimal or non-significant reductions in RRS.

Table 3A. Summary of BPA-funded studies of relative reproductive success (RRS) in steelhead populations in the Columbia River basin. Bold font indicates statistical significance and “NS” indicates lack of statistical significance of RRS<1 in the F1 generation; “?” denotes information is missing in the reports provided; “from slide” denotes information taken from the presentation.

	STUDY SITE			
STEELHEAD	Hood River	Little Sheep Creek	Abernathy	Methow
Project details	2003-054-00	1989-096-00	2003-063-00	2010-033-00
Lead Agency	OSU	NOAA	USFWS	WDFW
year started	1991	1999	2003	2009
year to end	2010 (RRS)	?	2020	2022 (original)
BYs reported	6 (in 2014)	13	8	6
BYs total by end	20?	?	11	10
generations by end	4	?	?	2
Hatchery history				
suppl. since	1991?	1982	2003	1968
source of brdstk	Big Creek	local	local	Wells
number of brdstk	?	?	?	?
pNOB	1	0.1	?	?
Natural spawning				
density (controlled?)	?	?	?	?
pHOS (controlled?)	?	0.5 (after 2004)	0.5 (yes)	0.5 (yes)
juv. life history	stream type	stream type	stream type	stream type
RRS (adult progeny)				
BYs reported	6 (Christie et al. 2014)	9	8	2
RRS female	0.37-1.05	0.48 (0.15-1.06)	0.15-0.6 (from slide)	0.77
RRS male	0.50-1.27	0.36 (0.24-0.80)	0-0.6 (from slide)	0.65
RRS (juv. progeny)				
BYs reported		13		4-6
RRS female		0.34 (0.15-0.97)		0.38-0.80
RRS male		0.41 (0.32-1.05)		0.35-0.63
differences observed				
age/life history?	yes		yes	yes
size/morphology?	yes	yes	yes	yes
migration/behavior?	yes	yes	yes	yes
physiology?	yes		yes	yes
gene expression?	yes			
mechanism				
ecological?	?	yes	?	yes
F0 parent effects?	yes		?	?
other genetic evid.?	yes		?	?

Table 3B. Summary of NOAA studies of relative reproductive success (RRS) in Chinook salmon populations in the Columbia River basin. Bold font indicates statistical significance and “NS” indicates lack of statistical significance of RRS<1 in the F1 generation; “?” denotes information is missing in the reports provided; “from slide” denotes information taken from the presentation.

CHINOOK_NOAA	STUDY SITE		
	Wenatchee River	Catherine Creek	Lostine River
Project details	2003-039-00	1989-096-00	1989-096-00
year started	2004	2002	2009
year to end	2022	?	?
BYs reported	6	11	2
BYs total by end	14	?	?
generations by end	3	?	?
Hatchery history			
suppl. since	1989	1995	1995
source of brdstk	local	local (captive brood)	local (captive brood)
number of brdstk	?	?	?
pNOB	?	?	?
Natural spawning			
density (controlled?)	?	?	?
pHOS (controlled?)	>>0.5 (later years?)	?	?
juv. life history	stream type	stream type	stream type
RRS (adult progeny)			
BYs reported	5	9	0
RRS female	0.3-0.7 (from slide)	1	
RRS male (age 4&5)	0.2-0.5 (from slide)	1	
RRS jacks	?		
RRS (juv. progeny)			
BYs reported	6	11	2
RRS female	0.4-0.6 (from slide)	0.84-1.77	0.92-1.12
RRS male (age 4&5)	0.2-0.5 (from slide)	0.75-1.64	0.78-0.84
RRS jacks	?		
differences observed			
age/life history?	yes		
size/morphology?	yes		
migration/behavior?	yes		
physiology?			
gene expression?			
mechanism			
ecological?	primary cause	NS	NS
F0 parent effects?	few (straying of F2)	NS	NS
other genetic evid.?			

Table 3C. Summary of CRITFC studies of relative reproductive success (RRS) in Chinook salmon populations in the Columbia River Basin. Bold font indicates statistical significance and “NS” indicates lack of statistical significance of RRS<1 in the F1 generation; “?” denotes information is missing in the reports provided; “from slide” denotes information taken from the presentation.

CHINOOK_CRITFC	STUDY SITE		
	Johnson Creek	Yakima River	Lookingglass Creek
Project details	2009-009-00	2009-009-00	2009-009-00
year started	2002	2007	2008
year to end	2019	2011	2019
BYs reported	9	1	7
BYs total by end	?	5	9
generations by end	1	1	1?
Hatchery history			
suppl. since	1998	1997	2004
source of brdstk	local	local	Catherine Ck
number of brdstk	?	?	?
pNOB	1	1	1
Natural spawning			
density (controlled?)	?	?	?
pHOS (controlled?)	?	?	>>0.5
juv. life history	stream type	stream type	stream type
RRS (adult progeny)			
BYs reported	4 (Christie et al. 2014)	0	0 (7 expect. in 2019)
RRS female	0.55-1.30		
RRS male (age 4&5)	0.43-0.91		
RRS jacks	0.32 (1 yr only)		
RRS (juv. progeny)			
BYs reported	0 (6 expect. in 2019)	1	7
RRS female		0.9	0.55-1.25
RRS male (age 4&5)		0.95	0.56-0.86
RRS jacks		0.72	?
differences observed			
age/life history?		yes	
size/morphology?		yes	
migration/behavior?			
physiology?			
gene expression?			
mechanism			
ecological?	NS?	primary (small males)	
F0 parent effects?	NS?	no	
other genetic evid.?			

Literature Cited in Programmatic Section

- Beckman, B.R. and D.A. Larsen. 2005. Up-stream migration of PIT-tagged age 2 (minijack) Chinook salmon in the Columbia River: behavior, abundance, distribution, and origin. *Transactions of the American Fisheries Society*. 134: 1520-1541.
- Catford, J.A., R.J. Naiman, L.E. Chambers, J. Roberts, M. Douglas, and P. Davies. 2013. Predicting novel riparian ecosystems in a changing climate. *Ecosystems* 16:382-400.
- Christie, M.R., M.J. Ford, and M.S. Blouin. 2014. On the reproductive success of early-generation hatchery fish in the wild. *Evolutionary Applications* 7:883-896.
- Donley, E.E., R.J. Naiman, and M.D. Marineau. 2012. Strategic planning for instream flow restoration: a case study of potential climate change impacts in the central Columbia River basin. *Global Change Biology* doi: 10.1111/j.1365-2486.2012.02773
- Ford, M., A. Murdoch, and S. Howard, S. 2012. Early male maturity explains a negative correlation in reproductive success between hatchery-spawned salmon and their naturally spawning progeny. *Conservation Letters* 5:450-458.
- Golladay, S.W., K.L. Martin, J.M. Vose, D.N. Wear, A.P. Covich, R.J. Hobbs, K.D. Klepzig, G.E. Likens, R.J. Naiman, and A.W. Shearer. 2016. Achievable future conditions as a framework for guiding conservation and management. *Forest Ecology and Management* 360:80-96.
- ISAB (Independent Scientific Advisory Board). 2015. Density dependence and its implications for fish management and restoration programs in the Columbia River Basin. Northwest Power and Conservation Council, Report ISAB 2015-1, Portland, Oregon. Available: www.nwcouncil.org/sites/default/files/isab2015-1_0.pdf
- ISAB (Independent Scientific Advisory Board). 2016. Predation Metrics Report: developing and assessing standardized metrics to measure the effects of predation on Columbia River Basin salmon and steelhead. Northwest Power and Conservation Council, Report ISAB 2016-1, Portland, Oregon. Available: www.nwcouncil.org/sites/default/files/isab2016-1.pdf
- ISAB (Independent Scientific Advisory Board) 2018. Review of the 2014 Columbia River Basin Fish and Wildlife Program. Northwest Power and Conservation Council Report ISAB 2018-3, Portland, Oregon. Available: www.nwcouncil.org/sites/default/files/isab-2018-3-review2014fwp23march.pdf
- Larsen, D.A., B.R. Beckman, C.R. Strom, P.J. Parkins, K.A. Cooper, D.E. Fast, D.E., and W.W. Dickhoff. 2006. Growth modulation alters the incidence of early male maturation and physiological development of hatchery reared spring Chinook salmon: a comparison with wild fish. *Transactions of the American Fisheries Society*. 135:1017-1032.

- Lindenmayer, D.B. and G.E. Likens. 2009. Adaptive monitoring: A new paradigm for long-term research and monitoring. *Trends in Ecology and Evolution* 24(9):482-486.
- Naiman, R.J. (ed.). 1992. *Watershed Management: Balancing Sustainability and Environmental Change*. Springer-Verlag, New York.
- Naiman, R.J., J.J. Magnuson, and P.L. Firth. (Guest editors). 1998. Integrating Cultural, Economic, and Environmental Requirements for Fresh Water. *Ecological Applications* (Invited Feature) 8:569-630.
- National Research Council. 1996. *Upstream: Salmon and Society in the Pacific Northwest*. The National Academies Press, Washington DC.
- Schroder, S.L., C.M. Knudsen, T.N. Pearsons, T.W. Kassler, E.P. Beall, S.W. Young, and D.E. Fast. 2011. Breeding success of four male life history types of spring Chinook salmon spawning in an artificial stream. *Environmental Biology of Fishes*. 94: 231-248.

VI. ISRP Comments on Each Project

Introduction

The ISRP’s questions and outline for review recommendations and comments for each project (Section VI) were designed to address the Council’s specifications for summary report contents (see [guidance letter](#)) and the Northwest Power Act criteria (see Appendix 1 for the ISRP review questions and comment outline).

The ISRP’s project review recommendations fell into two categories: *Meets Scientific Review Criteria* and *Meets Scientific Review Criteria (Qualified)*. Briefly, *Meets Scientific Review Criteria* is assigned to a project that substantially meets each of the ISRP criteria. *Qualified* is assigned to project recommendations for which additional clarifications and adjustments to methods, objectives, and results reporting by the proponent are needed to fully justify the entire project. The ISRP expects that needed changes to a project will be determined by the Council and BPA in consultation with the project proponent and addressed in the upcoming Category Reviews. Appendix 2 includes a full description of ISRP recommendation terms.

Please note that section four of our comments “2017 Research Plan uncertainties validation” is primarily intended to inform Council staff’s effort to update the 2017 Research Plan Uncertainties Database and is not intended for a broader audience.

Ocean Research, Monitoring, and Evaluation

199801400 - Ocean Survival of Salmonids

- [View summary in Box](#)
- Background info in Taurus: [Project overview](#) | [Reports](#) | [Past reviews](#)

Project proponent: National Oceanic and Atmospheric Administration

Recommendation: Meets Scientific Review Criteria

Comment:

1. Objectives

The Ocean Survival of Salmonids Project is a long-term (20-year) effort. The project monitors salmon and oceanographic conditions in the Columbia River plume and nearshore marine areas. The primary research hypothesis is that “variation in salmon survival during the first few months of ocean residency has the largest impact on cohort strength of all life stages for Pacific salmon.” The primary project objective is “to determine the physical, biological and ecological

mechanisms that control survival of salmon during their early marine life.” Hypotheses were grouped into three areas: (a) growth and survival; (b) hatchery-wild interactions and density dependence; and (c) modeling, scenario planning, and recovery.

The primary hypothesis is that marine growth and survival are determined by the combined effects of physical and biological processes in the coastal ocean; the abundance, species composition, and spatial distribution of predators; and the size and availability of salmon and alternative prey.

Because hatchery-wild interactions and density dependence cannot be observed directly, three hypotheses designed to infer the effects of hatchery/wild competition were addressed: (a) there is no difference between the diet and growth of hatchery and wild fish, (b) there is no difference between the distribution and migration timing of hatchery and wild fish, and (c) there is no difference between the synchrony of responses to marine drivers for hatchery and wild fish.

Modeling, scenario planning, and recovery hypotheses are based on assumptions that early ocean growth and survival of juvenile salmon and steelhead are determined through both bottom-up and top-down processes associated with the productivity of coastal ocean and plume habitats during spring and summer. It is also assumed that survival during this period is highly variable and has an exceptionally large impact on cohort strength and, therefore, future adult returns.

While these hypotheses are highly relevant to the Council’s Fish and Wildlife Program, they are difficult to quantify, achieve, and test because of the complexity and unpredictability of the marine ecosystem. A long time-series is needed to tease out the relative impact of many factors.

The project is now in its 20th year, and there is no indication of a specific future end date. The ISRP concludes that this project will continue to provide critical information into the future and that the value of this project to the Fish and Wildlife Program will grow each year. Nevertheless, the program should not remain static. The proponents indicate that they are making efforts to place their results into an ecosystem framework and are modifying the sampling strategy (e.g., via a smaller mesh liner) to provide more information on salmon and their prey simultaneously. These future activities should be reviewed to ensure that the program continues to collect data relevant to management questions, to examine changes in survey methods, and evaluate if the new types of data collection will fill important gaps in understanding of ocean survival (e.g., impacts of forage fish abundance).

One objective is to estimate early ocean survival, but this is not directly addressed. A major question is whether the program can be modified to estimate survival in the early and subsequent ocean life stages (e.g., by the reintroduction of acoustic survey lines).

2. Methods

At present the project is contracted by BPA on an annual basis, with clear milestones for specific work elements such as research vessel cruises as well as sample and data processing.

Juvenile Salmon and Ocean Ecosystem Surveys (JSOES) relies on estuary purse seines to capture salmonids along with measurements of physical and biological characteristics of the Columbia River plume and nearshore ocean. Two additional surveys compare the attributes of hatchery and natural origin juvenile fish (late May), and they characterize the spatial distribution of juvenile salmonids, the pelagic fish community, the salmon prey field, and characteristics of the ocean environment (June). In general, methods are scientifically sound, but some survey methods could be improved. For example, methods currently used are sufficient for collecting biological samples of salmon and associated species in the catch, and for providing indices of relative abundance (i.e., catch per unit effort) but not for directly estimating salmon survival or the abundance/biomass of salmon predators and prey.

A key assumption is that catch per unit effort (CPUE) is proportional to abundance. It is not clear if this been empirically tested using estimates of smolt outmigration from CSS vs. the CPUE from the trawls.

Varying levels of salmon predators add variability to survival proportions. This makes it harder to detect the effects of ocean conditions and also means that models based on earlier years, where the predators were not prevalent, are less and less reliable.

The original trawl survey design was developed primarily to determine the early ocean distribution of juvenile Columbia River salmon. Considering the current hypotheses being tested and the low CPUE of juvenile salmon in surface trawl catches, especially wild salmon, new fisheries-oceanographic ecosystem survey designs (e.g., a gridded survey, larger trawl) and methods (e.g., combined trawl and hydroacoustic surveys) might be considered.

3. Results

The project has made significant progress in addressing a progressive series of questions and hypotheses, ones that have evolved over time as more data are gathered.

Project results show that ocean productivity controls feeding and growth of juvenile salmon (i.e., bottom-up control), leading to multiple, nonexclusive hypotheses about how ocean productivity influences salmon survival. For example, when ocean productivity is high (a) rapid growth allows juveniles to escape size-selective predation and (b) abundant alternative prey for salmon predators reduces predation pressure on salmon juveniles. The investigators conclude, "Importantly, these ocean effects can be somewhat dependent on freshwater effects

(carryover effects, Gosselin et al. 2018⁴). Therefore, accurately evaluating freshwater management actions requires an accurate ocean context.” An economic analysis may be needed to compare the cost and effectiveness of management actions taken in freshwater (e.g., hydro-system actions) vs. actions occurring in the ocean (e.g., harvest management).

Project results addressing hatchery/wild interactions and density dependence CUs (Critical Uncertainties) were hampered by the low numbers of wild juvenile salmon in ocean research vessel catches because of low relative abundance and/or low sampling rates. Results indicate that hatchery salmon may be used as a proxy for wild salmon in some cases (e.g., migration timing, diets, and spatial distribution), but not others (e.g., size and condition factor). However, data are insufficient to determine “whether hatchery salmon have an advantage over wild salmon during different ocean conditions.”

Project results addressing modeling, recovery, and climate impacts CUs show that “stock-specific distribution, abundance, and survival of juvenile Columbia River salmon in the NCC [Northern California Current] vary synchronously with variable ocean conditions.” Investigators have developed a suite of physical, biological, and ecological indicators of ocean conditions that are useful qualitative predictors of salmon survival that are now being used by managers as early-warning indicators of recent ocean conditions or as covariates in statistical models. Initial results of marine survival modeling “confirm the importance of the marine stage in the salmon life cycle and suggest dramatic declines in population trajectories with a warming ocean.”

An important consideration is whether the project's primary objective (“to determine the physical, biological and ecological mechanisms that control survival of salmon during their early marine life”) is sufficient to guide policy or actions that benefit fish and wildlife. Future changes in climate and ocean conditions are not predictable. Thus, as discussed by the investigators in their project summary, a greater emphasis on long term, high quality monitoring of ocean conditions and assessment of changes in the ocean ecosystem that affect juvenile salmon survival is essential.

The project has an excellent publication record with over 121 publications listed. Project findings are shared with others within and outside the basin via numerous journal publications, project reports, conference presentations, an excellent web site, presentations to the Council, and via the Ocean Forum. However, the ISRP notes that communication of information within the Basin will likely decline because there are limitations to project funds to attend conferences and to support other communication portals, such as the Columbia Basin Bulletin.

⁴ Gosseline, J.L., R.W. Zabel, J.J. Anderson, J.R. Faulkner, A.M. Baptista, and B.P. Sandford. 2018. Conservation planning for freshwater-marine carryover effects on Chinook salmon survival. *Ecology and Evolution* 8:319-332

4. 2017 Research Plan uncertainties validation

The project narrative provided a comprehensive table and text that links its research to 39 CUs, organized into four categories: (a) survival and growth; (b) hatchery wild interactions and density dependence; (c) modeling, scenario planning, and recovery, masking effect of the ocean; and (d) other topics. The project directly addresses six CUs and indirectly addresses 33 additional CUs. Linkage to these CUs is generally appropriate, though Item F3 ([What factors within and outside of the Columbia River Basin influence trends in recruitment, mortality, and abundance of Columbia River Basin fish and wildlife populations?](#)) should have been identified as a direct link (current CUs on the web failed to make the link between this CU and the Ocean project).

Table 1 in the narrative identifies several new CUs associated with the project, including 19 new CUs. Information in the project narrative is not always sufficient to understand the new linkages, and additional justification may be needed. For example, some linkages were revised from direct to indirect and vice versa. The indirect relationships identified in Table 1 tend to be more inclusive than exclusive. Some of the linkages may be questionable (G1.1, G2.1, C1.5, F3.7, F3.8, B1, M3.1, F1.4). For example, CU 1.5 states “What are the range, magnitude, and rates of change of natural spawning fitness of integrated (supplemented) populations, and how are these related to management rules, including the proportion of hatchery fish permitted on the spawning grounds, the broodstock mining rate, and the proportion of natural origin adults in the hatchery broodstock?” and it is questionable how surveying juvenile fish in the early ocean period helps answer this CU.

Similarly, it is unclear why CU E2.5: “*What additional information is needed to assess the importance of tidal freshwater, estuary, plume, and ocean habitats and their biota on focal species (anadromous salmonids, White Sturgeon, Pacific Lamprey, Eulachon)?*” was not included in Table 1, given that CU E2.5 was considered by the Council to be directly addressed by this project in the Council's 2017 database.

Avian Predation

199702400 - Avian Predation on Juvenile Salmonids

- [View summary in Box](#)
- Background info in Taurus: [Project overview](#) | [Reports](#) | [Past reviews](#)

Project proponent: Oregon State University, Real Time Research

Recommendation: Meets Scientific Review Criteria (Qualified)

Qualifications:

Specific quantifiable objectives with time-based milestones should be developed to examine additive and compensatory density dependence predation effects. As part of this, the proponents should consider how their work fits in with ecosystem effects of predation. For example, these questions below among others should be addressed:

- What is the timing of predation and who are the key bird, fish and mammal predators and prey?
- How significant is predation in the lower river, estuary, and ocean plume?
- What is the role of prey fish abundance in buffering juvenile salmonids from fish predators?
- Where in the salmonid or predator life cycle is management intervention warranted?

Comment:

1. Objectives

This project has been a successful collaboration between universities, federal researchers, and environmental consultants. The 2018 research narrative includes general goals for the management of avian predation rather than specific, measurable objectives with time-based milestones for the research to be conducted. Hypotheses associated with the research were not stated in the summary. The numerous peer-reviewed publications do state clear objectives and hypotheses. The unstated objectives are probably quantifiable and testable based on the mortality attributable to avian predators.

Project results have been very relevant to the Program and have benefited fish (i.e., decreased mortality) but have probably had a negative effect on wildlife (i.e., reduced nesting of avian predators). The proponents indicate that funding is being reduced, and they believe that additional time is needed to address ongoing questions associated with the movement of avian predators and the emergence of additional species of avian predators. They do not, however, indicate specific actions, time frames, or end-dates for the additional work.

2. Methods

Based on the results and the numerous peer-reviewed publications, the methods are scientifically sound. It is relatively easy to measure changes in bird numbers (e.g., colony size) or redistribution of birds, but it was unclear how this was linked to changes in total predation. A linkage between the two should be addressed. The proponents discuss the need to determine whether the avian-based mortality of emigrating salmonids is additive or compensatory, but they do not describe how they would do such a study.

3. Results

Although the project summary does not include quantifiable objectives, the proponents have been successful in providing information to address critical uncertainties (CUs) in the Predation theme.

One concern with results is the plots of predation-rate versus colony-size (Figure 1, Research Narrative). It is difficult to discern or compare the functional relationships between predation rate and colony size in these plots because the x-axes do not start at zero pairs of breeding birds and the y-axes are scaled differently in each plot. The implicit assumption that the relationship is linear (i.e., shown by the dashed lines fitted to the data) is likely unrealistic, at least for Middle Columbia steelhead where the y-intercept appears to be positive, implying avian predation occurs in the absence of birds. It seems more reasonable to fit non-linear curves that pass through the origin. The shape of that curve—called the “functional response to predator density”—and particularly whether the curve is concave up or down has important consequences for modeling the dynamics of predation. The authors should consider presenting estimates of biomass or number of fish eaten by birds rather than showing predation as a fraction of the run.

As a result of this project, three avian predation management plans have been developed and managers have taken steps which have initially reduced mortality of emigrating salmonids to avian predation in the estuary. Reporting is generally excellent and includes many peer-reviewed publications. The latest annual report available through PISCES describes detailed results for 2016 and updates long-term time series and provides retrospective evaluations of the whole project. Collaboration and sharing of information among partners appear to be excellent. Despite these successes, many CUs remain, and recent developments suggest that predation impacts from piscivorous colonial waterbirds in the Columbia River Basin may be increasing at a time when funding for avian predation RM&E in the Basin is either being eliminated (USACE) or sharply reduced (BPA).

Rates of predation determined in this study are very site specific, but the study area is broad, including the Columbia River from the mouth (i.e., river km 0) to the head of the impoundment created by McNary Dam (i.e., river km 553). The project also monitors a variety of other piscivorous birds. Recent findings suggest that smolt predation rates by gulls nesting at some

colonies in the Columbia Plateau region are comparable to, if not higher than, those of Caspian terns and double-crested cormorants nesting at colonies in the Columbia Plateau region. Summary project data are available at the project website (www.birdresearchnw.org/), and it appears that the raw data are available—perhaps on request.

4. 2017 Research Plan uncertainties validation

Agree. This project addresses CUs in the Predation theme (The list of uncertainties on the 2018 Review database (<https://research.nwcouncil.org/2017/Projects>) does not include the questions posed in the Research Plan “Critical uncertainties by theme: Predation”).

Snake River Fall Chinook Life History

200203200 - Snake River Fall Chinook Salmon Life History Investigations

- [View summary in Box](#)
- Background info in Taurus: [Project overview](#) | [Reports](#) | [Past reviews](#)

Project proponent: Pacific Northwest National Laboratory, University of Washington, US Fish and Wildlife Service (USFWS), US Geological Survey (USGS)

Recommendation: Meets Scientific Review Criteria (Qualified)

Qualifications:

Adaptive Management and Public Outreach are not addressed as project objectives or activities; they should be integral parts of the project. Development of these objectives/activities and a response outlining the respective strategies for each objective/activity are needed for ISRP review.

The proponents have the experience and data to analyze and synthesize specific objectives in considerable depth, and the timing is right for providing broad scientific leadership to help other groups in the Basin and beyond. The lead proponent (Ken Tiffan, USGS) indicated in his presentation that he is working with Billy Connor, retired USFWS, on a complete history of Snake River Fall Chinook as well as two other synthesis articles. Ken Tiffan also indicated that he wants to re-examine University of Idaho professor emeritus Dave Bennett's work on historical conditions in the Snake River. The ISRP encourages the research team to prioritize completion of these syntheses.

Comment:

1. Objectives

There are three objectives:

- Understand how temperature and exposure to sublethal levels of total dissolved gas (TDG) influences Snake River fall Chinook subyearling predation risk;
- Quantify spatial and temporal variation of subyearling loss to predation in Lower Granite Reservoir; and
- Evaluate the use of otolith microchemistry to identify natal, rearing, and overwintering areas; and age, timing, and size at ocean entry of juvenile fall Chinook salmon.

The Snake River Fall Chinook project began in 2002 and has addressed a variety of objectives that are important to salmon management. The investigators have published more than 50 journal papers stemming from this effort, indicating that project objectives and hypotheses were specific and clearly defined, measurable, and testable. The narrative summarized how the various objectives were applicable to the Fish and Wildlife Program and management issues. Timelines were provided for some specific efforts, but the investigators note that new objectives continue to emerge through the ongoing effort. The investigators have a good grasp of complex issues that are important for the management of both mainstem and tributary reservoirs in the Snake River Basin. However, use of the broader literature specific to the objectives is lacking in the summary but perhaps is covered in the peer-reviewed publications.

2. Methods

While the ISRP did not review project methods from their cited literature in detail, the large body of peer-reviewed publications suggests that the methods used by this project were scientifically sound.

Note: the proponents suggest that projects 200203200 and 199102900 should be combined. As well, can the results be folded into life-cycle models (LCM)? What additional data would be needed to integrate into an LCM?

3. Results

Overall, this research has informed many management decisions in the Snake River Basin and the effort directly addresses several critical uncertainties (CUs), including issues involving reservoir management, species interactions, predation, invasive species, and density dependence. Some project findings are relevant to issues outside the Basin (e.g., the importance of reservoirs for rearing over winter, river velocity, food webs).

The proponents have conducted extensive investigations over many years; their results are important for several reasons:

- The increased court-ordered spill has increased TDG in the lower Snake and Columbia rivers. The project's results are directly applicable to understanding the effects of water temperature and dissolved gas effects on migrating Chinook. It seems that the first objective has been met.
- The researchers are documenting recent changes to the Snake River food web that affect not only Fall Chinook salmon, but all salmonids emigrating from the Snake River Basin. One concern, however, is that the project is focused on too few species while other potentially important predators, competitors, and prey are not addressed (e.g., channel catfish, other non-native species). As well, the proponents do not address modification to the natural habitat (with respect to effects on food webs) and the effects of chemical contaminants on food web dynamics.
- The otolith research directly addresses uncertainties about which contemporary fall Chinook salmon production areas are most important, where fish rear and overwinter, and what proportions of fish adopt yearling and subyearling life histories. These investigations could potentially provide useful information about carrying capacity and habitat attributes for successful smolt production.

4. 2017 Research Plan uncertainties validation

The project proponents provide a nice synthesis of how their project addresses CUs. It could serve as a model of what the proponents could do in future years. Nevertheless, it was difficult to cross check CU numbers in the narrative with the CU statement in the database or ISAB/RP report. It seems that the online database is missing some CUs that should be directly linked to this project such as Mainstem Habitats 1.2. Also, the investigators show that this project addresses Predation CUs 1.3, 1.4 and 2.1; Climate change CUs 1.3, 1.4, 2.1 and 2.2 (indirect); M&E CUs: 1.1, 1.2, 1.3, 2,1, 2.2. The CU database should be updated. This is true in other projects as well.

Fish Tagging Technology Development

198331900 - New Marking and Monitoring Technologies

- [View summary in Box](#)
- Background info in Taurus: [Project overview](#) | [Reports](#) | [Past reviews](#)

Project proponent: National Oceanic and Atmospheric Administration

Recommendation: Meets Scientific Review Criteria (Qualified)

Qualifications:

This project addresses the need for a skilled and experienced team to support research and development (R&D) of passive integrated transponder (PIT) technology. The two qualifications listed below are intended to formalize what are likely ongoing but informal channels of communication in the Basin and clarify the process by which activities are prioritized:

- Formal reporting of results and progress requires immediate improvement. Project proponents need to promote the sharing of information to a wider audience via annual reports, published detection efficiency trials, published research papers, published engineering solutions, published laboratory vs. field performance comparisons, and web site postings.
- Establish a more formal method to prioritize the many issues with PIT-tags currently under investigation. These issues range from engineering solutions (e.g., spill way detectors), evaluating and improving existing technology (e.g., testing PIT-tag arrays especially for freshwater streams and the estuary), and long-term research (e.g., PIT-tag loss). A key question is how the current activities are chosen (e.g., based on data-gap analysis in other projects, based on interests and skills of the project team, based on funding from outside sources, etc.). A holistic overview of the PIT-tag uses in the Basin, data gaps where PIT-tags could provide information is needed but is wanting, and the value of information currently missing would be helpful in deciding among activities that have low value vs. activities that are needed to fill important data gaps.

Comment:

1. Objectives

This project has a general objective of improving PIT-tag technology, but specific goals and objectives have changed over time. The current primary goals are to develop interrogation systems to detect PIT-tagged juvenile and adult salmonids in high-velocity areas in tributaries and dams, evaluating new PIT-tags and detection arrays for instream applications, detectors for deeper water (estuary) applications, and evaluation of PIT-tag loss.

The project's overall objective is to develop PIT tag interrogation equipment that can be used in diverse environments (e.g., spill-way and stream detection systems). Solutions appear to be site-specific, but once a solution has been developed it is often applied in similar situations. However, it was unclear how activities are prioritized. They also use measurable criteria to test whether their designs are functioning as desired. Although the timelines of testing activities are broadly stated (e.g., in spring 2019), the proponents do not indicate any specific end-dates and it is likely difficult to do so with any precision.

Improvements in tag detection are relevant to the Council's Fish and Wildlife Program because PIT tags are widely used to measure survival and migration timing salmonids and other species in the Basin.

2. Methods

The narrative indicates the project uses two approaches to develop new PIT tag technology. In some instances, engineering and design work is subcontracted to outside vendors. In other cases, in-house expertise is used to solve specific problems. A combined approach is appropriate for this type of project as it allows the proponents to bring in outside expertise when needed but still provides opportunities for in-house solutions. Scientific hypotheses are not being addressed by the project. Instead the project seeks solutions to engineering problems as they are identified.

3. Results

In its 35-year history, this project has continually addressed management questions by developing technologies to detect fish. For example, they developed and tested equipment that will be used to monitor the passage of juvenile PIT-tagged fish in dam spillways and advanced the design of flexible antenna configurations. They are also testing new detection methods in the lower Columbia River via a PIT tag detection barge. Future work will include: (a) designing new PIT tag detection arrays at the Bonneville Dam Ice and Trash Sluice and spill way, (b) testing of a satellite modem and data compression methodology for remote tag interrogation, and (c) testing of the new CANbus/power cable. Results are used throughout the Columbia River Basin in virtually any project that relies on PIT-tagged fish, and in some cases, these technologies represent important advances in PIT-tag detection and interrogation.

Presumably, their office is the "go to" place to receive information or resolve problems with PIT-tags in the Basin. Nonetheless, the project proponents need to formalize and improve on the sharing of their results. Annual reports have been spotty and brief, and there is no information on how managers and researchers in the Basin and rest of the world can access their products and expertise.

The proponents plan to study loss of PIT-tags at their research station in Alaska. It should be explained how that study will be integrated with the PIT/CWT study that is being conducted as part of the CSS on similar issues?

4. 2017 Research Plan uncertainties validation

While this project does not directly address any of the 2017 Research Plan critical uncertainties, it enables many other projects to do so. For example, improved detection of juvenile and adult salmonids increases the reliability of SARs developed through the Comparative Survival Study, and, in so doing, it provides managers information to manage Columbia River flows (e.g., spill) for the benefit of migrating salmonids.

The proponents indicate that detection and interrogation methods need to be developed for large and deep streams and rivers. The ISRP agrees and hopes that research and development of both new detection arrays/antennas and tag designs can be started to address this important monitoring need in the future.

All the current work involves detections in freshwater. Other projects are interested in survival studies in the saltwater. Is there any contribution from this project to these other projects?

Reintroduction of Anadromous Fish to Blocked Areas

201600300 - Habitat assessment in blocked areas

- [View summary in Box](#)
- Background info in Taurus: [Project overview](#) | [Reports](#) | [Past reviews](#)

Project proponent: Spokane Tribe

Recommendation: N/A – Project complete, results review only

Comment:

1. Objectives

This was a reconnaissance project, which gathered available data and used “intrinsic potential” (IP) and Ecosystem Diagnosis and Treatment (EDT) to assess the amount and suitability of potential habitat for Chinook and steelhead above Chief Joseph and Grand Coulee dams. The project does not include any hypotheses, and the summary explicitly states that they are not needed. “The Habitat Assessment in Blocked Areas did not pose or test hypotheses and was not intended to fully resolve uncertainties described by the ISAB/ISRP (2016).” This is debatable since the Research Plan explicitly states that, “research projects contain a clearly stated hypothesis...” There were no timelines or milestones provided to document implementation of this project nor was there any additional information on when the Phase 1 (or Phase 2) final report will be completed other than they are in development. Other groups are contributing to

the Phase 1 report, and it would be helpful to know what is to be included in the final Phase 1 report.

2. Methods

The methods were scientifically sound given the paucity of on-the-ground data available and the fact that this is a first cut at providing data and analyses for determining whether it is feasible to reintroduce salmonids above mainstem blockages. The applied methods for IP and EDT were not described in detail but are well established, although components contained in the habitat suitability model are limited (e.g., ignore riparian condition, water quality, contemporary watershed uses, historic legacies). The report would have been more complete and useful if the proponents had included references, so the reader could find missing information on the IP and EDT methods. Methods for the other aspects of the project (e.g., life cycle modeling) are not discussed at all.

3. Results

The project met its objective and provided data and analyses that will be used to address 2017 Research Plan critical uncertainties (CUs) under the Population Structure and Diversity theme question 2, which addresses the potential for reintroducing anadromous fish above blocked areas. The intrinsic potential model identified more than 700 miles of spawning and early rearing habitat for spring Chinook and 1600 miles of habitat within the blocked area of the upper Columbia River for steelhead spawning, rearing, and migration. It would be informative to summarize stream length by individual habitat quality category (e.g., low, medium, high) rather than total miles. The EDT model indicated habitat was suitable to support more than 200 spring Chinook, 7000 fall Chinook, and 1300 steelhead. An analysis of the uncertainty in the EDT model outputs would be beneficial since the proponents indicate that the EDT model runs were based on problematic data. They conclude that: “Results from this project provide compelling evidence that tributary and mainstem habitats for anadromous species are abundant in the blocked area and suitable for spawning, rearing, and migration.” However, while the total number of miles does seem high, it is not clear if the number of miles reduced by local barriers is still high. How can it be determined if this number is large or small to warrant investing in reintroduction, especially if the quality of the habitats is unknown (e.g., low vs. high IP).

The proponents point out that a significant effort went into compiling and characterizing data and data gaps; however, no results were presented to summarize this. One of the supporting documents prepared by ICF (i.e., the consulting firm that did the EDT modeling) included an objective addressing limiting factors assessment and data gaps. However, no methods, results or discussion addressed this objective. The final report for the project was completed less than a month prior to this review and a summary memo was provided to the Council on July 31, 2018. It is not known if further presentations will be made or publications written. One of the tasks listed in the summary is “Compile and integrate existing habitat data into a database.” The database was used in EDT analysis, but it is not known if the database is openly available.

4. 2017 Research Plan uncertainties validation

Agree. The authors note that the work aligns with Question 2.1 (*What are the results of the current efforts at reintroducing anadromous fish into blocked areas throughout the Pacific Northwest?*). However, it is not clear that they are addressing this CU directly, which they admit in their report. Instead, they focus the text on how the project addresses the 2014 Program. Perhaps the other products from this project (e.g., additional tributary and mainstem habitat assessments, life-cycle modeling, and results from a risk and donor stock assessment) will contribute more to addressing this CU? However, there is not a clear outline of the products or timelines for completion of the other products.

Habitat Status and Restoration Effectiveness Research and Monitoring

201600100 - BPA Project Action Effectiveness Monitoring (AEM) Programmatic

- [View summary in Box](#)
- Background info in Taurus: [Project overview](#) | [Reports](#) | [Past reviews](#)

Project proponent: Cramer Fish Sciences, Natural Systems Design

Recommendation: Meets Scientific Review Criteria (Qualified)

Qualifications:

The AEM project uses reach-level comparisons to evaluate how habitat and fish populations respond, in general, to restoration actions grouped into categories. The proponents have integrated two separate projects by third-party contractors into a single project. Several components of the originally proposed research have been completed or modified, but several subprojects are still being adjusted.

More information is needed on how the Multiple-Before-After-Control-Impact (MBACI) sites will be refocused. Also, the proponents need to provide information on the Adaptive Management strategy for identifying and selecting alternative approaches for modified subprojects as they complete the remaining research.

Additional information is needed on how estimates of fish abundance based on different sampling methods can be calibrated to estimate error and bias, and possible future methods to estimate capture probabilities.

The proponents need to provide a more specific implementation plan, analytical framework, and explicit description of the nature of inferences that will be possible for the last two

questions that AEM is designed to answer (see Objectives below). They also need to address how their sampling design across space can be used to extrapolate results to basin scales.

The proponents need to provide information on a public outreach strategy and the mechanics of how findings are being communicated to managers.

Comment:

1. Objectives

The ultimate goals of AEM are to 1) quantify localized reach-scale improvements in habitat and juvenile steelhead and Chinook salmon abundance resulting from restoration actions implemented in the Columbia River Basin and 2) guide future restoration efforts to ensure that BPA is investing in effective restoration and habitat improvement techniques. Specifically, AEM is designed to answer the following questions:

1. What is the effect of different action categories on habitat at the reach scale?
2. What is the effect of different action categories on fish and other biota at a reach scale?
3. Within an action category, why are some projects more successful than others in producing physical and biological improvements? For example, what is the relationship between the amount or intensity of habitat improvement and fish response?
4. Are there differences among geographic areas (ESUs) in the physical and biological success of action types?

The first two questions are achievable and testable at the reach scale, whereas the other two are more challenging, the last owing to the need for comparisons across regions. For the Summary Report, the proponents transformed the third question from a "why" question into a "what" question to make it more quantifiable. The fourth question on differences in the physical and biological success of various types of habitat restoration among ESUs is not addressed in their report.

The answers to the questions are important and represent a first step in a fuller understanding of how habitat restoration benefits focal fish species across spatial and temporal scales. For watershed scale restoration, a combination of treatments, both instream/floodplain and those occurring upslope (road decommissioning, silvicultural treatments) are typically applied for accomplishment of restoration objectives. Also, other approaches will likely be needed to better understand whether there are differences in habitat and population effects, within action categories, due to differences in project design, intensity and location. Other monitoring approaches will be required for the landscape-scale predictions that will be needed, for example, to inform life cycle models.

Milestones and end dates were clearly defined and apparently on track, given the changes to a single contractor.

2. Methods

For the first two questions, the MBACI vs. Extensive Post Treatment (EPT) designs are well explained and the analyses generally were appropriate for the scale of investigation. Several critical aspects of the methods, however, are not explained in adequate detail.

Though characteristics of control and treatment sites are described in the supporting documentation, it is unclear what design was used to select sites for either the barrier removal or LWD studies. An ideal design involves creating a database of all possible sites, then selecting a subset for sampling by some stratified random method (e.g., Generalized Random-Tessellation Stratified design, GRTS). Instead, the reader is left with the impression that the sites were selected haphazardly and geographically clumped (e.g., barrier removal projects cluster near Seattle and in northern Idaho). If so, does this sampling design provide strong inference for extrapolating across basins or regions?

Additionally, it was not clear how controls are selected. Does the AEM project identify many sites with similar geomorphic features as treatments and then randomize? Some of this is described in the annual reports, but a synopsis in the Summary Report is needed. It may be possible to improve the EPT design by using multiple control reaches at each site. This would provide information on reach-to-reach variation and may improve statistical power, which could be quantified.

The Summary Report does not indicate whether bankfull flows or greater have occurred in restored sites. It is important that sites have successfully experienced design flows when determining whether they passed fish.

Reach lengths for investigating physical or biological responses differed by type of restoration action. The full barrier removal sites are small streams and most of them lacked anadromous salmonids, which limits their benefits for the Fish and Wildlife Program. Will sampling of 50 m of habitat be sufficient to yield strong inference about potential differences after barrier removal? Paired sites had similar habitat and fish abundance (see Clark et al. MS in supporting documents), but numbers of pools were few in all cases, and even fish abundance was often low. For example, only about a third of the sites had more than 20 fish of all species in either the treatment or control sites, suggesting that comparisons may suffer from low statistical power.

Results for the two types of habitat restoration assessed relied on different methods of estimating abundance, ranging from three-pass removal estimates, which account for capture probability, to snorkel counts, which do not. As a result, these measure only relative abundance with unknown confidence. Future reports and work should address how estimates of relative abundance can be calibrated to estimate error and bias. In the best case, future work would employ methods to estimate capture probabilities.

Table 1 in the barrier report (document [P149035](#)) indicates that three-pass electrofishing and snorkel survey data are mixed, which may be valid in a paired design. However, more worrisome is that the raw counts range from < 10 to close to 100. Differences then cannot come from a single distribution and the paired-t-test on the raw counts is not appropriate. Similarly, were pairs with no fish deleted prior to analysis? It would be better to analyze log(ratio) or use Poisson ANOVA to deal with these issues. Only p-values but no estimates of effect sizes are reported (with standard error/confidence interval). The 2017 report describing analysis of wood restoration (document [P158833](#)) includes an analysis of log(ratio) values. Estimates and confidence intervals are presented along with p-values. This type of analysis should be used for the barrier removal analysis.

The proponents report that their measurements of summer abundances of juvenile anadromous salmonids are consistent with estimates of total smolt production, based on Ogston et al. (2015).⁵ However, limiting factors that occur during winter may have stronger effects on ultimate smolt production than summer habitat. More detail on this relationship in final reports and publications would be highly useful for managers and researchers.

Chelgren and Dunham (2015)⁶ provide a sophisticated analysis of the abundance of fish species after barriers are removed for coastal Oregon streams. Their method accounts for probabilities of capture and detection for multiple species. This might be useful as a reference and when considering next steps but was not cited in the Clark et al. manuscript.

The report indicates that evaluation of fencing (i.e., livestock exclusion) was dropped because of inadequate sample size. This needs better explanation because bank stabilization and fencing are two of the most common river restoration actions. Why can the project not find more sites to create a more powerful experimental design? The summary report should describe the cause for the low number of potential study sites and explain why the restoration action should be dropped from their project.

Question 3 (why are some projects more successful?) is open ended. The approach for identifying the range of factors that can affect project success is not thoroughly described either in the report or the background documents. The wide array of restoration methods, site conditions, fish assemblages, timing of implementation, geomorphic and hydrologic histories, and land uses present challenges for unbiased analysis of factors responsible for success of restoration. For example, in the project's analysis of the success of wood restoration practices, they would need to assess important variables such as size of material, whether anchored or

⁵ Ogston L, S Gidora, M Foy, and J Rosenfeld. 2015. Watershed-scale effectiveness of floodplain habitat restoration for juvenile coho salmon in the Chilliwack River, British Columbia. *Canadian Journal of Fisheries and Aquatic Sciences* 72(4):479-490.

⁶ Chelgren ND and JB Dunham. 2015. Barriers to passage of aquatic organisms at stream road crossings are a major cause of habitat fragmentation in stream networks. *Ecological Applications* 25:1357-1372.

not, design and intensity/density of placement, or location of placement. The proponents should provide additional information on how they will frame their assessments of factors responsible for differences in success between projects and the specific limits of their inferences or conclusions for practitioners.

Question 4 focuses on the ESU scale for assessing restoration project success, but it lacks a clear description of how the spatial scales of the ESU will be addressed by the research design. The proponents need to address how their sampling design across space can be used to extrapolate results to watershed and basin scales, and what caveats may be necessary about this inference if no statistical sampling design was used to select sites. The 2013 ISRP review ([ISRP 2013-2](#)) recommends stratification of sites by stream size or discharge. Presentation of the results and conclusions will require clear description of the scope of inference for the studies and the spatial scales for which the results are applicable.

3. Results

The report presented results for the studies of barrier removal and large wood restoration projects. Studies of other restoration projects are ongoing and will be reported in the future. The researchers encountered challenges finding sites that met the requirements of the MBACI designs, which may require future modification of the study.

The proponents have made solid progress in evaluating the overall effectiveness of several basic categories of restoration actions. One of the strengths of the AEM Project is its publication of literature reviews, project results, and research protocols. The research both provides documentation of the scientific background and specifics of the research design, but it also informs many other participants in the Fish and Wildlife Program and associated state programs within the Columbia River Basin.

While the objectives generally are clear, the project is incomplete. The EPT evaluations of barrier removal and LWD are complete, but the MBACI portion of the project appears to have had implementation issues and was re-contracted. Results will not be available for a few more years. Assuming no further problems, this should be feasible.

As noted above, the project has completed initial sampling and analysis of two restoration types: fish passage restoration at full barriers (32 paired sites) and LWD placement (29 paired sites). The results are useful as a first step in addressing the management question of whether removing barriers to movement or adding large wood has any detectable effects at the reach scale on summer daytime abundance of juveniles of anadromous salmonids. Whether this translates into higher survival and more smolts produced per redd is the next question, requiring much more work to assess.

Results of the barrier removal study includes many zeros (Table 3), and presumably these values are removed prior to analysis, though this is not stated in the methods. This leaves a single site for comparing coho abundance, and consequently there is little information on the

impacts on this species. Only four sites can be used for analysis of Chinook salmon, one of which had a single fish. Some of the values from Table 1 in the detailed analysis of the barrier removal project differ from Table 3 in the summary. The report concludes that there are "no significant differences," but this is a meaningless statement. With such small sample sizes, only large effects could be detected. Proponents should clarify how zero abundances were addressed in the analysis and present effect sizes and measures of uncertainty (SE/CI).

The third and fourth questions were not addressed or discussed. The report on LWD (Clark and Roni 2017, AEM 2017 Annual Report) briefly mentioned a result that addressed the fourth question (i.e., p. 16-17; "Fish response did not differ by ESU for any species [ANOVA; $p > 0.20$]").

4. 2017 Research Plan uncertainties validation

The proponents' statement clearly identified linkages to critical uncertainties in the 2017 Research Plan. In several cases, the linkages are valid, but the contributions of the restoration actions may be relatively small. For example, it is difficult to identify a physical process that would cause restoration of large wood to cool streams.

200301700 - Integrated Status and Effectiveness Monitoring Program (ISEMP)

201100600 - Columbia Habitat and Monitoring Program - (CHaMP)

- [View summary in Box](#)
- Background info in Taurus: [Project overview](#) | [Reports](#) | [Past reviews](#) (also see [ISRP 2013-2](#) and [ISAB/ISRP 2016-1](#))

Project proponent: National Oceanic and Atmospheric Administration

Recommendation: N/A – Projects complete, results review only

Comment:

1. Objectives

The integrated report states that the single objective for both programs was to develop RME methods to assess status and trends, restoration opportunities, and the benefits of habitat restoration actions on salmon and steelhead and their habitat in the tributary environment. The larger spatial framework of these two programs is a critical context for evaluating whether they were scientifically sound. "The goal of ISEMP and CHaMP was to support the development of more realistic, spatially explicit, tributary habitat restoration scenarios and to quantify the degree to which these restoration actions might benefit salmonid populations in the interior Columbia River Basin." In addition, the integrated report explicitly states eight major questions

the two programs were designed to answer. The objectives, methods, and analytical techniques are adequately described.

The two projects were terminated in late 2017 and early 2018.

2. Methods

The methods used in the ISEMP and CHaMP programs are thoroughly documented, and the ISRP evaluated the projects' scientific soundness in multiple review processes from their beginning through 2013.⁷ In addition, the ISAB and ISRP evaluated the projects' contributions toward the Program's critical uncertainties in 2015-2016 ([ISAB/ISRP 2016-1](#)). The ISRP found the projects' methods generally to be scientifically sound and offered recommendations for improvements. Methods and results are also published in top peer-reviewed journals in fisheries, geomorphology, and ecology, and thus the methods underwent peer review by experts in those fields.

A review of the utility of CHaMP measurements and their protocols was contracted by BPA and completed by Wildlands Hydrology. Neither the ISRP nor ISAB have reviewed Wildland Hydrology's assessment, which raised concerns, particularly about channel bedform classifications and identification of bankfull channel. In response to questions during their public presentation, leaders of Wildland Hydrology's assessment team indicated that the CHaMP measurements of several of the major factors in habitat quality in the Columbia River Basin (e.g., riparian vegetation, large wood, temperature, and sediment particle size) are scientifically sound.

One of the fundamental characteristics of the ISEMP and CHaMP programs that differentiates them from AEM is the spatial and temporal scales for which they were designed. These two programs are designed to "assess status and trends, restoration opportunities, and the benefits of habitat restoration actions on salmon and steelhead and their habitat in the tributary environment." They are designed to identify these properties at the scale of entire watersheds or basins. AEM is designed primarily to assess the effectiveness of specific types of restoration actions at the site and project scale rather than entire watersheds or basins. Measurements in these different programs have the potential to be complementary rather than mutually exclusive if the necessary cross walks and data consistency for the individual site data are developed.

3. Results

The ISEMP/CHaMP project broke new ground at the cutting edge of (a) measuring and modeling stream habitat across a wide range of spatial scales, and (b) relating this to salmonid

⁷ [ISRP 2013-2](#) includes a comprehensive history of ISRP and ISAB reviews of the projects beginning on page 5.

abundance and production. The integrated ISEMP/CHaMP report provided summaries of three intensively monitored watersheds, 10 studies of fish and habitat status and trends, 23 tools for restoration assessment and planning, 6 life-cycle models, and 4 data support projects. CHaMP sampled more than 800 sites in 8 years, which will provide critical information and a foundation for monitoring for years to come. Data/models and source code are readily available through cloud-based data warehouses and GitHub sites. Unlike most monitoring of local reaches, the data and analysis from ISEMP/CHaMP can be extrapolated from study reaches to the Basin. It is not an overstatement that many of the methods and results will be useful for decades to come among researchers and managers in the Columbia River Basin and worldwide.

Of the 46 subprojects summarized in the report, several have contributed substantially to our understanding of status and trends in major basins, design of future monitoring, and decision making in the Fish and Wildlife Program. We highlight several of these to illustrate the value of the results from these two programs:

- ISEMP/CHaMP developed methods to estimate juvenile salmon and steelhead density throughout a river network based on measures of the primary production of benthic algae, the ultimate source of food for invertebrates that feed fish communities. About half of the variation in fish abundance is explained by these algae growing on the streambed. In turn, gross primary production (GPP) can be predicted from models of stream temperature, conductivity, and solar energy, allowing researchers to calculate estimates of fish abundance from maps of these three physical variables.
- ISEMP/CHaMP adapted the Barker Model to analyzing mark-recapture data where fish are marked at one place and time, such as with PIT tags, but then captured (or detected by PIT-tag antennas) at distant locations over a wide range of times. This analytical technique is a key to measuring effects of habitat restoration on migratory fish like salmon and steelhead, which have smolts that emigrate. Without it, analysis of the abundance of fish with these complex life cycles is very difficult. The model will improve estimates of salmonid survival as they migrate through the river network and hydrosystem
- To relate fish abundance to habitat, Quantile Regression Forest models were developed. These models can address the thorny problem that habitat is not always the sole limiting factor for fish abundance and so data are often highly variable. This statistical method can deal with this problem.
- ISEMP/CHaMP created six life cycle models, which represent an extremely important tool for future analyses and decision making throughout the Basin. In recent reviews, the ISAB concluded these life cycle models provide holistic analyses of potential limiting factors over the full life cycle and geographic range of anadromous salmon and steelhead ([ISAB 2017-1](#), [ISAB 2018-1](#)). These models will assist landscape-level assessment of status and trends by the Fish and Wildlife Program in the future and will greatly assist decision makers in the region.
- The Intensively Monitored Watersheds revealed several major findings, illustrating the value in this approach. The studies revealed both positive responses to restoration

actions in one basin and no response in another basin. The balanced and unbiased analysis of the research data should be a model for other projects, because sometimes the desire or commitment to provide benefits to fish populations and habitats colors the interpretation of project results.

- The status and trends subprojects provided a scientifically strong foundation for analysis of future trends. As examples, the temperature subproject and the survival estimation subprojects identified critical issues about habitat conditions and population status while providing valuable analytical tools. The temperature estimation approach incorporated riparian condition, floodplain conditions, and discharge, which are significant predictors and elements of many restoration actions within the Basin. The visualization techniques for temperature will contribute to future temperature studies in the Northwest.
- ISEMP and CHaMP developed more than 23 restoration tools to assist restoration practitioners and assist in the analysis of ISEMP and CHaMP data. Several of these have been used by other projects and have substantially contributed to the synthesis of ISEMP and CHaMP data. Examples of major contributions are the Quantile Regression Forest models for fish habitat relationships, geomorphic network analysis tool box, riparian condition assessment tool, wood recruitment assessment tool, and river classification and geomorphic condition tool. These analytical tools will continue to assist and inform restoration planning and design.

Many of the ISEMP projects created GIS mapping tools to estimate variables needed to drive other models. For example, abundance and productivity of salmonids are different in valleys of different types (i.e., wide valleys with low gradient where the stream meanders vs. narrow and steep valleys where the stream is mainly cascades). To address this relationship in life-cycle models, they developed a tool to measure valley bottom width from digital maps using GIS.

A key finding from these projects is the need to design monitoring studies of restoration actions at appropriate scales of space and time for expected resource outcomes. Projects were able to detect local improvements but often failed to detect population-wide responses (e.g., Entiat IMW). Not unexpectedly, population metrics suffer from spatial mis-matches (e.g., population spatial scale is much larger than restoration spatial scale), from high variability in responses, from influences by many factors over and above restoration, and a longer-time lag for restoration actions to become effective. Detection of population scale responses to local restoration actions likely will need much longer time scales than are typically included in most monitoring programs.

The tests of the effects of habitat restoration carried out and published by the ISEMP/CHaMP program are among the best conducted to date, worldwide. An example is the research on the effects of Beaver-Dam analogs on steelhead in the Bridge Creek watershed of the John Day

River (Bouwes et al. 2016⁸). As a result, this approach that requires less heavy equipment and site disturbance is being used increasingly in other programs throughout the Basin.

The program also broke new ground in determining how to measure habitat across a wide range of spatial scales from local sites to whole sub-watersheds, and where best to focus sampling efforts in such a daunting task. For example, a key result was that measuring more sites at intermediate intervals (e.g., 3 years) is more important than measuring fewer sites every year, because variation in habitat is larger across sites than among years within a given site.

Another key finding was that some of the most striking improvements in habitat and fish numbers have been achieved from lower cost projects that focus on natural-processes, such as small-scale structures and beaver input, not just from larger and more expensive projects.

Key project findings were shared widely in the refereed literature. The list of 53 peer-reviewed publications from the project, many of which appeared just in the last few years, is very impressive.

Lessons Learned and Areas for Improvement

The CHaMP protocol has been used by more than 10 state and Federal agencies and tribes to monitor fish habitat and restoration projects. Researchers and managers will continue to reap benefits from the tools developed and the papers published by the ISEMP/CHaMP program for decades to come. Despite the body of information developed by ISEMP and CHaMP, the lack of effective outreach and information sharing was a major weakness of the programs.

The programs did not provide frequent and timely syntheses of their measurements for use by regional projects and leaders of the Council and BPA. The programs were not successful in showing managers and policy makers why the results they were producing were useful. Examples of practical information for managers and decision makers in clear language free of jargon were needed. Instead, many of the reports were difficult to read and interpret, often because the writing was suitable for statisticians and GIS experts but not the intended audience. Most of the audience is lost by jargon, such as “site level sample inclusion probabilities,” “riparian vegetation departure products,” and “user-defined non-zero probability” in the Summary Report. Great results cannot be used if the audience who is supposed to use them cannot easily understand them.

⁸ Bouwes, N, N Weber, CE Jordan, WC Saunders, IA Tattam, C Volk, JM Wheaton and MM Pollock. 2016. Ecosystem experiment reveals benefits of natural and simulated beaver dams to a threatened population of steelhead (*Oncorhynchus mykiss*). Sci. Rep 6:28581. 10.1038/srep28581. <http://www.ncbi.nlm.nih.gov/pubmed/27373190>. <https://isemp.egnyte.com/dl/i3zz8KMhML>.

One area that did not receive much attention in the project was the linkage of upslope/upstream processes and management to conditions in the downstream, valley bottom and fish bearing sections of watersheds. Although the need to provide tools or links for including these considerations was identified in past reviews, it does not appear to be included in the summary reports. Certainly, this would have added complexity to the work, but it is an important component for ultimately understanding, managing and restoring aquatic habitat and fish populations at watershed scale.

A final goal for ISEMP/CHaMP would be to show managers and decision makers results they can really use. The projects have ended, but NOAA Fisheries and collaborators are continuing to analyze, synthesize, and present their findings. It will be beneficial for the Fish and Wildlife Program to track and publicize when and where the findings and data are available into the future.

Design of Future Monitoring Programs

Although the projects are now closed, some observations looking back on the multi-year effort may be useful in designing and implementing future, large scale projects, particularly those that address similar research questions. The ISRP recommends that design of future monitoring should incorporate many of the 54 monitoring protocols and 800 CHaMP monitoring sites to take advantage of the 7-yr database for future trend analysis. The results of ISEMP and CHaMP can be used both for designing M&E projects and as prior long-term data for future monitoring sites. The investment in ISEMP and CHaMP has produced a substantial body of habitat data, methodological advances, analytical tools, and life cycle models, which provide a foundation on which to build future monitoring programs. This legacy should be carefully considered when developing the new tributary habitat RME strategy co-led by BPA, Council, and NOAA.

The analysis of measurement noise and overall variance for 54 different habitat measurements provides important insights for future monitoring. This analysis identifies the influence of different sources of variance for the habitat metrics used in the monitoring program. For example, most of the variance in estimates of coniferous riparian forest cover was related to either watershed or site components of variance, and variance in large wood fish cover was related primarily to site components. Interannual differences in their estimates were small, and they suggested greater information could be obtained by sampling a greater number of sites less frequently. They also found that crew-to-crew differences had little effect on the variance of their metrics. These results of the ISEMP/CHaMP programs should inform future design of monitoring programs in the Basin.

One of the most critical challenges for RME projects is providing information that can be directly applied to management issues throughout the life of the project, not just at the end. This requires agreement at the start of the project between the funders and the investigators about the degree of uncertainty that decision makers/management are willing to accept and the format for reporting. This also would require all users to understand that interim information be updated or revised in the future. More discussion and agreement on this issue

between funders and project leaders at the outset of this long-term project would have been useful.

One of the innovative organizational aspects of the integrated final report is the concise and informative summaries of the individual sub-projects. The format provides a diagrammatic road map for the 46 sub-projects, graphical description of the relationships between the projects, concise nontechnical descriptions of the subprojects, concisely stated major findings and uses, contact information, and URL links to products, publications, web pages for tools or computer code, locations of data, and supporting files. The Council and BPA should consider using similar formats for other reports and products in the future.

4. 2017 Research Plan uncertainties validation

The summary report did not explicitly identify linkages to the 2017 Research Plan, but the 2017 Research Plan critical uncertainties database identifies direct or indirect linkages with 18 critical uncertainties for the ISEMP and CHaMP projects. The proponents did not directly crosswalk against the database. A quick review of the uncertainties database showed that most of them were covered by the projects except perhaps (a) resiliency to climate change, (b) additional habitat actions that are needed, and (c) estuary and plume actions and monitoring.

200900400 - Monitoring Recovery Trends in Key Spring Chinook Habitat Variables and Validation of Population Viability Indicators

- [View summary in Box](#)
- Background info in Taurus: [Project overview](#) | [Reports](#) | [Past reviews](#)

Project proponent: Columbia River Inter-Tribal Fish Commission (CRITFC)

Recommendation: Meets Scientific Review Criteria (Qualified)

Qualifications:

Provide more explicit, quantitative objectives and guiding hypotheses for future activities associated with each of the sub-projects. As well, additional details are needed on the basis for selecting the narrowed set of CHaMP/monitoring metrics and on the approach for ensuring that time-series analyses can be conducted using metrics and results from previous habitat monitoring. With the 2018 habitat assessment protocol being modified to provide a pared down list of metrics to be used for comparison with data developed from remote sensing analysis, the ISRP would appreciate an opportunity to review and provide feedback on the modified protocol in the near future.

Establish an effective Adaptive Management strategy that can guide research and restoration directions as well as management decisions. Approaches for Adaptive Management within the project should be described. It would be helpful for the ISRP to know if the project intends to collaborate in the development of Adaptive Management processes for the Grande Ronde Model Watershed.

Overall, a synthesis of project Results/Findings and a list of recommendations for management/restoration would be appreciated. In the project synthesis, an overarching statement about how the collection of projects reflects a strategic and coordinated effort to address the project objectives is needed. This could be accomplished by mapping subprojects to the broader program objectives. In addition, an expanded narrative showing linkages between only the most relevant critical uncertainties (CUs) and the individual research components for the project would be beneficial.

Comment:

1. Objectives

There are three general objectives:

- Assess current status and trends in fish habitat characteristics considered to be key limiting factors to viability of spring Chinook salmon populations;
- Evaluate effectiveness of aggregate stream restoration actions aimed at improving key limiting habitat factors; and
- Develop a life-cycle model to link biotic responses of spring Chinook populations to projected changes in stream habitat conditions.

The objectives are largely descriptive and do not include hypotheses. They are broadly stated such that project success in meeting the objectives cannot be evaluated. While they serve as useful goal statements for the project, quantitative and measurable objectives are needed. These changes would likely enhance the focus of important findings and their relevance to management.

An overarching statement about how this collection of projects reflects a strategic and coordinated effort to address the project objectives is needed. The summary report provides an overview and accomplishments only for 2017 for each of nine sub-projects. The summary of projects generally links to project objectives, though not in any structured or organized way. Although requested for this review, no summary of accomplishments for the full, 9+ year duration this project was provided. Such a summary would have been greatly appreciated and would have aided in a more comprehensive review.

A general annual timeline was provided. There is only one project listed after 2018 (i.e., the development and application of the rapid habitat assessment); all other projects will have been completed.

2. Methods

Overall the applied methods appear to be standardized and well documented as evidenced by the numerous technical papers produced. While methods for each of the subprojects are not fully described in the report provided for this review, the annual reports and publications include extensive documentation of methods. While many of the research methods appear scientifically sound and directly address the project's broad overall objectives, the ISRP would appreciate an opportunity to review the use of historical information as a valid point of reference for restoration targets. Further, the report could have been improved by adding specific names (e.g., "a mechanistic water temperature model") and references for the methods.

The ISRP notes that the 2018 habitat assessment protocol has been modified to provide a pared down list of measurement designed to be consistent with data developed from remote sensing analysis. This new approach should be reviewed by the ISRP soon.

No information is provided about the project's adaptive management process. An adaptive management strategy should be central to this project, especially as it related to important management decisions about future restoration actions. A comprehensive discussion regarding adaptive management for the project is needed and should be incorporated into project activities starting in 2019.

3. Results

This project is one of the most productive in the Basin, and its researchers have published extensively in top-tier journals. In 2017 alone, they produced five publications and have five more in preparation. Results from this project have been used to design ongoing restoration efforts and a hatchery supplementation program in the Grande Ronde Basin. Their results and lessons learned have been used widely in the Grande Ronde Basin for integration of habitat data, historical reconstruction, food web analyses, and implementation of new technologies in watershed management and restoration.

A primary outcome of this work was development of a life-cycle model that has been refined using locally gathered field data. This has provided valuable insights into priorities for landscape-scale restoration in these two drainages and initial quantitative estimates of the likely habitat and biological responses for various, general restoration scenarios.

The Spring Chinook Habitat Monitoring Project collaborates widely with tribes, Oregon Department of Fish and Wildlife, the Grande Ronde Model Watershed, and regional habitat monitoring programs. This clearly is a strength of the project but is an area that requires

additional description. The ISRP has called for the development of an Adaptive Management plan for the Grande Ronde Basin, and this project is one of the major collaborators. The proponents should provide information about the Adaptive Management approach used internally for the project as well as externally with its collaborators. The need for clearly defined adaptive processes is underscored by the recent changes in regional habitat monitoring programs and this project's revision of its own habitat monitoring.

The proponents are conducting public outreach activities, although they seem to be exclusively directed at fellow scientists and perhaps mid-level managers. It appears that there needs to be a set of activities directed at the general public and private landowners. If this is not occurring, such an effort targeted at the general public, particularly land owners, would be a valuable addition. One key benefit would be the opportunity to emphasize the importance of the Grand Ronde river/watershed to the future of Pacific salmon and the local region.

4. 2017 Research Plan uncertainties validation

The ISRP generally agrees with the proponents' statement on linkages to the 2017 Research Plan. However, it is not clear how most of the indirect critical uncertainties are connected to the research program. The proponents should provide an expanded narrative articulating the linkages. For instance, identified linkages to population structure and diversity, non-native species, contaminants, climate change, and monitoring and evaluation methods are not always self-evident. Project linkages to non-native species and contaminants are indirect (as noted by the proponents); the ISRP questions whether they should be listed.

200725200 - Hyporheic Flow Assessment in Columbia River Tributaries

- [View summary in Box](#)
- Background info in Taurus: [Project overview](#) | [Reports](#) | [Past reviews](#)

Project proponent: Umatilla Confederated Tribes (CTUIR)

Recommendation: Meets Scientific Review Criteria (Qualified)

Qualifications:

The project has provided important findings and potential general applications for a hyporheic perspective in restoration planning. After a number of years, however, results are less detailed than originally projected and, to date, are limited to the specific location studied. More information on biological responses and restoration applications would be useful.

The proponents are asked to provide:

- A quantitative description of the influence of hyporheic exchange on redd locations and the causes for warming in the restored reach of Meacham Creek;
- A description of how past outreach and guidance has been incorporated into better management practices; and
- Specific hypotheses, quantitative objectives, timelines, expected products, and the application of products for improved management practices associated with Phase 3 of the project.

Note: The proponents provided an excellent response to a previous set of qualifications (i.e., 2007-252-00, Response to ISRP Memo dated 11/6/2013). They provided an outstanding example of direct, informative answers to questions raised in a previous ISRP request for response.

Comment:

1. Objectives

The long-term goal of this project is to produce credible scientific insights for understanding the role of alluvial aquifers and associated hyporheic exchange relative to conservation of Pacific Northwest salmonids. This improved understanding was to provide a foundation for development of improved restoration strategies including location and design of projects. Unfortunately, the three major objectives are broadly stated and lack specific description of their intent and the specific hypotheses on which they are based. While the objectives are clearly worded, they are not quantitative or time bound. They function as main goal statements. For instance, the first objective was to understand the distribution of Chinook and summer steelhead, but there was no identification of the specific hyporheic attributes related to the distribution of the fish. The overarching hypothesis is equally broad and vague, simply stating that hyporheic exchange is important in the distribution of anadromous salmonids. Sub-hypotheses are provided in the description of current work, but these also are broadly stated and lack sufficient detail.

2. Methods

The proponents appear to have organized a comprehensive program. Previous annual reports describe their specific research measurements and analyses. Not only are the scientific methods sound, an Adaptive Management strategy and active Public Outreach activities are also key project components.

3. Results

The project has provided a substantial body of research on hyporheic exchange and its relation to the ecology of anadromous salmonids and habitat restoration. The project summary report

describes the completion of Phase Two of a three-part project. Explanations of the measurements and analyses were provided in previous annual reports. The summary provides only general annual end dates for project activities.

While the body of research is scientifically sound, several conclusions are questionable. The researchers conclude that hyporheic exchange is an important consideration for management of spawning habitats because redds are found upstream of nick points. The research did not actually measure hyporheic exchange associated with the location of redds. Protection and restoration of a hyporheic exchange is warranted, but caution should be used in interpreting these results.

The Meacham Creek Restoration Project resulted in increased warming through the restoration reach. The project leaders attributed this to removal of riparian shade to allow large equipment to realign the channel. While this hypothesis may be correct, caution should be used in interpreting the results. Other physical processes could be responsible for the observed warming. The final project summary simply states that lack of shade counterbalanced the cooling effect without providing a qualifying statement that this was a hypothetical conclusion.

The hydrological model of hyporheic exchange, which was developed, is a beneficial tool in managing stream temperature. The inclusion of components addressing both shade and hyporheic exchange strengthens the model, and both are used by other researchers in modeling hyporheic processes.

The project has significant benefits for guidance for water temperature management and habitat restoration throughout the region. The proponents have made some interesting discoveries that have general benefits for restoration if a hyporheic perspective could be more broadly applied. The summary describes the benefit to habitat monitoring programs but also identifies a link between their hyporheic research and the First Foods management approach of the CTUIR River Vision. This linkage between habitat restoration in the First Foods concept is extremely important and should be highlighted in monitoring and presentations of their findings in the future. The summary would be strengthened by identifying additional outreach activities, which are provided in previous annual reports.

4. 2017 Research Plan uncertainties validation

The project addresses Critical Uncertainties (CUs) associated with the efficacy of stream and habitat restoration efforts [A 1.1, 1.2, 1.4, 2.2], while providing additional knowledge relevant to focal species response to restoration actions [E 1.1], and stream temperature response to climate change [J 1.3, 2.1].

The project summary briefly explained linkages between the research and the CUs but did not address whether the linkage was direct or indirect. In general, the ISRP agrees with the general description of linkages. One CU listed in the Council's 2017 Research Plan Database (B.

Mainstem habitat) was not included in the project summary. We agree that it is not closely linked to this research.

200901400 - Biomonitoring of Fish Habitat Enhancement

- [View summary in Box](#)
- Background info in Taurus: [Project overview](#) | [Reports](#) | [Past reviews \(ISRP 2012-17\)](#)

Project proponent: Umatilla Confederated Tribes (CTUIR)

Recommendation: Qualified

Qualifications:

This project is underperforming. Given the extensive changes to this project, as well as general uncertainty regarding funding and the future of the three Basin-wide monitoring programs, this project needs to be re-examined and re-defined with updated monitoring questions, quantitative objectives, and realistic timelines.

As soon as possible, the proponents need to provide the ISRP with:

- Quantitative objectives that can guide future research activities;
- Clear responses addressing the three main questions currently guiding the program;
- An Adaptive Management strategy;
- An overview of the data management system and provisions for comprehensive analyses;
- A list of peer-reviewed publications and meeting presentations; and
- An effective strategy for Public Outreach.

The proponents agreed to provide a detailed response to the qualifications for the next review. An explicit project framework that describes the research/monitoring path for future activities is required. The ISRP believes that the proponents need to re-group and seek sustained (multi-year) scientific mentorship, both internally and externally. Externally, the scientific mentorship perhaps could be provided by CRITFC (e.g., Dale McCullough and others) or independent advisors with experience on similar projects.

This project is a victim of changes to funding and priorities for RME. It is suggested that this project be re-examined and re-defined based on future, near-term funding decisions and changes.

Comment:

1. Objectives

This ambitious project has been pared down from its initial design due to several factors. Initially it was to address six individual hypotheses that focused on biological responses of restoration activities at a scale that would complement CHaMP and ISEMP across five sub-basins. With current plans for scaling back/curtailing CHaMP and uncertainties about renewal of Accord funding, there are major questions about the relevance of this project, particularly how its future design compares with the work that was originally proposed. Most work to date has focused on pre-project, baseline data gathering. Initial results are provided for only four projects. It is stated that post-project monitoring will need to continue for 10 years (i.e., instream work) or longer (i.e., riparian/floodplain work). No additional detail is provided regarding timelines for evaluation of data for current projects or addition of any new projects.

The 2016 annual report states that due to reductions in staffing and funding, current activities only address action effectiveness of projects implemented under the Biological Opinion. The summary report does provide a listing of two general objectives for the current project. These are not quantitative or time bound, but they do address goals for monitoring biological and physical response to restoration. They provide five anticipated responses to their restoration actions as hypotheses, but these are simply desired outcomes and not hypotheses with explicit mechanisms. It is noted that current work is focused mainly on site/reach scale habitat responses to restoration and on juvenile fish responses (e.g., densities and distribution, original hypotheses 1 and 5). The proponents acknowledge difficulties in dealing with complexities of determining biological and physical responses at the site scale due to restoration actions. The ISRP noted this as an issue in an earlier review.

2. Methods

Methods are clearly documented; however, changes in funding have required changes in focus and approach for current monitoring activities.

One of the strengths of the Biomonitoring Project is that it attempts to be consistent with the protocols of the regional CHaMP, AEM, and Physical Habitat Monitoring Strategy (PHAMS) monitoring programs. As such, the methods are scientifically sound and comparable to measurements of other programs in the region. The three regional programs are designed to identify habitat trends at different spatial and temporal scales, but the Biomonitoring Project has decided to focus at the site scale for habitat actions under the Columbia Basin Fish Accords. They indicate that responses at the population and watershed level will require different methods and analyses in the future under a different project design.

Additionally, measurements have changed because of cost limitations, delays in implementation of projects, and other changes in methods. It is unclear whether the collection

of different or modified measurements will be adequate to assess the response to restoration actions as originally designed.

No Adaptive Management strategy is discussed. Given the unforeseen changes in funding, implementation of restoration projects, ability to tag adequate number of juveniles, and weather/environmental events, the proponents need an explicit process for assessing the status and findings of the project and identifying modifications to the study design that are more likely to be successful. This could be linked to a regularly scheduled presentation of the projects progress and findings in a science meeting that is open to Tribal members, scientists, managers, and public.

The report listed no peer-reviewed publications or meeting presentations from the project, and no Public Outreach is mentioned. In the near future, these actions or needs should be initiated to strengthen project effectiveness.

3. Results

Implementation of this ambitious project is in the early stages and reflects a significantly pared-down version of original plans. The report presents quantitative results for 12 sites. Most work has focused on gathering pre-restoration, baseline data on habitat and juvenile fish abundance. A limited amount of post-restoration work has been completed and that focuses on site/reach scale responses for four projects. Future synthesis of the responses to restoration will be valuable, but changes in measurements and protocols may weaken comparisons. Careful consideration of future measurements and consistency will increase the likelihood of successful project completion.

The discussion of fish response to restoration is confusing and generally indicates changes in fish density in response to restoration have been highly variable and provide no consistent evidence of the benefits of restoration. For instance, findings have generally shown increases in juvenile abundance attributed to increased wetted useable habitat area but also show declines in densities. Difficulties of spatial scale and only initial post-restoration data are noted as issues in being able to make definitive conclusions.

The overall project is either incomplete or yielding results that indicate variable responses to restoration actions at the reach level. Future activities will require coordination and implementation that has been lacking. While the project anticipates benefits of coordination with other RM&E projects and the PHAMS program, the summary does not describe how that will happen.

4. 2017 Research Plan uncertainties validation

The ISRP agrees with the proponents' statement (direct or indirect) on linkages to the 2017 Research Plan, but no explanation of how their project links to those uncertainties is provided.

Freshwater Mussels

200203700 - Freshwater Mussel Research and Restoration

- [View summary in Box](#)
- Background info in Taurus: [Project overview](#) | [Reports](#) | [Past reviews](#)

Project proponent: Umatilla Confederated Tribes (CTUIR)

Recommendation: Qualified

Qualifications:

The ISRP is greatly impressed by this project. Our comments and qualifications are given with the intention of making this project even more scientifically meaningful to the Fish and Wildlife Program.

The potential contribution of this program to conservation and restoration is huge for the study area, and the Columbia River Basin, through better understanding the distribution and ecology of mussels and their use as sentinel species to track environmental conditions. The Xerces Society is a good partner for communicating information on the project to the public, as well as for providing guidelines on avoiding damage to mussels with restoration projects. The ISRP is not yet sure how the mussel project will share information with the Biomonitoring Project and other restoration and lamprey projects; the ISRP would appreciate a discussion of this with the proponents. There are several questions to address. Would salmon and mussel restoration be beneficial in similar areas? Are there risks? Mussels can also provide a retrospective look at past environmental conditions. The ISRP urges the proponents to work with EPA and others on contaminants, as well as on other factors implicated in population declines.

The ISRP recognizes that the project is in a discovery phase. However, about two years from now, the proponents will need to have quantitative restoration objectives, as well as concrete information on factors causing population declines. It would be prudent to start on this in the very near future, using collaborators and ad-hoc advisors to provide critical feedback.

Comment:

1. Objectives

The proponents have two objectives:

- to restore native freshwater mussel populations in the Umatilla River, and
- to further conservation efforts across the Tribe's ceded territory.

Research continues along three broad lines of investigation to: (a) determine the status, trends, and distribution of mussels in the Tribe's ceded territory; (b) understand the physical and biological factors that control distribution; and (c) characterize the population level genetic structuring of western mussels.

Based on past annual reports and publications, the research has been quantitatively rigorous. Unfortunately, there are no guiding hypotheses and the objectives are not quantitative and time bound, so the effectiveness of meeting them cannot be fully evaluated. As well, there are other collaborators on this project (which is good), but the results generated by the proponents cannot be delineated from those produced by others. Further, the description of the project timeline is vague and uninformative. No clear milestones or end dates are indicated.

2. Methods

The methods described in the annual reports and publications are scientifically sound. Nevertheless, the ISRP has three suggestions to improve the program:

- The research does not address non-native mussels and clams, such as *Corbicula*, or chemical contaminants. These have threatened mussel populations in other regions of the Pacific Northwest, and this project would be strengthened by developing research to explore these issues.
- There was no description of population dynamics. Given the observed declines of most populations of western mussels, a better understanding of the population dynamics of these mussels is needed. Some important questions include: What are the size and age class distributions in these local populations? What are the recruitment rates in stable and declining populations? What are the movement rates, and is there movement between sub-populations?
- Greater detail about the propagation research for western mussels is needed. This is an important aspect, both for restoration and identification of potential host fish.

3. Results

The Freshwater Mussel Research Project has provided critical information about the distribution, abundance, and status of western mussels in several major rivers of eastern Oregon. This is potentially important for conservation and restoration efforts and expands the freshwater community perspective of the Fish and Wildlife Program. The lessons learned are applicable to the entire Columbia River Basin and western United States. Collaboration with the Xerces Society is a particularly strong aspect of this research project. Both the Xerces Society and the Freshwater Mussel Project are to be commended for their development of best management practices for restoration project planning. However, the project summary does not provide a thorough description of its outreach efforts beyond its collaboration with the Xerces Society.

The project has been productive, publishing six papers since 2013.

4. 2017 Research Plan uncertainties validation

The ISRP generally agrees but feels that the proponents overstate their case for indirectly examining critical uncertainties related to Contaminants (No. 35), Human Development (No. 40), and Monitoring and Evaluation (No. 44). The text provided on these topics is too general to be useful. Data, as well as some level of quantification, are required.

Resident Fish Habitat Enhancement and Passage

200811100 - Twin Lakes Enhancement

- [View summary in Box](#)
- Background info in Taurus: [Project overview](#) | [Reports](#) | [Past reviews](#)

Project proponent: Colville Confederated Tribes

Recommendation: N/A – Project complete, results review only

Comment:

1. Objectives

This project is a very good example of well-designed research with clearly stated goals, and hypotheses with measurable results. The milestones and end dates are clearly stated. The proponents established suitable hypotheses to guide the research. However, it seems that quantitative objectives were not established and are needed, even though South Twin Lake was the sole statistical reference.

Despite having South Twin Lake as a reference site, the project design did not consider several issues that would affect the conclusions of the project. Significant are the high levels of rainbow trout angling mortality (Cross, B. K. 2014. Twin Lakes enhancement 2011–2013 annual reports. Annual Report to the Bonneville Power Administration, Project 2008-111-00, Portland, Oregon.), trout movement between lakes, and emigration during spring and fall when surface temperatures were more suitable for trout. These should have been controlled or accounted for if the reference lake was to be used as a valid comparison. A very positive aspect of the project is the collaboration between the project proponents and faculty and students at Washington State University. This is a model that many other projects should follow.

2. Methods

The design of the evaluation of the oxygenation system was sound. The proponents incorporated a treatment lake and a control lake into the evaluation, monitored a wide array of water quality, food web, and fish population variables in both lakes over multiple years, and conducted appropriate statistical analyses of the data. One issue with the design is that trout can move between lakes. The proponents PIT-tagged some fish and tracked them. They estimated that 10% of tagged fish moved between lakes, but the movement was not in the peak stratification period, so the proponents do not think it compromised their design. The proponents provided an excellent example of M&E within the context of Adaptive Management.

3. Results

The evaluation data indicated that oxygenation of the hypolimnion resulted in more nutrient production, more habitat for trout, and more food for trout. However, the trout population did not increase in abundance, and fish did not show increases in body condition. The conclusion was that the management action did not significantly enhance the trout fishery.

This project was effective in meeting its objectives and clearly answering stated hypotheses. Although the situation at Twin Lakes may be rare in the Pacific Northwest, the approach and results will be of value to similar lakes throughout North America. The Critical Uncertainties (CUs) report aligned this project with the uncertainty of reducing non-natives. While some results do address largemouth bass, it is not clear whether the rainbow trout, which are the focus of the project, are native to the Twin Lakes. About 250,000 rainbows are stocked in the lakes each year. In the presentation to the ISRP, the proponents stated that there was a native population of red-band trout that has been extirpated. So, they are, in essence, introducing a non-native trout to the system. The proponents suggest that the project also addresses CUs in the Tributary Habitat theme, and that hypolimnetic oxygenation “could buffer against climate change by creating suitable habitat for cold water fish in waters that are currently limited by hypoxic conditions.” This project has exemplary record of numerous peer-reviewed publications and student theses and dissertations. A great deal of data were collected in this project, but its general availability is not known.

4. 2017 Research Plan uncertainties validation

Agree. While the overall results were not positive in terms of enhanced trout production, the proponents did learn a great amount about manipulating lakes for fish production. The proponents should use their remaining time to prepare refereed publications and conduct public outreach.

200724600 - Restoration of Bull Trout Passage at Albeni Falls Dam

- [View summary in Box](#)
- Background info in Taurus: [Project overview](#) | [Reports](#) | [Past reviews](#)

Project proponent: Kalispel Tribe

Recommendation: Meets Scientific Review Criteria (Qualified)

Qualifications:

The project was refocused in 2015 to develop a trap and haul program for bull trout at Albeni Falls Dam (and other dams) until an effective fish passage structure can be constructed at the dam. However, well-defined hypotheses and quantifiable objectives are needed along with a description of the specific methods to be used to address each objective and to assess progress within an Adaptive Management framework. The following important questions need to be addressed:

- What kind of guidance will the proponents provide to the development of a permanent passage structure?
- Is this primarily a monitoring project?
- Have the proponents quantified the number of fish above and below the dam?
- The Y-maze choice experiment needs a careful review of design, analysis, and reporting.

Comment:

1. Objectives

The study was initiated in 2007 to determine movements and genetics of bull trout captured below Albeni Falls Dam as a first step in assessing bull trout passage at the dam. At that time the objectives were to: (a) relocate bull trout collected below Albeni Falls Dam to a release site upstream from the dam, (b) use microsatellite DNA analysis to assign the most probable natal tributary of each fish, and (c) determine if genetically assigned natal tributaries match the actual tributary use for spawning. In 2015, the focus of the project shifted to evaluating a temporary floating trap installed in the Albeni Falls Dam's powerhouse tailrace and understanding bull trout use of cold-water refuges downstream of Albeni Falls. Objectives of the project as stated in the 2016 annual report were to: (a) tag bull trout collected downstream of Albeni Falls Dam, (b) operate and evaluate effectiveness of the fish trap, (c) evaluate bull trout interactions with the trap, and (d) evaluate bull trout and westslope cutthroat trout movements downstream of the dam. Objectives need more quantification. For example, if the new trap captures 1 fish/year, is this enough? What are the decision points on “go” versus “no-go” for parts of the proposed fish passage facility?

The small number of bull trout actually collected is of concern. One key question is how many bull trout are actually in the system upstream and downstream of Albeni Falls Dam? In the presentation to the ISRP, the proponents indicated there are 10's of thousands in the reservoir but were unclear as to the number that have moved downstream and are unable to return past the dam. The project objectives include a time-frame for accomplishment with an end-date of 2024—the completion of fish passage at the dam. Timelines for the laboratory studies are specific; however, the proponents do not present specific timelines for field testing trap modifications. This is perhaps because the proponents are waiting for results of laboratory studies.

2. Methods

Trap and haul methods have been reviewed before and are suitable. The use of laboratory experiments and surrogate fish species to pre-test possible fish passage variables are very productive and cost efficient. Additional information is needed on the statistical analysis methods. For example, was each fish used multiple-times in each Y-maze experiment and did the analysis accommodate this? The proponents also mentioned in the presentation that multiple species were combined in the analysis, but no details were provided on how this additional factor was incorporated into the analysis. The proponents need to define the minimum effect size that is biologically significant. For example, is a p (choice) of 0.55 sufficiently better than 0.5 to be useful? The description of statistical methods is dated, e.g., accepting or rejecting hypotheses, simply reporting $p < 0.05$ rather than actual p -value, and not presenting effect size estimates. The proponents will need to have the analysis reviewed carefully by a statistician to address issues including: (a) the proponents used the wrong critical value, that is, 5.99 is for 2 degrees of freedom (df), but the Y-maze experiment appears to have 1 df; (b) the second control experiment was not integrated into the analysis; and (c) a slightly more complex experiment could have investigated the impact of all three factors simultaneously.

With the refocusing of the project and new qualitative objectives established in 2015, the methods changed. A temporary floating fish trap was installed on the left side of the powerhouse spillway. The temporary trap was used to capture fish for research purposes and potentially facilitate a trap and haul passage strategy for fish at Albeni Fall Dam. Captured bull trout were to be surgically implanted with radio transmitters and released downstream of the dam to evaluate their interactions with the trap and movements downstream of the dam.

Given the ESA status of the bull trout and the specific concern of the project that bull trout above Albeni Falls Dam are threatened with extinction, it is surprising that the local PUD was able to collect fish from above the dam and take them many miles downstream to Box Canyon Dam. The collaboration between the Kalispel Tribe, Eastern Washington University, and Pacific Northwest National Laboratory is an excellent model for others to follow.

3. Results

The project has made significant progress toward meeting its objectives. The hypotheses stated for the lab studies are being answered, and the results of these and the field studies will help inform the development of a fish passage facility at Albeni Falls Dam. While the objectives are to address passage at Albeni Falls Dam, the results of the lab studies will be of use to others concerned with passage. It is possible that the lab studies with non-native brown trout will be of use in separating them from bull trout in streams where they might be hybridizing. The project is addressing key critical uncertainties (CUs) indicated in the 2017 Research Plan relating to population structure and diversity. The proponents suggest correctly that the project also addresses CUs in the Hydrosystem Flow and Passage Operations theme. Project reporting is appropriate, and the proponents intend to prepare articles for peer-reviewed journals.

During the entirety of the study initiated in 2007, only 21 bull trout were tagged and released upstream of Albeni Falls Dam. Seventeen of these fish migrated into Lake Pend Oreille and six of those were found to enter predicted tributaries based on genetic analyses and two others entered secondary natal tributaries. Two additional fish entered non-predicted tributaries. The results indicated that genetic assignments were highly accurate for bull trout, but they were less accurate for indicating specific tributaries to which the fish may migrate. Overall, small sample numbers of bull trout captured, radio tagged, and relocated affected the amount of movement and genetic data obtained, and the interpretation of the results.

In 2016, no fish of any species were found within the trap. Eleven bull trout had a combined 1,576 detection events for over 30 hours at an underwater antenna at the location of the fish trap, but none were captured by the trap. Inability to obtain radio transmitters in time to tag bull trout captured downstream from Albeni Falls Dam in 2015 limited the extent of movement data. However, movement data were obtained from bull trout tagged and released by other researchers upstream of Box Canyon Dam. Bull trout made repeated movements to Albeni Falls Dam and were detected near the trap. The results indicate that the current trap design is not suitable for capture of bull trout and that a new configuration, or new attractants, are needed to attract and capture bull trout.

Regarding the Y-maze choice experiment, preliminary results are shown but with insufficient detail. For example, an effect was detected, but how big was the effect (i.e., did fish choose a specified arm 0.55, 0.70, 0.90 of the time)? With a sufficiently large sample size, very minor effects can be detected.

A significant amount of data has been collected in addressing the various objectives of this project, but there is no indication if it is readily available.

4. 2017 Research Plan uncertainties validation

Agree with the proponents' identification of CUs.

Fish Genetics, Salmonid Supplementation, and Hatchery Reform

200850400 - Sturgeon Genetics

- [View summary in Box](#)
- Background info in Taurus: [Project overview](#) | [Reports](#) | [Past reviews](#)

Project proponent: Columbia River Inter-Tribal Fish Commission (CRITFC)

Recommendation: Meets Scientific Review Criteria

Comment:

1. Objectives

The previous proposal in Taurus lists three objectives with corresponding hypotheses: (a) evaluate population differentiation and migration (gene flow) among reservoirs; (b) determine relatedness, mean productivity, and number of spawners within each reservoir; and (c) characterize broodstock by identifying origins (i.e., reservoir or population) and degree of relatedness among candidate broodstock fish. More recently, the proponents have developed two additional objectives involving whole genome sequencing to: (d) quantify adaptive variation within and among the sampled populations, and (e) search for a sex-linked marker that can be used to sex sturgeon at any age. Hypotheses were not developed for the two new objectives.

Overall, the goals and hypotheses are well defined, measurable, testable, and relevant to the Fish and Wildlife Program. No specific milestones or timelines are associated with any of the objectives, but it is clear from the narrative and project reports that steady progress is being achieved.

2. Methods

White sturgeon present challenges for genetic analysis because of their tetraploid ancestry, longevity, and the difficulty of obtaining adequate sample sizes. The proponents are to be commended for their skills in developing cost-effective methods (e.g., GT-seq) to screen genotypes at hundreds of DNA loci (SNPs) for application in parent-based tagging and other tools of genetic analysis. Sampling and analytical protocols seem appropriate and are clearly documented in Annual Reports, which include useful links to *onlineresourcemonitoring.org* websites.

Standard methods are being used and statistically reliable results are being produced. Measures of effect size (e.g., confidence intervals) are provided to support most conclusions. An exception is Figure 3 (i.e., comparing haplotype frequencies between pooled samples representing Snake and Lower Columbia stocks) and the AMOVA results (p.9) in the 2017

Annual Report that lack statistical tests and sample sizes, so the strength of the evidence for differences among stocks is unclear. Questions also remain regarding sample sizes needed to adequately characterize populations in individual reservoirs, and to clarify the influence of sturgeon movements among reservoirs, especially the downstream movement of fry and young-of-year fish.

Two very recent papers by C.D. Waters and colleagues seem highly relevant to identifying and quantifying adaptive variation among white sturgeon populations (objective d). In case these papers are unfamiliar to the proponents, the references are:

Waters C.D., Hard J.J., Brieuc M.S.O., Fast D.E., Warheit K.I., Knudsen C.M., Bosch W.J., and Naish K.A. 2018. Genomewide association analyses of fitness traits in captive-reared Chinook salmon: Applications in evaluating conservation strategies. *Evolutionary Applications* 11: 853-868.

Brieuc, M.S.O., Waters C.D., Drinan D.P., and Naish K.A. 2018. A practical introduction to Random Forest for genetic association studies in ecology and evolution. *Molecular Ecology Resources* 18: 755-766.

3. Results

A major strength of this project is the successful development of a novel suite of 117 SNP markers and the use of the GT-seq high throughput sequencing method. Prior to 2017, genetic monitoring of white sturgeon had been investigated with a small published set of 13 microsatellite markers. The set of SNP markers developed in 2017 is currently being expanded, which will likely improve our knowledge of population structure and facilitate the application of parent-based tagging and other genetic tools.

It is reassuring that preliminary analyses of population structure based on the new SNP markers are corroborating previous results based on microsatellite loci. The metapopulation structure of white sturgeon is characterized by low genetic diversity and small effective population size. The low diversity and relatively small individual pairwise genetic distances likely stem from small numbers of families and/or few effective spawners within several impoundments. Broodstocks from the Yakama hatchery that are used for supplementation in the Middle Columbia River are genetically similar to the wild populations from which they are derived, which justifies their continued use. Gene flow has been highly restricted by barriers in the hydrosystem. The strong pattern of isolation by distance evident in genetic data supports the hypothesis that white sturgeon movement is largely downstream through the hydrosystem. In contrast, white sturgeon in the Lower Fraser and lower Columbia appear genetically similar; these populations have unimpeded access to the Pacific Ocean and may continue to intermix to some degree.

The proponents are now undertaking to sequence the genome of a single female white sturgeon, primarily to develop a practical genetic technique for non-lethally differentiating males and females at any age. The project is also making significant progress toward developing

a parentage database that would allow juvenile fish to be assigned to parents spawning in the wild or to identify hatchery-origin fish without the need for other types of identifying marks.

Development of a reliable suite of genetic markers for white sturgeon is a critical step in understanding ecological and evolutionary dynamics of populations in the Columbia Basin and for future genetic monitoring of stocks in the basin. The ultimate utility of this program rests on its ability to track a population of long-lived fish over many years to fully ascertain some key population parameters. Translocation (i.e., stocking) of hatchery juveniles into upper Columbia River areas might be a useful strategy to compensate for the lack of recruitment or loss of productivity and diversity in blocked areas. But first, it will be necessary to examine the genetic population structure of white sturgeon in the impoundments between Priest Rapids Dam and Grand Coulee Dam and to investigate the conservation implications of possible introgression between remnant wild populations and hatchery fish derived from non-local broodstocks.

Collaboration and sharing of information among partners appear excellent. Annual reporting has been timely with satisfactory detail. However, in future reports, the ISRP would like to see more interpretation of results relative to stated objectives and hypotheses, and more discussion of how data from this project will be used in adaptive management strategies for population management and supplemental stocking programs.

4. 2017 Research Plan uncertainties validation

There is a mismatch between the list/numbering in the Research Narrative versus the Uncertainties Database or 2017 Research Plan. The ISRP concludes that this project indirectly (rather than directly) addresses the three critical uncertainties (CUs) listed by the proponent.

The Uncertainties Database indicates that six questions are being directly addressed by the project, but of these, it seems that only two (F1.4 and F3.2) are directly addressed, and the others are indirectly addressed.

As stated in the 2015 CUs review, "it is unclear how results obtained thus far and those anticipated in the future will be used help make decisions needed for sturgeon hatcheries and stock recovery. A critical uncertainty for these fish is: are observed genetic differences among fish from different reservoir pools indicative of adaptations to specific areas or just the result of recent segregation of putative stocks and thus not of great importance to managers?"

200890700 - Genetic Assessment of Columbia River Stocks

- [View summary in Box](#)
- Background info in Taurus: [Project overview](#) | [Reports](#) | [Past reviews](#)

Project proponent: Columbia River Inter-Tribal Fish Commission (CRITFC)

Recommendation: Meets Scientific Review Criteria

Comment:

1. Objectives

The Research Narrative for this suite of inter-related studies lists four main objectives with corresponding hypotheses: (a) discover and evaluate SNP markers in salmon and steelhead and other anadromous fishes; (b) expand and create genetic baselines for multiple species including Chinook, steelhead, sockeye and kokanee, coho salmon, and Pacific lamprey; (c) implement stock ID programs to evaluate mainstem harvest of Chinook, sockeye and steelhead fisheries; and (d) use parent-based tagging (PBT) and genetic stock identification (GSI) to estimate stock composition of fish passage at Bonneville Dam (steelhead, sockeye and Chinook salmon).

All hypotheses are clearly defined, measurable, testable, and highly relevant to the Program and harvest management. The project continues to refine and improve stock identification techniques and baselines for Chinook, sockeye, and steelhead, and does not have specific timelines. By its nature, PBT requires annual collection and genotyping of tissue samples from hatchery broodstock. Similarly, GSI of salmonids harvested in mainstem fisheries or passing Bonneville Dam requires annual collection and analysis of mixture samples. Consequently, the project is expected to continue for the foreseeable future.

2. Methods

A major strength of this project is the successful development of cost-effective methods (e.g., GT-seq) to screen genotypes at hundreds of DNA loci (SNPs) for application to PBT and GSI. Sampling and analytical protocols are clearly documented in the Annual Reports, which include useful links to *onlineresourcemonitoring.org* websites. Standard methods are being used and statistically reliable results are being produced. Confidence intervals or significance test probabilities are provided to support most conclusions.

Another innovation of this project is the combined application of PBT and GSI to successfully evaluate the stock composition of fish passing Bonneville Dam and harvests in mainstem fisheries. Assignment testing and PBT analytical methods are statistically sound. However, it would be helpful to include more justification for (or explanation of the advantages and disadvantages of) setting the assignment threshold at >80% correct self-assignment.

The Methods section (e.g., p. 77) of the 2017 Annual Report indicates that the proponents estimate stock composition by classifying individuals to reporting groups in the baseline (i.e., the individual assignment method), rather than by estimating mixing proportions (i.e., mixed stock analysis). However, it is typically not necessary to identify the provenance of individual fish if the objective is merely to determine stock composition. In that case, estimating mixing proportions is a simpler mathematical problem than classifying individual fish and is less prone to bias when baseline populations are difficult to distinguish (Koljonen et al. 2005⁹). The proponents should clarify or justify their statistical approach by demonstrating that the individual assignment method performs as well as mixed stock analysis in this application.

3. Results:

This project has developed the genetic (i.e., SNP) baselines and technical capacity to routinely identify the stock composition of mixed stock harvests in the Columbia River and to estimate the run timing and abundance of populations of hatchery and natural origin spring Chinook, steelhead, and sockeye as they pass over Bonneville Dam. SNP-based genotyping has been used to identify the origin of steelhead harvested in an ocean fishery, and a SNP panel has been developed to identify the origin of lamprey stocks.

SNP markers have been especially useful for PBT and other pedigree studies to estimate reproductive success. Importantly, some SNP markers are linked to adaptive genes and offer an opportunity to characterize adaptive variation for evaluating adaptive divergence of populations to specific environments. It is noteworthy that the proponents are now focusing on techniques to expand information about adaptive genetic variation within the Columbia Basin. Thus, SNP markers combined with genomic and physiological analysis could likely be used to predict and track adaptability of salmon populations to climate and landscape changes.

Bonneville Dam seems like an ideal fixed location for annual GSI sampling, but the proponents note that trapping limitations at Bonneville continue to pose a major challenge for sampling. Sample rates for Chinook, sockeye, and steelhead are often lower than desired due to restrictions imposed by USACE and NMFS on sampling at the Bonneville AFF.

Another limitation of the GSI approach is that the current fisheries management units are not identical to the reporting groups for which stock composition is estimated (i.e., based on their genetic differentiation). Fisheries managers continue to explore how to best incorporate genetic monitoring results with more traditional monitoring/tagging programs.

⁹ Koljonen, M-L., J.J. Pella, and M. Masuda. 2005. Classical individual assignments versus mixture modeling to estimate stock proportions in Atlantic salmon catches from DNA microsatellite data. *Canadian Journal of Fisheries and Aquatic Sciences* 62: 2143–2158

In principle, PBT and GSI based on SNP markers are now sufficiently developed that they could replace the main functions of the coded wire tag (CWT) program for hatchery fish. However, replacing the CWT program would require continued annual genotyping of hatchery broodstock, fish passing Bonneville Dam, and harvested fish. The proponents also note that some changes to the management of these stocks would have to be agreed upon by the various parties involved in the U.S. v OR Management Agreement. To replace CWT in ocean fisheries management, the PBT baseline would have to be expanded to include additional hatcheries throughout the range of Chinook salmon.

In summary, the project is meeting its objectives by testing hypotheses that help to address critical uncertainties. A variety of impressive findings are documented in 49 journal publications published in the past 10 years. These results directly contribute to practical advice for fisheries management.

4. 2017 Research Plan uncertainties validation

There is a mismatch between the list/numbering in the Research Narrative versus the Uncertainties Database or Research Plan.

The proponents suggest that this project directly addresses the third critical uncertainty (CU) in their list regarding the effects of fishery interceptions and harvest in mixed stock areas on the abundance, productivity and viability of ESUs or populations. The project clearly contributes to addressing this CU by providing stock composition and run timing data for mixed-stock catches and escapements. However, it might be argued that the actual run reconstruction and population productivity analyses needed to determine fishery effects on ESU abundance or viability are being done by other projects or agencies. If that is true, then this project is addressing the CU *indirectly* rather than directly according to the definitions of terms in the Uncertainties Database. The distinction is subtle, however, and we acknowledge that innovations by this project have made it feasible to address this CU and that the project continues to play a critical role.

The project also addresses L2.3 indirectly and M2.1 directly.

200900500 - Influence of Environment and Landscape on Salmonid Genetics

- [View summary in Box](#)
- Background info in Taurus: [Project overview](#) | [Reports](#) | [Past reviews](#)

Project proponent: Columbia River Inter-Tribal Fish Commission (CRITFC)

Recommendation: Meets Scientific Review Criteria

Comment:

1. Objectives

The project has two overarching objectives. One examines the effects of environmental and landscape conditions on the genetic profiles of steelhead and Chinook populations located throughout the Columbia River Basin. This objective has two associated hypotheses. First, that environmental and landscape features act as drivers of selection leading to local adaptation of fish populations. Second, that genome scans can identify candidate genes involved with local adaptations. The second objective is to determine the genetic basis for the expression of a variety of phenotypic traits in steelhead and Chinook. The second objective also has two hypotheses. The first hypothesis is that association mapping and gene expression can be used to identify candidate genes associated with specific traits. The second hypothesis is that markers (SNPs) from candidate genes can be found and incorporated into cost efficient assays that will allow large numbers of individuals to be genotyped. If true, this will allow genetic variation for phenotypic traits to be monitored and evaluated at broad scales.

The objectives are clearly defined, measurable, have proven to be achievable and testable, and are relevant to the Council's Fish and Wildlife Program. As the proponents note, understanding broad geographic patterns of neutral and non-neutral genetic variation can be used by the Program to set regional conservation priorities and guide the long-term conservation of steelhead and Chinook in the face of ongoing climate change. Genetic traits such as temperature tolerance, for example, could be used to identify candidate stocks in reintroduction efforts. Additionally, project findings emphasize that genetically based adaptation to local conditions occurs in the Basin's salmonid populations. These adaptations may be lost if strays or domesticated hatchery fish interbreed with locally adapted fish.

No end dates for the completion of work were provided. Substantial results have been produced, but more work will be needed to fully address the project's objectives and hypotheses. Additionally, similar work is needed on other species, such as bull trout, cutthroat, sockeye, chum, and coho.

2. Methods

The project uses state of the art techniques, which are continually evolving. Numerous peer-reviewed publications describing the results of the project have been published, indicating that the methods and conclusions being reached are scientifically appropriate. If the proponents are not already familiar with, or not yet using Random Forest in their genetic association studies, they may find the following paper useful:

Brieuc, M.S.O., Waters C.D., Drinan D.P., and Naish K.A. 2018. A practical introduction to Random Forest for genetic association studies in ecology and evolution. *Molecular Ecology Resources* 18: 755-766.

3. Results

The project is meeting its objectives and testing and evaluating its hypotheses. Recent results indicate that precipitation, elevation, and temperature are important environmental factors that drive adaptive genomic divergence in salmonids. The proponents are also conducting multiple studies that are examining the genetic basis for run-timing, age-at-maturity, disease resistance, and thermal adaptation. Candidate genes for several of these traits have been identified in both steelhead and Chinook. As these genes have been discovered, SNP markers from these regions are being incorporated into standard genotyping panels enabling the genetic variation in these traits to be assessed in large numbers of individual fish.

As global climate change continues to affect the Basin, the results of this study will help guide conservation efforts by indicating the evolutionary flexibility of the Basin's stocks to changes in precipitation, temperature, and other environmental factors. The methods and results of this work are of importance both within and outside of the Basin. Key findings have been shared via peer-reviewed publications (20 primary articles since 2011), annual reports, and in conferences.

4. 2017 Research Plan uncertainties validation

The Council's 2017 Research database indicated that the project is examining Critical Uncertainties (CUs) in six major categories (i.e., A-Tributary Habitat; B-Mainstem Habitat; C-Fish Propagation; E-Estuary Plume and Ocean; F-Population Structure and Diversity; and J-Climate Change). Two of these categories were not identified by the proponents (Mainstem Habitat and Estuary, Plume, Ocean). They, however, indicated that one uncertainty in the Harvest category would also be indirectly examined. In summary, we agree that the project will directly examine ten CUs and potentially provide information on ten additional CUs across seven Research Plan categories.

200900900 - Basinwide Supplementation Evaluation

- [View summary in Box](#)
- Background info in Taurus: [Project overview](#) | [Reports](#) | [Past reviews](#)

Project proponent: Columbia River Inter-Tribal Fish Commission (CRITFC)

Recommendation: Meets Scientific Review Criteria

Comment:

1. Objectives

The project provides technical and financial support to studies that are supplementing or reintroducing salmonids within Tribal ceded lands. Recommendations of the ISAB/ISRP (2005) and Ad Hoc Supplementation Working Group (2008) were used to help select the studies receiving assistance. The project has three general objectives to: (a) evaluate the effects of supplementation on depressed populations of salmonids, (b) assess the behavior and productivity of out-of-basin hatchery (HO) and natural-origin (NO) salmonids that were reintroduced into areas where an indigenous population had been extirpated, and (c) evaluate the role of genetic and environmental factors on fish performance (e.g. early maturation) during hatchery rearing. Currently, the project is assisting eight ongoing projects.

The research narrative lists the main hypotheses for each of the eight studies. Yet, quantitative goals for some of the studies were not mentioned. For instance, what are the long-term goals for re-establishing salmon runs in some of the basins, achieving natural sustainability and some level of harvest, or continuing supplementation? All the studies have clear benefits to the Fish and Wildlife Program and, in some cases, to other projects in the Basin (e.g., minijack production, relative reproductive studies or RRS). Timelines and end dates were provided for some research efforts, but other components (e.g., fish re-introduction) will be ongoing.

2. Methods

Methods are described clearly and in detail in the project's Annual Reports, and they appear to be appropriate. A notable strength of this project is the deliberate effort to design studies capable of replicating findings in different locations. Study results are also enriched through the clever and systematic application of modern techniques of genetics analysis.

Two factors separate this project's assessments of RRS from most others in the Basin. First, collections of juveniles are being analyzed to test if genetic results from migrating smolts produce similar RRS values to those obtained from adult tissues. The proponent's note that juveniles are more abundant and available than adults. They hypothesize that samples from juveniles may provide more robust estimates of RRS than those derived from adult tissues due to larger sample sizes, an approach pioneered by NOAA researchers. Second, RRS comparisons

are being made in two ways: among hatchery origin (HO) and natural origin (NO) adults that had successfully produced offspring and then among all the HO and NO parental fish whether they had produced offspring or not. Typically, comparisons are made among all parental fish regardless of their reproductive success.

Additionally, the methods used to examine the possible effects of paternal age and environmental factors on early maturation rates in artificially reared male spring Chinook were scientifically appropriate. In this study, fish from artificial crosses were reared in a common garden rearing experiment, and blood plasma, liver, and pituitary samples were assayed to evaluate early maturation. Genetic analyses were used to determine the pedigrees of the sampled fish.

3. Results

Project objectives are being met. Hypotheses are being addressed and Program uncertainties are being directly investigated. Results are applicable within and outside of the Basin and are being used to help manage supplementation and fish reintroduction efforts. For example, results from the two studies that are examining the effects of supplementation on wild spring Chinook have suggest an advantage of using 100% NO fish as broodstock. Moreover, analyses from the two studies examining reintroduction efforts have shown that salmonids put into new watersheds can possess enough genetic variation to adjust to the novel conditions they are encountering. Additionally, results of the RRS studies occurring in these watersheds indicate that over time NO fish produced from introduced out-of-basin parents often have greater productivity rates than HO adults, suggesting that adaptation to the new environment is taking place. Precocious maturation of spring Chinook in the Basin's hatcheries is a persistent problem. Results from the proponent's investigation into this problem will provide valuable information on possible approaches (e.g., reduction in feed lipid content, photoperiod manipulations, use of food additives, etc.) that can be used to reduce early maturation rates.

Collaboration and sharing of information among partners are appropriate. Annual reporting is excellent, as is the record of primary publications, presentations, and training opportunities. The Research Narrative and 2017 Annual Report indicate that important analyses of final results for several studies will be completed in 2019.

4. 2017 Research Plan uncertainties validation

Critical uncertainties (CUs) linked to the project in the Council's 2017 Research Plan fall under the Fish Propagation and Population Structure and Diversity sections. It is clear from the narrative that Question #2 and CU 2.1 in the 2017 Research Plan's Population Structure and Diversity category are also being directly examined by the project. These CUs should be added to those already in the 2017 Research Plan database.

198909600 - Genetic Monitoring and Evaluation (M&E) Program for Salmon and Steelhead

- [View summary in Box](#)
- Background info in Taurus: [Project overview](#) | [Reports](#) | [Past reviews](#)

Project proponent: National Oceanic and Atmospheric Administration

Recommendation: Meets Scientific Review Criteria (Qualified)

Qualifications:

The ISRP advises the proponents to specify new objectives or refine existing hypotheses that can be tested in the future. Three suggestions for refocusing the studies of relative reproductive success (RRS) are to:

(a) investigate how the history of pHOS and PNI in the study populations has influenced RRS values. The ISRP is concerned that findings to date that RRS is not significantly less than 1 for Chinook salmon at the Catherine Creek and Lostine River sites may underestimate the effects of hatchery supplementation in more natural Chinook salmon populations.

(b) focus on genetic effects rather than known ecological effects arising from differences in the distribution of hatchery and natural origin spawners. For example, efforts should be made to eliminate known differences in spawner distribution in Sheep Creek, first by resolving issues with the acclimation pond, and then as necessary, manipulating fish numbers transferred over the weirs.

(c) evaluate the extent to which hatchery supplementation might limit the ability of small wild salmon and steelhead populations to adapt to changes in their local environments.

Comment:

1. Objectives

Two major goals are described in the Research Narrative: (a) evaluate the nature and extent of genetic changes in out-planted hatchery stocks, and (b) quantify the genetic impact of out-planting on targeted and non-targeted natural stocks. Three objectives are also listed in the previous proposal in Taurus: (a) monitor population genetic relationships within and among populations of Chinook salmon and steelhead in the Snake River Basin; (b) determine the degree to which supplemented populations affect non-supplemented populations of Chinook and steelhead; and (c) monitor relative reproductive success of hatchery and wild Chinook and steelhead in the Snake River Basin.

These tasks are clearly defined, measurable, testable, and relevant to the Program. The Research Narrative notes that the project is flexible with no set end-point and will terminate when co-managers and subbasin planners agree that critical uncertainties (CUs) have been satisfied and there is no longer the need to monitor the effects of supplementation.

Although these studies continue to provide valuable information to Snake River subbasin planners and co-managers, it seems that some of the original objectives have been adequately addressed. The ISRP recommends that the proponents specify new objectives or refine existing hypotheses that can be tested in the future. For example, we recommend that future studies focus on clarifying genetic (rather than ecological) mechanisms for reduced RRS and the extent to which hatchery supplementation limits the ability of small wild salmon and steelhead populations to adapt to changes in their local environments.

2. Methods

The study has mostly relied on a well-developed microsatellite DNA (GAPS) protocol but recently transitioned to Single Nucleotide Polymorphisms (SNPs) in concert with other major genetic-monitoring programs in the Basin. A time-series approach is being used to study general trends in genetic diversity, population structure, and effective population sizes of Chinook salmon and steelhead in the Snake River basin, together with more focused studies of RRS of hatchery and wild origin fish at three study locations. Sampling and analytical protocols are clearly documented in the Annual Reports through links to *resourcemonitoring.org* websites. Standard methods are being used, and statistically reliable results are being produced. Confidence intervals or significance test probabilities are provided to support most conclusions. Efforts are still underway to document and complete analyses following the recent transition from GAPS microsatellite markers to SNP markers; publication of up-to-date results is expected later in 2018.

A notable strength of this project is the deliberate effort to replicate RRS studies in different locations with different species. However, two complications that warrant further discussion are the small initial population size of the study populations and the high level of interbreeding that has occurred prior to and during the investigation. These complicating factors could be expected to reduce the power to detect real differences in reproductive success between hatchery and natural origin spawners. The ISRP is concerned that findings to date, which indicate that RRS is not significantly less than 1 for Chinook salmon at the Catherine Creek and Lostine River sites, may underestimate the effects of hatchery supplementation in more natural Chinook salmon populations. It would be useful to consider how the history of pHOS and PNI in these study populations is influencing results.

3. Results

This project has clarified evolutionary relationships among salmon populations in the Snake River and provided new insights on demographic, ecological, and evolutionary processes in

these populations. Collaboration and sharing of information among partners seem excellent. Sampling efforts are coordinated closely with other BPA-funded projects to best leverage the available resources and incur the least disturbance possible to the fish being sampled. The project has generated 43 reports and publications and continues to inform management actions. Key findings include:

Population structure and diversity studies: Supplementation efforts in the Salmon and Grande Ronde rivers appear to have had a minimal effect on the genetic diversity of Chinook salmon populations over the time frame of this project. Results indicate no general decline in heterozygosity or allelic richness in 2,400 individuals sampled over a 3-4 generation time span in 8 of 9 Chinook salmon populations examined in the Salmon River. Similarly, heterozygosity or allelic richness did not decline in any of the Grande Ronde populations examined and actually increased in some populations (e.g., Lookingglass Creek, Upper Grande Ronde River, and Wenaha River). The estimated effective number of breeders has been stable, tracking trends in total population size, except in Lookingglass Creek where the number of breeders has declined in recent years. Introgression from the Rapid River Hatchery stock was particularly noticeable in the early 1990s, but it appears to have had a substantial effect on only two of the native populations (i.e., Lookingglass Creek and the upper Grande Ronde River) despite ample opportunities for introgression to occur. All seven of the native populations sampled have maintained their levels of within-population genetic diversity throughout the sampling period.

Relative reproductive success studies: In the steelhead study at Sheep Creek, the overall geometric mean reproductive success of hatchery origin fish was only 0.4 relative to their natural counterparts, measured both from juvenile and adult offspring. Hatchery males and females both continued to do poorly relative to wild counterparts, even after 2005 when new procedures were adopted to move hatchery fish upstream to reduce the concentration of hatchery-origin spawners remaining near the weir.

In contrast, no evidence of differential reproductive success was detected between natural-origin (NO) and hatchery-origin (HO) Chinook spawning in Catherine Creek over the adult spawn years 2002-2013, whether measured with juvenile offspring (geometric mean RRS = 1.05) or adult offspring (geometric mean = 0.96).

An important finding of this study is that RRS based on juvenile offspring appears to be comparable to that based on adult returns. If confirmed, this conclusion could justify quicker and statistically more robust evaluations of RRS given the greater speed and ease of collecting large samples of juveniles as opposed to scarcer adults. This type of monitoring work is now an essential part of hatchery reform and the goal of using widespread hatchery propagation in recovery of natural populations.

Overall, these projects illustrate that HO and NO interactions can be similar in some locations and species, yet strikingly different in others. Consequently, results from a single study should not be applied across all species and programs. The ultimate goal of these studies is to investigate the causal mechanisms behind any observed deficits in RRS. The more that can be

learned about factors determining RRS, the more managers will understand the effects of supplementation, and the more they will be able to achieve the stated goals of sustainably increasing natural production.

4. 2017 Research Plan uncertainties validation

The Research Narrative indicates that the proponents agree with the summary in the 2017 Uncertainties Database regarding critical uncertainties being addressed by the project. In summary, the project directly addresses C1.2, C1.3, C1.4 and C1.5 and indirectly addresses C1.1, F1.1, F1.4 and F3.6.

199305600 - Advance Hatchery Reform Research

- [View summary in Box](#)
- Background info in Taurus: [Project overview](#) | [Reports](#) | [Past reviews](#)

Project proponent: National Oceanic and Atmospheric Administration

Recommendation: Meets Scientific Review Criteria

Comment:

1. Objectives

As the proponents note, the vast majority of steelhead reared in the Columbia Basin are released as one-year old smolts. In nature, steelhead typically become smolts after 2 or 3 years of freshwater rearing. The proponents hypothesize that the high growth rates experienced by age-1 smolts likely contribute to maladaptive traits and may ultimately be responsible for reduced fitness in hatchery steelhead. The overarching goal of this project is to evaluate the genetic, physiological, and life history impacts of rearing one- and two-year-old steelhead smolts.

Eight clearly defined objectives that are quantifiable, testable, and relevant to the Council's Program were developed to accomplish the project's overall goal. These objectives led the proponents to: (a) compare the survival and migration rates of age-1 and age-2 steelhead smolts in the mainstem, (b) determine the percentage of released age-1 and age-2 smolts that residualize in freshwater, (c) evaluate the ecological effects of residual steelhead produced from both types of smolts on natural steelhead populations, (d) assess the smoltification status of each type of smolt via saltwater challenges, (e) compare the reproductive fitness of adults produced from age-1 and age-2 smolts in an observation stream, (f) determine the breeding success of mature residual males produced from age-2 smolts, (g) evaluate possible epigenetic effects on gamete quality in male and female steelhead produced from age-1 and age-2

hatchery smolts, and (i) develop a life cycle model that compares the survival of age-1 and age-2 smolts at four periods in the life cycle—from hatchery release to spawning adult. Each of these objectives has clearly defined end dates.

The 2018 research narrative and annual reports are organized around hypotheses that address the critical uncertainties listed in the Council’s Uncertainties Database. The emphasis on addressing uncertainties in the research narrative is appreciated by the ISAB/RP. Explicitly listing null hypotheses to be tested experimentally also helps to track and evaluate progress.

2. Methods

Annual reports and the project’s peer-reviewed publications indicate that appropriate experimental designs and statistical analyses are being employed. Additionally, innovative behavioral and physiological assays are being used by the project to address its objectives.

3. Results

Experiments have been successfully conducted to meet the project’s objectives and test hypotheses. Critical uncertainties in the Council’s 2017 Research Plan were carefully linked to the project’s objectives. Additionally, suggestions on the how the project could, with added resources or supplemental data, provide additional information related to these uncertainties were also made.

The project is evaluating questions that are designed to help improve the artificial culture of steelhead. Results to date have indicated that natural origin broodstock can be used, that it is possible to rear and release age-2 smolts on a production basis, and that clear differences exist in the behavior, survival, and physiology of age-1 and age-2 steelhead smolts and in the adults produced from those smolts. All these results are directly related to how steelhead hatcheries could be managed in the future. An example of how the results of this study may guide future hatchery operations is the suggestion that hatcheries should be using natural origin broodstock and rearing and releasing both age-1 and age-2 smolts. The proponents report that fish destined to smolt at age 1 or 2 can be separated soon after ponding, making it possible for facilities to segregate and rear fish smolting at these two different ages.

However, one possible consequence of releasing age-1 and age-2 smolts that was not addressed in the research narrative or annual reports is the possible effect that this strategy may have on the overall fecundity of an integrated population. Adults originating from age-2 smolts typically return as adults after only 1 year at sea whereas age-1 smolts generally spend 2 years at sea. This difference in marine age would presumably cause females originating from age-2 smolts to be smaller, and to possibly have smaller or fewer eggs than those produced from age-1 females. Would such differences affect the overall productivity of an integrated hatchery population that released age-1 and age-2 smolts? The benefits of releasing both age-1 and age-2 smolts will be evaluated over the next several years at the Winthrop National Fish Hatchery.

Project results and key findings have been published in the peer-reviewed literature, in annual reports, and presented at conferences as well as in presentations to the Council.

4. 2017 Research Plan uncertainties validation

The Council's 2017 Research Plan's database indicates that the project is directly assessing Fish Propagation uncertainties 1.1, 1.2, 1.3, and 1.5 as well as potentially providing data and information on three (1.1, 1.2, and 3.6) uncertainties in the Population Structure and Diversity category. The proponent's narrative shows how their project is providing information on all these uncertainties.

200203100 - Growth Modulation in Salmon Supplementation

- [View summary in Box](#)
- Background info in Taurus: [Project overview](#) | [Reports](#) | [Past reviews](#)

Project proponent: National Oceanic and Atmospheric Administration, University of Washington

Recommendation: Meets Scientific Review Criteria

Comment:

1. Objectives

The proponents found that hatcheries rearing yearling Chinook (i.e., spring, summer, and fall races) are producing substantial percentages of males that mature at age-2. In some cases, greater than 50% of the males were maturing as "minijacks." The production of these precocious parr or minijacks reduces the production of anadromous fish, may lead to deleterious ecological and genetic interactions with native fishes, and complicates (i.e., biases) the computation of important demographic metrics such as SAR, SAS, and R/S values.

The overarching goal of this project is multi-faceted: (a) accurately determine the prevalence of minijacks in hatcheries that are releasing yearling Chinook smolts, (b) discern the environmental and genetic factors responsible for early maturation in hatchery settings, and (c) develop hatchery guidelines that can be used to reduce their occurrence. The project has developed clearly defined and measurable objectives to accomplish its overarching goal.

For example, surveys have been conducted to estimate the occurrence of minijacks in a number of the Basin's Chinook hatcheries. These assessments occurred in both segregated and integrated hatchery programs. Common garden rearing studies were performed to determine if genetic factors were influencing early male maturation rates. Moreover, the effects of multiple

environmental factors on minijack prevalence (e.g., feeding rates in the autumn/winter period, lipid content in foods, water temperatures during rearing, and feeding periodicity) were examined via carefully designed experiments.

The production of minijacks is a persistent problem faced by hatchery operators that rear and release yearling Chinook salmon. The project's objectives directly and indirectly address several Fish Propagation uncertainties identified in the Council's 2017 Research Plan. Consequently, the objectives of this project are relevant to the Council's Fish and Wildlife Program. Furthermore, all the objectives and work described in the project's narrative are time-based with clear end dates.

2. Methods

The proponents are using blood plasma 11-ketotestosterone assays to detect precocious maturation in juvenile Chinook. This assay has proven to be one of the most effective methods that can be applied to detect early maturation in male salmonids. Their annual reports, peer-reviewed papers, and presentations indicate that the project's experimental designs and statistical approaches are appropriate. The narrative states that publications associated with this effort will be completed by 2022. However, given the key findings of this effort, we suspect the project team will continue to develop new hypotheses and conduct experiments that will directly benefit hatchery management in the Basin.

3. Results

The project is meeting its objectives, testing hypotheses, and addressing a number of Fish Propagation uncertainties contained in the Council's 2017 Research Plan. Recent results from the project indicate that: (a) a wide range (e.g., 8 -71%) of hatchery-reared male chinook salmon mature precociously as age-2 minijacks throughout the Basin, (b) integrated hatchery stocks are frequently more susceptible than segregated stocks to early male maturation, (c) different stocks reared under identical conditions display an approximate 10-fold variation in minijack proportions (range 4.3-47% of males), (d) manipulation of ration and dietary lipid to match a "wild fish template" for growth significantly reduced minijack and jack rates in yearling Fall Chinook, and (e) a rearing design that uses a "wild fish template" for growth, through use of cold-water winter rearing acclimation facilities, increased age at maturation and improved SARs in hatchery Summer Chinook salmon.

The findings from the proponent's common garden experiments have implications regarding broodstock transfers among facilities, most notably, when adult return numbers in one basin are inadequate to meet production goals in a given year. Transferring stocks with lower thresholds for early male maturation may result in higher than expected minijack rates in progeny from these stocks. This practice may fulfill short-term production goals but result in negative long-term consequences to the program depending on the specific stock and facility.

Results of the project have been used by managers to reduce minijack production in individual hatcheries. Additionally, the surveys for minijacks at Chinook hatcheries, controlled laboratory studies, and the proponent's hatchery production experiments have substantially increased our understanding of the genetic and environmental factors that influence early male maturation. Idiosyncratic features at individual hatcheries (e.g., water sources, stock origins, whether hatcheries are operated as segregated or integrated programs, etc.) have all been identified as elements that can affect the incidence of early male maturation. As a result, each hatchery will need to implement a customized suite of strategies to reduce the occurrence of minijacks. There is no universal strategy. Although minimizing growth in the autumn and reducing the lipid content in feeds appear to be generally useful.

Future work is being directed toward assessing the physiological consequences of the measures used to reduce the prevalence of minijacks. Determining how shifts in diet formulations, feeding rates, water temperature, and other strategies designed to limit early maturity may affect smoltification, juvenile migration behavior, overall survival, and maturation age are also important. We encourage the project to continue its investigations into these questions.

Project results are being shared with hatchery operators and through annual reports and numerous peer-reviewed publications. Results are applicable both within and outside of the Columbia Basin.

4. 2017 Research Plan uncertainties validation

The Council's 2017 Research Plan indicates that the project is addressing Fish Propagation uncertainties. These uncertainties coincide with those mentioned by the proponents.

Relative Reproductive Success

200303900 - Monitor and Evaluate (M&E) Reproductive Success and Survival in Wenatchee River

- [View summary in Box](#)
- Background info in Taurus: [Project overview](#) | [Reports](#) | [Past reviews](#)

Project proponent: National Oceanic and Atmospheric Administration, Washington Department of Fish and Wildlife (WDFW)

Recommendation: Meets Scientific Review Criteria

Comment:

1. Objectives

Three objectives are listed in the 2017 Annual Report: (a) directly measure the relative reproductive success (RRS) of hatchery origin (HO) and natural origin (NO) Chinook salmon in both natural and hatchery settings; (b) determine the degree to which any differences in reproductive success between HO and NO Chinook salmon can be explained by measurable biological characteristics such as run timing or size; and (c) estimate the relative fitness of hatchery-lineage Chinook.

These objectives are clearly stated, measurable, and highly relevant to the Council's Program. The project began in 2003 and field sampling and data collection are scheduled to end in 2022, providing information on three full generations of HO and NO spring Chinook spawning in the Wenatchee subbasin. Additional genotyping, data analyses, and report writing are expected to occur until 2024.

2. Methods

Methods are not described in detail in the Research Narrative or Annual Reports but are documented in peer-reviewed publications and seem appropriate. Accepted methods are being used to trap, sample, and enumerate downstream juveniles and returning adults. DNA-based pedigree procedures are employed to identify and enumerate smolts and adults produced by HO and NO spring Chinook spawning naturally. The panel of loci being used for pedigree assessments was shifted from microsatellites to single-nucleotide polymorphisms (SNPs) beginning with adults returning in 2010. Pedigree assignments based on microsatellites and SNPs were successfully compared for the 2010 fish.

A primary emphasis of the study in recent years is to examine co-variables, such as age, size, run timing, spawning location, and spawning behavior to determine the causes of differences in reproductive success between HO and NO fish. Appropriate methods are being used to

measure biological attributes (e.g., adult size, maturation timing, age at maturity) and behavioral traits (e.g., spawning location, redd geomorphology, straying rates within and outside of the Wenatchee subbasin).

3. Results

The project is meeting its objectives and providing information of value to managers in the upper Columbia River and throughout the Pacific Northwest. The key finding that hatchery rearing and release practices affect subsequent spawning success of released fish will help to refine future hatchery procedures. The project has been used to develop escapement goals for tributary streams within the Wenatchee subbasin.

Specific results include:

- RRS has been estimated for 6 brood years (others still in progress);
- Hatchery Chinook have ~50% lower reproductive success in the wild than natural fish;
- Reductions in female hatchery Chinook reproductive success are driven by spawning location, an environmental effect associated with hatchery release location;
- Reductions in male hatchery Chinook reproductive success are driven by spawning location and changes in age structure;
- Hatchery Chinook, and their natural origin progeny, stray at higher rates within the Wenatchee River than natural Chinook;
- Hatchery Chinook males return at younger ages than natural males and can have very low individual reproductive success as a result; and
- In contrast to steelhead in the Wenatchee and Hood Rivers, there is no evidence that hatchery x hatchery Chinook broodstock have lower reproductive success than wild x wild broodstock

More detail is needed to explain the abundance-based rule to manage PNI mentioned in the last paragraph under “Management questions...” in the Research Narrative, as follows: *“Within the Wenatchee Basin, our results have been used in the development of a management plan in order to establish tributary escapement goals while controlling the proportion of hatchery fish on the spawning grounds. Management of hatchery fish at Tumwater dam consist of prioritizing fish with the greatest relative reproductive success. In practice, all hatchery jacks are removed at Tumwater Dam and of the hatchery adults removed, males comprise the majority. However, depending on the abundance of wild spring Chinook Salmon at Tumwater Dam, a sliding scale is used to manage the PNI of the population.”*

Annual reporting is adequate, and the record of primary publications and conference presentations is excellent. The Research Narrative and 2017 Annual Report indicate that important analyses of final results will not be completed until 2022. Collaboration and sharing of information among partners seem appropriate.

4. 2017 Research Plan uncertainties validation

The ISRP agrees with the proponents (Research Narrative) that the project directly addresses critical uncertainties C1.3, C1.4, C1.5 and indirectly addresses F1.1, as well as uncertainty about “Effects of hatcheries on population structure,” which was not listed as a critical uncertainty in the database.

200305400 - Evaluate the Relative Reproductive Success of Hatchery-Origin and Wild-Origin Steelhead Spawning Naturally in the Hood River

- [View summary in Box](#)
- Background info in Taurus: [Project overview](#) | [Reports](#) | [Past reviews](#)

Project proponent: Oregon State University

Recommendation: Meets Scientific Review Criteria

Comment:

1. Objectives

The main objectives of this project have been to: (a) estimate the fitness effects of raising steelhead in a hatchery, and the effects of those fish on wild populations of steelhead in the Hood River; and (b) identify mechanisms causing hatchery fish to become different from wild fish and suggest ways to alleviate the problem. The second objective has become the focus of current research.

Other objectives for specific experimental studies are clearly defined, measurable, testable, and relevant to the Council’s Program. The Research Narrative indicates how long it may take to achieve specific results and that it will likely take another decade to identify methods to improve hatcheries so that they have less genetic impact on natural steelhead.

2. Methods

Hypotheses and experimental methods are clearly described in the Annual Reports. The proponents have developed many novel approaches to investigate differences in relative reproductive success (RRS) of hatchery origin (HO) and natural origin (NO) salmonids, and the reasons for those differences. Their statistically rigorous analyses are documented in numerous peer-reviewed papers. The combination of experimental manipulations of the hatchery rearing environment and gene scanning approaches is a potentially powerful method to reveal the mechanisms for domestication selection in hatcheries.

3. Results

Since this project began in 2003, it has demonstrated that multi-generation HO stocks of steelhead have much lower fitness than NO fish (RRS = 0.1 to 0.3) when both spawn in the wild but that first-generation hatchery fish (i.e., created using NO parents as broodstock) have only slightly lower fitness than wild fish (RRS = 0.85). A comparison between first and second-generation fish raised side-by-side in the same hatchery showed that each generation spent in the hatchery substantially reduces the performance of HO fish in the wild, that the difference is genetically based, and that the difference can be explained by strong selection on phenotypic variation generated among fish in the hatchery. Fish that experienced one generation in the hatchery made much better broodstock than NO fish. Among NO fish used for broodstock, there is a tradeoff such that families that do best in the hatchery do worst in the wild. Consequently, both theoretical and empirical evidence strongly suggests that rapid adaptation to the hatchery is a sufficient explanation for the fitness declines observed in first- and second-generation fish when they spawn in the wild. The project has also shown that hundreds of genes are differentially expressed between the offspring of HO fish and NO fish when all were raised in the same environment and that a single generation of hatchery selection produces heritable changes at the DNA level that cannot be explained by environmental or maternal effects.

Annual reporting is excellent, and an impressive number of primary publications have been produced to document earlier results. Overall, results from this project have been widely disseminated in a timely fashion and have had a large impact on the fishery genetics literature.

This project has focused on steelhead; a similar focus on Chinook salmon would be useful.

4. 2017 Research Plan uncertainties validation

The Research Narrative lists three critical uncertainties (CUs) being directly addressed by the project. These CUs are not identical to options available in the Uncertainties Database, but they would be subsumed by question C1. The ISRP agrees that the project directly addresses questions C1.1, 1.2, 1.3, C1.4 and C1.5, and indirectly addresses questions F1.1, F1.4 and F3.6.

200306300 - Natural Reproductive Success and Demographic Effects of Hatchery-Origin Steelhead in Abernathy Creek, Washington

- [View summary in Box](#)
- Background info in Taurus: [Project overview](#) | [Reports](#) | [Past reviews](#)

Project proponent: US Fish and Wildlife Service (USFWS)

Recommendation: Meets Scientific Review Criteria (Qualified)

Qualifications:

(1) The strength of the evidence for reduced relative reproductive success (RRS) seems understated and warrants further statistical evaluation. The ISRP advises the proponents to:

(a) examine the distributions of point estimates of RRS across years and sex categories, and use non-parametric methods to test for statistically significant differences in the medians;

(b) summarize any available information on percent straying by cross type for Abernathy Creek and adjacent control streams; and

(c) recognize that estimates of RRS based on juveniles per spawner would be less subject to potential bias from differences in straying of hatchery origin (HO) and natural origin (NO) progeny than estimates of RRS based on adult returns per spawner.

(2) Insufficient information was provided on the objectives and approach associated with issues identified in the following timeline: *"We anticipate that analyses conducted in the final years of this project will yield additional insights regarding gene expression in relation to lipid in fish feed, differential behavior of juvenile fish produced by HOR and NOR adults spawning in the natural environment, the effects of lipid feed level on HOR nutrition, growth, physiology, survival, and migration behavior."*

Comment:

1. Objectives

The overall goals of this project are to determine the relative reproductive success (RRS) of HO and NO steelhead spawning naturally in Abernathy Creek, Washington, and to assess the overall demographic effects of hatchery supplementation relative to two adjacent control streams, Germany and Mill creeks. The previous proposal in Taurus also lists nine more specific objectives, some of which include quantitative elements.

In general, the project has well defined, measurable objectives and testable hypotheses. Results produced from the study are relevant to the Program. The project is scheduled to end in 2020.

2. Methods

Methods are described in detail in the Annual Reports and seem appropriate. Rigorous procedures are used to test for physiological, morphological, and genetic differences between HO and NO fish at both juvenile and adult stages. RRS is calculated using established procedures, but the sample sizes of mature fish are often small, and the precision of the estimates is unknown. Trends in RRS are based on point estimates that do not include any measure of uncertainty associated with the estimates. Future analysis should focus on measuring the precision of these estimates and testing the statistical significance of measured differences in reproductive success.

Two adjacent streams are being used as controls to distinguish shared annual and environmental effects on steelhead productivity from any demographic response to supplementation in the Abernathy population. However, straying among the three streams has been higher than expected and the logistics of the fieldwork have often frustrated efforts to obtain accurate counts and adequate sample sizes of adult spawners. These issues complicate the assignment of adult progeny back to parents and could lead to biased estimates of RRS if HO and NO progeny stray at different rates. Stray steelhead from out-of-basin hatcheries are also common, sometimes accounting for more than 25% of the run. Those captured at the electric weir are identified and removed, but any missed fish could complicate the assessment of RRS and genetic effects. Recent snorkel surveys indicate the presence of untagged fish above the electric weir in Abernathy Creek, likely indicating that some steelhead were able to bypass the weir.

Although the unforeseen logistical challenges with small sample sizes and high straying rates have somewhat compromised the reliability of findings related to RRS, the study design is appropriate and the project has provided valuable information.

3. Results

This project will end in 2020 and has largely addressed its goals. The proponents successfully created a native hatchery brood stock by capturing age 0+ natural origin juvenile steelhead and rearing them to sexual maturity. Hatchery supplementation increased the number of HO steelhead in Abernathy Creek, though results for NO steelhead have been mixed. The study also yielded numerous insights about monitoring and culturing techniques, and the ecology and life history of steelhead.

Overall, the proponents conclude that conservation hatchery practices implemented in Abernathy Creek appear to have failed to maintain the genetic integrity of the NO population. Substantial genetic drift occurred despite incorporating NO spawners into the hatchery brood

line. As a result, the hatchery line was genetically less diverse and differentiated from the NO population. Estimates of RRS are less certain than desired (due to complications noted above), but in most years, reproductive success was lower for HO than NO adults spawning naturally ($RRS < 1$). Smolt production was neither positively nor negatively affected by the hatchery when compared to control streams.

These results and lessons learned are of general interest and are being shared through presentations at conferences and publications. Annual reporting is up to date with considerable detail and good retrospective discussion of the entire project. Specific results have also been documented in numerous primary publications.

The ISRP notes that the Hatchery Scientific Review Group recommends a proportionate natural influence (PNI) of 0.67 for integrated hatchery populations. This project appears to have targeted a PNI of 0.5, and actual values may have been lower due to low NO returns. The ISRP suggests that more NO spawners need to be incorporated into the hatchery broodstocks to examine the consequences of a more ideal integrated program. Nonetheless, this project has provided valuable results, and indicates the importance of limiting production goals in conservation hatcheries where the principal goal is to restore natural populations.

4. 2017 Research Plan uncertainties validation

The ISRP agrees with the proponents that this project directly addresses the following critical uncertainties (CUs) in the 2017 Uncertainties Database: Fish propagation (C1.2, C1.3, C1.4 and C1.5) and Population structure and diversity (F3.6). The project also indirectly addresses C1.1 and F1.1 and F1.4.

201003300 - Study Reproductive Success of Hatchery and Natural Origin Steelhead in the Methow

- [View summary in Box](#)
- Background info in Taurus: [Project overview](#) | [Reports](#) | [Past reviews](#)

Project proponent: Washington Department of Fish and Wildlife (WDFW)

Recommendation: Meets Scientific Review Criteria

Comment:

1. Objectives

The goals of this project are to: (a) directly measure the relative reproductive success (RRS) of hatchery origin (HO) and natural origin (NO) steelhead in the natural environment using a DNA pedigree approach; (b) determine the degree to which any differences in reproductive success between hatchery and wild steelhead can be explained by measurable biological characteristics such as run timing, morphology, spawn timing, age composition, length-at-age, sex ratio, fat content, fecundity, egg weight or spawning location; and (c) estimate the relative fitness of hatchery-lineage steelhead after they have experienced an entire generation in the natural environment. The proponents developed a suite of null hypotheses for each of these goals.

Hypotheses are clearly defined, measurable, testable, and relevant to the Council's Program. Clear time lines for each objective have been established and are being met. The project end-date has been extended to accommodate hatchery reforms that impacted the study design. The revised study will allow inferences about the effectiveness of these recent reforms and includes three new objectives: (d) evaluate the effectiveness of using local broodstock to improve the reproductive success of HO steelhead; (e) conduct a common garden experiment to directly measure the RRS of NO and HO adults produced from age-1 and age-2 steelhead smolts; and (f) measure and compare the reproductive fitness of reconditioned kelts, repeat spawners, and maiden spawners.

2. Methods

Data and methods are clearly described in the Annual Reports. Accepted methods are being used to trap, sample, and enumerate downstream juveniles and returning adults. DNA-based pedigree procedures are used to identify and enumerate parr, smolts, and adults produced by HO and NO steelhead spawning naturally. A generalized linear model is used to estimate the relative influence of demographic and biological variables such as fish origin, fork length, run timing, spawner density, somatic lipid content, on reproductive success in male and female steelhead. The statistical methods seem appropriate for screening a suite of traits for differences between HO and NO fish. Future analyses should consider the influence of changes in PNI during the course of the study.

The notation “WxW” and “HxW” used to distinguish Twisp and Wells HO fish is not clearly explained. The notation gets confusing, in part, because objective (c) in the Research Narrative refers to four cross types (HH, HW, WH and WW) and because the term RRS is used (on page 3 of Research Narrative) when only reproductive success (i.e., not the ratio) is intended.

The ISRP (2010) review expressed the concern that “... *likelihood of substantial past crossing of wild and hatchery fish will complicate using a difference in relative reproductive success between the hatchery- and natural-origin steelhead as a valid basis for drawing biological conclusions and useful management implications.*” Measuring RRS in the Methow River, given the history of transplants and interbreeding there, might underestimate differences that would exist in other rivers without a history of transplants. Even so, any improvement in RRS over successive generations could provide evidence for local adaptation of HO fish to the natural environment of the Twisp River.

3. Results

This project is meeting objectives and successfully testing hypotheses. Parentage and RRS analyses are complete for some life stages for up to six brood years (2009–2014). Average reproductive success measured as age-1, age-2, and smolt offspring was significantly less in both males and females for Wells-hatchery stock than for wild counterparts (i.e., $RRS < 1$). No significant difference was evident in adult returns, but as yet, only 4 brood years are available for that comparison. Based on a single brood year of data available for Twisp hatchery stock, average reproductive success measured as age-1 offspring was significantly lower for males but not females.

The proponents evaluated a large suite of traits looking for differences that might explain why $RRS < 1$ in a natural environment (e.g., run timing, spawn timing, spawning distribution, age composition, sex ratio, length, weight, fat content, fecundity, and egg size). Preliminary results indicate that the best predictors of reproductive success for both males and females are same-sex competitor density, fish origin, length, and somatic lipid content.

This project is similar and complementary to other studies of RRS within the Columbia Basin. Given the history of steelhead transplants to the Methow River, the genetic makeup of NO steelhead in the Twisp River is likely a mixture of many natural and hatchery stocks. Thus, the baseline for reproductive success of NO spawners may have already been shifted by past impacts of out-of-basin HO fish. However, this situation is probably common elsewhere in the Basin too.

Annual reporting is up to date with adequate detail and some good synthesis and retrospective discussion of results for the entire project. Effective collaboration and sharing of information among projects are evident in that the proponents recently proposed (and initiated) an extended study to test the effect of rearing steelhead smolts for release at age 2 (versus age 1) based on findings and support from a project conducted by NOAA (199305600, Advance Hatchery Reform). The Research Narrative indicates that data collection for the original study

will be complete by 2025. However, the proposed extension to test the strategy for improving RRS of HO steelhead by releasing age-2 smolts would require additional data collection for an additional 8-12 years.

The extended project would be particularly useful to managers involved in hatchery reform and kelt reconditioning within the Methow subbasin and of general interest to managers and researchers elsewhere. Primarily, it would help to guide the future of steelhead hatchery program management by directly comparing reproductive success of NO steelhead spawners, HO spawners arising from age-1 releases, and HO spawners arising from age-2 releases in a common garden design. The extended RRS study would also include some reconditioned kelts and could evaluate the effectiveness of kelt reconditioning (i.e., reconditioned vs. repeat spawner vs. maiden spawner) in the conservation of wild steelhead populations. The ISRP has previously recommended that the reproductive success of reconditioned kelts be investigated.

4. 2017 Research Plan uncertainties validation

The ISRP agrees with the proponents that this project directly addresses critical uncertainties C1.1, C1.2, C1.3, C1.4 and C1.5, and indirectly addresses F1.1, F1.4 and F3.6.

Appendix 1: ISRP Review Questions and Outline for Comments

The ISRP's project review comment outline and questions to reviewers below were designed to address the Council's specifications for summary report contents (see [guidance letter](#)) and the Northwest Power Act criteria which direct the ISRP to review projects for consistency with the Council's Fish and Wildlife Program and to evaluate if projects 1) are based on sound scientific principles, 2) benefit fish and wildlife, 3) have clearly defined objectives and outcomes, and 4) contain provisions for monitoring and evaluation of results.

- 1. Objectives:** Were the project's research objectives and hypotheses 1) specific and clearly defined, 2) measurable (quantifiable), 3) achievable and testable, 4) relevant and applicable to the Program with benefits to fish and wildlife, and 5) time-based with clear milestones and end-dates? Please provide specific comments on timelines and end-dates. Any suggestions for improvement?
- 2. Methods:** Were the methods used to test the hypotheses scientifically sound? Any suggestions for improvement?
- 3. Results:** To what extent did the project meet its objectives, answer its hypotheses, address critical uncertainties (specifically those in the Council's 2017 Research Plan), inform management questions, and ultimately guide policy or actions that benefit fish and wildlife? Were the results and lessons learned specific to the proponents' projects or broadly applicable to those inside and outside the Basin; that is, was there evidence of project or program-level adaptive management? Examples of application include changes in management or policy, new or improved technology, changes in best practices or methods? To what extent were key project findings shared with others in the Columbia Basin, e.g., project reports, journal publications, conference presentations, presentations to the Council? Any suggestions for improvement?
- 4. 2017 Research Plan uncertainties validation:** The Council asked project proponents to confirm that the 2017 Research Plan questions listed for their project are correct. This linkage information is from the ISAB/ISRP Critical Uncertainties Report ([2016-1](#)). The Council developed a [database](#) for the critical uncertainties (research questions) in the 2017 Research Plan. The database includes a "projects" [tab](#) that shows the link by the ISRP/ISAB between the 25 research projects and the research questions. Please indicate whether you "agree" or "disagree" with the proponents' statement on linkages to the 2017 Research Plan and provide comments if you disagree.
- 5. Recommendation:** Meets, Meets (Qualified), Meets in Part, or Does Not Meet Scientific Review Criteria (see Appendix 2: ISRP Recommendation Terms). The review did not include a response loop.

Appendix 2: ISRP Recommendation Terms

For each proposal, the ISRP provides a recommendation using the following terms:

- Meets Scientific Review Criteria
- Meets Scientific Review Criteria (Qualified)
- Meets Scientific Review Criteria - In Part
- Meets Scientific Review Criteria - In Part (Qualified)
- Does Not Meet Scientific Review Criteria
- Not Applicable

For preliminary reviews, the ISRP also uses “Response Requested.”

The full definitions of the ISRP’s recommendation categories are:

1. Meets Scientific Review Criteria is assigned to a proposal that substantially meets each of the ISRP criteria. Each proposal does not have to contain tasks that independently meet each of the criteria but can be an integral part of a program that provides the necessary elements. For example, a habitat restoration project may use data from a separate monitoring and evaluation project to measure results as long as such proposals clearly demonstrate this integration. Unless otherwise indicated, a “Meets Scientific Criteria” recommendation is not an indication of the ISRP’s view on the priority of the proposal, nor an endorsement to fund the proposal, but rather reflects its scientific merit and compatibility with Program goals.

2. Meets Scientific Review Criteria - In Part is assigned to a proposal that includes some work that substantially meets each of the ISRP criteria and some work that does not. The ISRP specifies which elements do not meet the review criteria. In general, the proposal element that does not meet criteria is adequately described, but that element is not sound, is redundant, or would not benefit fish and wildlife. Required changes to a proposal will be determined by the Council and BPA in consultation with the project proponents in the final project selection process.

(Qualified) is assigned to recommendations in the two categories above for which additional clarifications and adjustments to methods, objectives, and results reporting by the proponent are needed to fully justify the entire proposal. Occasionally, the ISRP uses “Qualified” for proposals that are technically sound but appear to offer marginal or very uncertain benefits to fish and wildlife.

The ISRP expects that needed changes to a proposal will be determined by the Council and BPA in consultation with the project proponent in the final project selection process. Regardless of the Council’s or BPA’s recommendations, the ISRP expects that, if a proposal is funded, subsequent proposals for continued funding will describe how the ISRP’s qualifications were addressed.

3. Does Not Meet Scientific Review Criteria is assigned to a proposal that is significantly deficient in one or more of the ISRP review criteria. One example is a proposal for an ongoing project that might offer benefits to fish and wildlife but does not include provisions for monitoring and evaluation or reporting of past results. Another example is a research proposal that is technically sound but does not offer benefits to fish and wildlife because it substantially duplicates past efforts or is not sufficiently linked to management actions. In most cases, proposals that receive this recommendation lack detailed methods or adequate provisions for monitoring and evaluation, and some propose actions that have the potential for significant deleterious effects to non-target fish or wildlife. The ISRP notes that proposals in this category may address needed actions or are an integral part of a planned watershed effort, but the proposed methods or approaches are not scientifically sound. In some cases, a targeted request for proposals may be warranted to address the needed action.

4. Not Applicable is assigned to proposals with objectives that are not amenable to scientific review.

5. Response Requested is assigned to a proposal in a preliminary review that requires a response on specific issues before the ISRP can make its final recommendation. This does not mean that the proposal has failed the review. In general, the ISRP requests responses on most proposals and most proposals provide sufficient information in the response loop to meet the ISRP's scientific review criteria.