Research Plan for the
Columbia River Basin Fish and Wildlife Program

Public Review Draft

Northwest Power and Conservation Council

(January 17, 2017)

I. Introduction

For 35 years, the Northwest Power and Conservation Council (Council) has supported a diverse range of research to clarify assumptions critical to the strategies and scientific foundation and principles of the Columbia River Basin Fish and Wildlife Program (Program). The Program, as directed under the Northwest Power Act, contains strategies that organize the various measures to protect, mitigate and enhance fish and wildlife, including spawning grounds and habitat in the Columbia River affected by the development, operation and management of hydroelectric projects. In its 2014 amendment to the Program, the Council continued its commitment to an adaptive management approach that uses research and monitoring data to understand, at multiple scales, how Program projects and measures are performing, and to assess and report on the status and trends of focal species and their habitat.

To that end, the Program includes a plan to organize research; identify critical uncertainties, priority areas and future needs for research; inform adaptive management of strategies and actions that implement the Program; and guide the Council's future project-funding recommendations to the Bonneville Power Administration.

A. Science foundation and principles

The Council understands that to succeed in achieving its vision, strategies and actions implemented through the Program, the Program must be founded on the best available science. The Council's Program contains a set of guiding scientific principles to provide a stable scientific foundation. The foundation and principles recognize that significant ecological and environmental modifications have occurred in the Columbia River and its tributaries, and that a combination of actions is necessary to protect, mitigate, and enhance the fish, wildlife, and habitat impacted by the hydrosystem. Uncertainties persist related to the best available science, and by researching these critical uncertainties the Program foundation should strengthen over time.

B. 2014 Fish and Wildlife Program directive

Recognizing the need to continue to refine and focus research conducted under the Program, the Council committed in the 2014 amendment that it will, with federal and state fish and wildlife agencies and tribes, review and update its research plan every three years. The Council's research plan was first developed in 2006. Some regional review and discussion occurred during the interim, but a formal update has not occurred until now. The Program states that the revision will begin with an update of how previous research funds were allocated to particular categories and critical uncertainties. The Program also calls for the Independent Scientific Review Panel (ISRP) and the Independent Scientific

Advisory Board (ISAB) to assist with updating the critical uncertainties, taking into account evolving topics and reporting on the results of past research.

Research and monitoring are both elements of the Program's adaptive management strategy and are closely related. Research may often incorporate data from monitoring efforts in its investigations. The goal of critical uncertainties research is to either experimentally or observationally (ISRP, 2005) test the validity of key assumptions implied or stated in the Program. According to the Program, "Research seeks to resolve critical uncertainties identified in the council's research plan and assesses new methods and technologies to improve the program". A common set of characteristics helps identify research projects for the purpose of this plan, such as having a clearly stated hypothesis that links to critical uncertainties in this research plan and proposed end or completion dates (section IV below). These characteristics of research projects help distinguish research from status and trend monitoring.

C. Approach and purpose

For the draft 2017 research plan, the Council evaluated past research budget allocations (draft) and the ISAB and ISRP provided a report, *Critical Uncertainties for the Columbia River Fish and Wildlife Program* (2016-1). The report provided an updated list of prioritized critical uncertainties and reviewed the extent to which current projects addressed critical uncertainties listed in the Council's 2006 Research Plan. This update of the Council's research plan included opportunities for public input and gave consideration to critical uncertainties submitted during the Program amendment process.

As the Council began the process to update its research plan, it became evident that the Program and research plan would benefit by 1) continuing to improve the reporting of results and conclusions, and 2) focusing on Program critical uncertainties. This will improve the ability of the Council and others to apply results to validate Program assumptions and improve decisions regarding measures designed to protect, mitigate and enhance fish and wildlife affected by the hydrosystem.

The purpose of this research plan is to help the Council, Bonneville, project sponsors and the independent science panels: 1) continue to improve organization of research conducted under the Program and reporting of results and conclusions; 2) identify critical uncertainties for the Program; 3) identify priority areas of current and future research; 4) inform adaptive management and 5) along with other considerations, guide funding recommendations.

This research plan is organized into four sections: introduction; research themes and uncertainties (specific uncertainties in Appendix A); priorities for action; and implementation.

II. Research themes and uncertainties

As requested by the Council, the ISAB and ISRP completed their report on *Critical Uncertainties for the Columbia River Basin Fish and Wildlife Program* in January, 2016. The ISAB and ISRP critical uncertainties were synthesized from the Fish and Wildlife Program, recommendations to amend the Program, past scientific reviews and reports, and other regional recovery efforts. Subsequent public review and further organization informed the final set of uncertainties, which are organized into 14 research themes, as follows.

A. Themes

The themes are useful categories for organizing critical uncertainties in this plan as well as to track ongoing research through time.

A. Tributary Habitat
B. Mainstem habitat
C. Fish propagation
D. Hydrosystem flow and passage operations
E. Estuary, plume and ocean
F. Population structure and diversity
G. Predation
H. Non-native species
I. Contaminants
J. Climate change
K. Human development
L. Harvest
M. Monitoring and evaluation methods
N. Public engagement

The research themes, suggested by the ISAB and ISRP in their critical uncertainties report, generally align with the Program's strategies, although it is not an exact match. The 2014 Program does not include strategies for human development, fish harvest, population structure and diversity, although measures related to these themes can be found throughout the Program in various sections including the vision and strategies. The theme of contaminants is related to the water quality strategy in the Program.

B. Critical uncertainties

The critical uncertainties associated with each theme (see Appendix A) are described at a high level so that the research plan can provide long-range guidance while preserving flexibility of implementation in the near-term. Moreover, the critical uncertainties are presented this way in order to elicit the development of specific research hypotheses and project proposals without constraining innovative approaches. The critical uncertainties are generally organized by a set of policy questions arranged into two general categories: 1) research related to measures that are currently implemented and 2) areas of research that may lead to different measures or to understand factors that may influence Program progress. Research results should resolve or at least advance understanding of critical uncertainties and thus validate or invalidate key Program assumptions and inform improved Program development and implementation.

III. Research Priorities

For over three decades, a variety of research projects have been implemented to address many of the critical uncertainties in the Program. This research takes place through projects funded through the Bonneville direct program and the Corps of Engineers' Anadromous Fish Evaluation Program (AFEP), which receives annual appropriated funds from Congress through the Corps' Columbia River Fish Mitigation (CRFM) program. Some research also occurs through the Corps' operation and maintenance program and the Lower Snake River Compensation Plan hatchery programs. All of these research projects are and should continue to be reviewed periodically in their various project review processes. The purpose of this plan is not to review and make recommendations on particular research projects. That will occur in these other processes.

A. Immediate Priorities

One of the important purposes of this research plan is to identify priority areas of research that require immediate and focused science and policy review outside of the regular project review process. These research themes (or topic areas within a theme) require focused review and tracking because of the importance to the Program of the underlying uncertainties; the amount of money and effort expended both on the management actions and on the related research; and persistent questions about progress on resolving the underlying critical uncertainty or uncertainties.

1. Tributary habitat research

The program invests significantly in tributary habitat improvements for salmon and steelhead, based on the underlying assumption that improvements in tributary habitat conditions not only boost survival and productivity of juvenile fish in that life stage but also have significant life-cycle/adult return survival benefits. It is not yet clear that progress is being made through research and evaluation on resolving the important underlying uncertainties about the nature and extent of survival benefits from tributary habitat actions, or how long and at what cost will it take to make significant progress so as to conclude the research activities. As part of an ongoing effort (see Council's 2011 RM&E review recommendations) and reiterated in this research plan, the research and evaluation activities devoted to assessing the benefits of tributary habitat improvements need an immediate and focused review of results and expected future activities and expenditures, with a conclusion as to which efforts should be continued as-is or with slight modifications, significantly reframed, or curtailed. This work is anticipated to occur in 2017. Section IV- A. below describes important review elements, such as a set of key review questions to assist with science and policy reviews. These review elements should be incorporated into this focused review as well.

2. Fish propagation research

The Council's Program and to a larger extent, other regional programs (such as the Mitchell Act) invest significantly each year in artificial propagation efforts as mitigation for the impacts due to the hydrosystem. Under the Council's Program, individual production programs have substantial research and evaluation elements, and the results of these efforts are being used to improve the performance of particular facilities and programs. At a higher scale (also described in the Council's 2011 RM&E review recommendations), it remains less certain what progress is being made at evaluating propagation efforts collectively.

The Council, in partnership with Bonneville, has initiated a policy review of a set of research projects that are assessing the relative reproductive success of naturally spawning hatchery and natural origin salmon and steelhead in order to assess the results of these projects and determine if some of the projects have completed their work or if continued investment is still warranted. This review is expected to conclude in early 2017. During a workshop to discuss the relative reproductive success projects, project proponents indicated interest in a continued opportunity to share information, coordinate and improve the efficiencies of their projects.

The Council also has a continued interest in research related to fish propagation and will pursue further consideration of how research in this theme is progressing towards addressing the critical uncertainties. The Council is interested in determining if current research will be helpful in evaluating whether propagation efforts collectively are 1) successfully producing fish for harvest, recovery and conservation and 2) improving the understanding of the magnitude of benefit or detriment to natural origin anadromous and resident fish from natural spawning of hatchery fish.

B. Emerging research priorities

It is important to periodically assess if any Program critical uncertainties are not being sufficiently addressed by ongoing research whether implemented and funded through or outside the Program. If so, steps should be taken to initiate discussion, through review processes or topic-based forums, to determine what new or expanded research activities related to these uncertainties are warranted. A set of emerging Program priorities are included in the investment strategy for the 2014 Program, and uncertainties exist in regard to these priorities as well as other Program strategies. At the time of the revision of this research plan, critical uncertainties in the following areas have been identified as possibly under-addressed and in need of investigation:

- Predation theme: the extent of marine mammal predation on anadromous and resident fish
- Tributary and mainstem habitat and climate change themes: the significance of water temperatures, cold water refuges, and impacts on tributary and mainstem habitat
- Contaminants theme: the relative impact and importance of toxic contaminants
- Non-native and invasive species theme: the relative impact and importance of these species
- Population structure and diversity theme: the role of density dependence and carrying capacity generally, and also in establishment of escapement goals and the feasibility of reintroduction of anadromous species to habitat currently blocked by dams
- Various research themes: Specific research related to sturgeon, lamprey or eulachon

IV. Implementation

Implementation of the research plan over the next three years will focus on clarifying and organizing the research conducted under the Program through several implementation steps. First, as described in Section III, some areas of Program research warrant priority and immediate review: tributary habitat and artificial propagation. All other areas of Program research will undergo regular review, which includes annual administrative check-ins and periodic science and policy review as needed. These reviews should highlight research results for a given uncertainty and determine if additional work is needed on the topic. As research questions are addressed and answered, the Council and Bonneville, working with others in the region, will determine the next priority need based on available funding. The Council recommends that Bonneville consider all appropriate contracting mechanisms to encourage research projects to focus on addressing specific research hypotheses. The Council encourages collaboration among projects to address the high-level critical uncertainties that cannot be addressed at the project level. In their Critical Uncertainties report, the ISRP and ISAB highlighted the need for multi-entity partnerships to develop collaborative approaches to evaluate or to evaluate data from multiple projects and sources

A. Reviews for uncertainties research

1. Administrative check-ins

An annual administrative check-in will provide an opportunity to ensure that all Program research projects have a fully completed, updated research, monitoring and evaluation (RM&E) reporting template on file. This check-in will provide an opportunity to identify if projects are on track for reaching their completion dates. This will largely be a tracking exercise performed by the Council with assistance from Bonneville staff and researchers as necessary and will use information compiled by the ISAB in Appendix D of the critical uncertainties report.

2. Science and policy reviews

Periodic and less frequent science and policy reviews should occur to ensure projects are producing results and progressing toward addressing critical uncertainties. As described in the Program and further developed in the critical uncertainties report in Appendix A (figure 1), the risk-uncertainty assessment provides focused questions and context for the selection and evaluation of research projects. Answers to these and other important questions below will focus research programs on critical questions, produce conclusions that inform decisions and support a more cost-efficient research program.

Key questions that must be addressed during review of existing and new projects are:

- Is the information gained through the research critical and unknown?
- Is the project able to provide that information?

- Is the funding of the project appropriate?

For example,

- If progress is being made on addressing an uncertainty, how much longer should the research continue?
- If progress is being made, is it worth the cost of the research activities to continue?
- If no progress is being made, are there modifications in research design or implementation that might better address the uncertainty or should the project be ended? Is there an alternative research approach that might have better promise?

B. Research Reporting

The Council emphasizes the importance of annual reporting from all projects, including research projects. The Council supports the following reporting elements:

- Annual written reports, based on Bonneville's reporting template, made publicly available. In its 2014 Fish and Wildlife Program, the Council called on Bonneville to require all research, monitoring and evaluation projects to report annually, providing an electronic summary of their results and interim findings, as well as the benefits to fish and wildlife. A high priority is to separate research reports from monitoring reports. The former should address hypotheses and critical uncertainties and the latter should provide important data about implementation, status and trends. As appropriate, action effectiveness should be reported as part of research reports. The ISAB and ISRP noted in their critical uncertainties report that data from non-research projects could be useful to inform hypotheses with appropriate coordination, design and evaluation. Required elements of research project reports include:
    - Projects sponsors will provide draft template reports to Bonneville in January of each year; Bonneville will be responsible for ensuring reports meet and include all required information
    - Project sponsors should issue their annual reports to Bonneville by March of each year using the template format
    - Project sponsors should prepare final written reports for research that is complete, based on the reporting template
    - Inadequate reports will be sent back to sponsors and Bonneville to remedy

- Annual reports for research projects should be made available from Bonneville to the Council generally in May each year in order to support administrative check-ins and science and policy reviews.
- The Council will consider opportunities for oral presentations either as part of evaluation or as otherwise necessary for information sharing.

C. New research

Through its forums or review groups, the Council will identify the need, opportunity and scope for new research efforts. The Council and Bonneville will prepare solicitations for proposals (requests for information or requests for proposals), and the Council will recommend proposals to Bonneville for implementation. Pre-proposals may be utilized if appropriate. These proposals will undergo science and policy review. If funded, the projects would then be subject to the reporting and review elements previously discussed in this plan.

D. Tracking research

The Council, using a database developed in conjunction with the critical uncertainties report, along with research project reviews and CBFish.org, will compile and track the information important to evaluating the progress of research to address the research plan's critical uncertainties. This information will include the rationale for why these uncertainties are critical for the Program, recommendations from the ISAB report, source information from each of the critical uncertainties, which projects are directly and indirectly addressing these uncertainties, and links to annual and final reports and completion dates.

E. Assessment of progress toward addressing critical uncertainties

There is a need to periodically consider the results of critical uncertainties research at a *programmatic* level to determine what progress is being made. The Council will review the research plan every three years, with the assistance of the independent science panels and other regional partners. The Council will, as necessary, sponsor forums, workshops or conferences to inform this update. In their critical uncertainties report, the ISRP and ISAB highlighted the need for multi-entity partnerships to develop collaborative approaches to evaluate or to evaluate data from multiple projects and sources. A key question to be asked each time the plan is updated will be whether the steady accumulation of research project reviews indicates sufficient progress is being made across the research plan in addressing the Program's critical uncertainties.

V. Appendix A. Critical uncertainties by theme

Theme A. Tributary Habitat

Question 1. Do investments in tributary habitat restoration mitigate for degraded mainstem habitat and passage conditions?

1.1. To what extent do tributary habitat restoration actions improve the survival, productivity, distribution and abundance of native fish populations?

1.1.1. How much does improving habitat and eliminating barriers (removing dams and culverts, or transporting migrating fish above dams) increase carrying capacity and contribute to recovering important fish populations?

1.1.2. To what extent is an increase in carrying capacity usurped by non-native invasive species, preventing recovery of native fish and wildlife populations?

1.1.3. How do fish adapt their behavior to mitigate for extremely warm water temperature?

Question 2. What additional habitat restoration projects should be implemented to benefit fish and wildlife?

2.1. What combinations of protected and restored aquatic, riparian and upland habitat are most effective at meeting the life cycle needs and sustaining populations of fish and wildlife in tributaries?

2.2. Do some restoration efforts provide resilience to buffer against climate events and recover native species of interest?

2.2.1. How can habitat restoration activities or hydrosystem operations modify groundwater/surface water interactions and floodplain habitats to provide refuges during extreme events and improve overall survival, productivity, distribution, and abundance of anadromous and resident native fish populations?

Theme B. Mainstem Habitat

Question 1. Do hydrosystem operations dedicated to improve mainstem habitat provide the expected benefits for fish?

1.1. What are the impacts of hydrosystem operations on mainstem habitats, including the freshwater tidal realm from Bonneville Dam to the salt wedge? How might hydrosystem operations be altered to recover mainstem habitats and enhance prey production and the carrying capacity of mainstem habitats?

1.2. Did reductions in historical mainstem habitat, including dam construction, change the density-dependent responses of salmon, sturgeon, and other anadromous and resident species?

Question 2. What additional hydrosystem operations or passage strategies should be considered to improve mainstem habitat to benefit fish?

2.1. What should be the magnitude and timing of restored flows, ramping rates, and temperature regimes for the free-flowing segments of the river?

2.2. What would be the effects of operational changes for optimizing water temperatures and water quality for fish in shoreline and riparian habitats?

2.3. Where, when, and at what frequency under different conditions do salmonids and other native species use cold water thermal refuges in the lower Columbia, upper Columbia and Snake rivers?

2.3.1. To what extent can managed releases from high-head dams mitigate or mask the effects of climate change by regulating water temperatures and thereby optimizing habitat for endangered fish downstream of such structures?

2.3.2. What would be the effects of operational changes for optimizing water temperatures and water quality for fish in shoreline and riparian habitats, as well as for wildlife in these habitats?

2.4. How much spawning and rearing habitat is available to White Sturgeon above and below Bonneville Dam under a range of actual operational conditions?

2.5. How do operational changes and habitat conditions, including temperature, differentially affect spawning success and juvenile growth and survival to the recruitment stage for White Sturgeon?

Theme C. Fish propagation

Question 1. Are current propagation efforts successfully producing fish for harvest and conservation?

1.1. What is the relationship between basinwide hatchery production and the survival, fitness and growth of naturally produced fish in freshwater, estuarine and ocean habitats?

1.1.1. Can hatchery production programs meet adult production and harvest goals (integrated and segregated) while protecting naturally spawning populations?

1.1.2. What are the effects, by life stage, to natural populations from competition, predation (direct and indirect), and disease caused by interactions with hatchery-origin juveniles, from harvest in fisheries targeting hatchery-origin adults and from hatchery effluent?

1.2. What is the magnitude of any demographic benefit or detriment to the production of natural-origin juveniles and adults from natural spawning of hatchery-origin supplementation adults?

1.2.1. 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?

1.3. What are the risks to wild sturgeon from hatchery practices?

1.3.1. What are the potential impacts on wild sturgeon from mixing of genetic stocks as part of broodstock and larval fish rearing mitigation efforts?

Question 2. Can hatcheries successfully support Pacific Lamprey?

2.1. What is the potential role of lamprey propagation and translocation as a way to mitigate for lost lamprey production when passage and habitat improvements alone are insufficient to restore lamprey populations? Specifically, can artificial propagation be used to supplement and restore depressed populations of Pacific Lamprey?

Theme D. Hydrosystem flow and passage operations

Question 1. Do hydrosystem operations dedicated to benefit fish provide the expected benefits?

1.1. What is the relationship between levels of flow, spill, total dissolved gas and survival of fish (including salmonids, eulachon, sturgeon, lamprey, and other focal species) through the Columbia Basin hydrosystem (including the Columbia, Snake and Willamette rivers)?

1.2. What are the effects of spill operations on returning adults that subsequently affect adult fish migration behavior, straying, pre-spawning mortality, and smolt-to-adult return ratios (SARs)?

1.3. How does the existing hydrograph affect reproductive and recruitment success for sturgeon and burbot and thus conservation aquaculture operation decisions in the Kootenai River subbasin?

1.4. How does dam passage affect fish?

1.4.1. How does juvenile passage through multiple dams versus transportation affect adult fish migration behavior, straying, and pre-spawn mortality, and juvenile-to-adult survival rates?

1.4.2. Do juvenile bypass systems negatively affect smolts making them less fit or are less fit smolts more likely to end up in the bypass system?

1.4.3. How do dams affect lamprey during migration?

1.5. How do hydrosystem reservoirs affect food web, predator-prey interactions, competition, survival and growth?

1.6. What is the flexibility of the hydrosystem to be optimized for different species needs (flow, temperature, etc.)?

Question 2. What additional hydrosystem operations or passage strategies could be considered to benefit fish?

2.1. What are the effects of water temperature at mainstem dams and reservoirs on fish passage (both juvenile and adults)?

Theme E. Estuary, plume and ocean

Question 1. Are investments in the estuary having the expected beneficial effects?

1.1. What are the responses of focal species (anadromous salmonids, White Sturgeon, Pacific Lamprey, and Eulachon), life history types, and populations to alternative restoration actions and locations in the estuary that best inform management decisions?

1.2. How can we efficiently and effectively manage and restore estuarine habitat to increase the carrying capacity of the estuary for salmonids and other focal species (anadromous salmonids, White sturgeon, Pacific Lamprey, and Eulachon)?

Question 2. What should we know about the estuary, plume, and ocean that will improve life cycle survival forecasts or inform management actions?

2.1. How much do specific factors impact growth, fish condition, residence time, age at maturation and survival of focal fish species (anadromous salmonids, White Sturgeon, Pacific Lamprey, Eulachon) in the estuary, plume, and ocean?

2.1.1. How do upstream nutrient fluxes influence hypoxia below Bonneville Dam?

2.2. How do climate change, hypoxia, and ocean acidification affect survival of focal fish species (anadromous salmonids, White Sturgeon, Pacific Lamprey, Eulachon) in the estuary, plume, and ocean?

2.3. How large are density dependence effects for salmonids in the estuary and ocean, including the influence of hatchery fish and/or invasive species (e.g., American Shad juveniles)?

2.4. To what extent can predictive models be used to evaluate the potential impacts of hydrosystem projects on estuary, plume, and coastal marine habitats and their biota?

2.5. What tidal freshwater, estuary, plume, and ocean habitats and their biota are most important to focal species (anadromous salmonids, White Sturgeon, Pacific Lamprey, Eulachon)?

Theme F. Population structure and diversity

Question 1. What level of population diversity is necessary to ensure population integrity?

1.1. What is the relationship between genetic diversity and ecological and evolutionary performance, and to what extent does the loss of stock diversity reduce the fitness, and hence survival rate and resilience, of remaining populations?

1.1.1. How effective is genetic assessment for determining trends in population status and population diversity?

1.1.2. What is the biological goal for spawning escapement for focal fish and wildlife populations including consideration of carrying capacity and nutrient return?

Question 2. What is the potential for reintroducing anadromous fish above blocked areas?

2.1. What is the success rate of the current efforts at reintroducing anadromous fish into blocked areas throughout the Pacific Northwest?

2.2. What is the feasibility of reintroducing anadromous fish at each federal and non-federal project that currently blocks anadromous fish from historic habitat? Specifically, what is the feasibility of implementing adult and juvenile passage at dams that currently do not have passage?

2.2.1. Will the novel biotic communities that have assembled since barrier construction—with their predators—allow the reintroduction of productive native fish populations?

2.2.2. What is the feasibility of upstream and downstream passage options for salmon and steelhead in the upper Columbia (above Chief Joseph and Grand Coulee dams)?

2.2.3. Can extirpated populations be recolonized by relying on out-of-basin brood stock?

2.2.4. In particular, what are the potential benefits and risks of re-introducing anadromous fish into blocked areas throughout the Pacific Northwest?

2.2.5. What is the potential for and likelihood that reintroduced salmon will form adfluvial populations above barriers without volitional passage, and how will this impact population growth and persistence of the anadromous population?

Question 3. 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?

3.1. What are the relative contributions of habitat loss, harvest, predation and mainstem passage to reduced riverine survival and production of anadromous salmonids and other fishes targeted in the Fish and Wildlife Program?

3.1.1. How do fish move among rearing habitats, and what is the importance of habitat connectivity and spatial distribution?

3.1.2. How does changing hydrosystem, harvest, hatchery and habitat actions affect salmon and steelhead status and trends given the influence of ocean conditions?

3.1.3. What factors are limiting recruitment of White Sturgeon above and below Bonneville Dam?

3.1.4. Do the mainstem dams isolate sturgeon populations, and if so, what is the feasibility of restoring connectivity to maintain genetic diversity in the long-term?

3.2. What life history strategies are utilized by Columbia River Basin fishes (e.g., Pacific salmon, lamprey, sturgeon, Eulachon), and how do they influence survival and growth in tributaries, the mainstem Columbia River above and below the dams, the estuary, and the ocean plume?

3.2.1. After anticipated restoration of tributary habitats and given the range in ocean conditions and spawner densities, what level of SARs is needed for each salmon ESU in order to (1) provide for a self-sustaining population, and (2) provide harvests that meet harvest goals?

3.3. How can the abundance and diversity of fish in the Columbia River be increased and sustained over the long term given the multitude of biological, physical, and cultural constraints?

3.3.1. What are the levels of genetic diversity and degree of spatial genetic differentiation among populations or aggregations of Pacific Lamprey from the Columbia River Basin and rivers along the West Coast of North America? Specifically, what are the genetics of anadromous and resident lamprey populations (e.g., existence of genetically distinct population structure, rate of gene flow, population/subpopulation characteristics, etc.)?

3.3.2. What are the potential risks of reconnecting two groups of fish separated by a barrier (e.g. are the two groups still similar or have they adapted to their separate habitats resulting in negative effects if reconnected)?

Theme G. Predation

Question 1. How effectively are undesirable impacts of predation ameliorated by management actions including hydrosystem operations, habitat modifications and predator population control?

1.1. To what extent is the viability or abundance of native fish and wildlife populations in the Columbia River Basin jeopardized by predation?

1.1.1. What proportion of adult salmon and White Sturgeon are killed by sea lions (and other marine mammals) during their upstream migration below Bonneville Dam?

1.2. To what extent is the productivity or viability of salmon populations increased by management actions to reduce avian and fish predation on smolts during the downstream migration versus actions to reduce marine mammal predation during the upstream migration below Bonneville Dam?

1.2.1. How does the cost-effectiveness of actions to control predator populations compare to that for alternative actions (e.g., flow and habitat modifications, hatchery supplementation) to increase the productivity or viability of natural salmon populations?

Question 2. Are there actions other than removing predators that could reduce predation on listed species?

2.1. How does increasing the total density of prey through hatchery releases, and alternative prey species such as Eulachon affect the rate of predation on natural-origin juvenile and adult salmon, steelhead, sturgeon and lamprey?

Theme H. Non-native species

Question 1. Are current efforts to prevent the introduction and reduce the populations of nonnative species effectively protecting native species?

1.1. What are the primary pathways of introduction of invasive and non-native species, and what management actions could control and limit them?

1.2. To what extent is the viability or abundance of native fish and wildlife species in the Columbia River Basin jeopardized by non-native species?

Theme I. Contaminants

Question 1. Can toxic substances undermine fish and wildlife recovery efforts?

1.1. What are the distributions, uses and concentrations of toxics, including emerging contaminants, in the Columbia River Basin, and what are their trends over time?

1.1.1. What are the impacts of different hydrologic scenarios and management actions (e.g., dam operations and flow management) on contaminant distributions and transfer of contaminants to food webs?

1.2. How do toxic substances, alone and in combination, affect fish and wildlife distribution and abundance, survival and fitness, and productivity in the Columbia River Basin?

1.2.1. What are the cumulative and/or synergistic effects of multiple toxic contaminants, particularly pesticides, on riparian insects and other organisms that impact the carrying capacity of the Columbia River ecosystem (including estuarine, coastal ocean and riverine habitats), as well as interactions between these chemicals and non-chemical stressors?

1.2.2. How do food web transfer, sediment transport, and biological effects of emerging and legacy organic contaminants under current management regimes affect key Columbia River species, the success of restoration projects within the basin, and human health (i.e., the success of harvest mitigation)?

1.2.3. What levels of chemicals of emerging concern (CECs) impact the health of focal species including Pacific Lamprey, White Sturgeon, and salmonids?

Theme J. Climate change

Question 1. How are long-term climate trends expected to impact recovery efforts for fish and wildlife in the region?

1.1. What food web effects are associated with long-term climate trends predicted for the Columbia River Basin?

1.2. Are the Program's habitat restoration actions and hatchery facilities able to effectively respond to rapid changes in water availability and quality?

1.2.1. How secure are surface and ground water sources as aquifers are being depleted because of multiple and competing uses?

1.3. What are the potential effects of climate change on river hydraulics, temperature and sediment movement in tributaries and mainstem reaches of the Columbia River Basin?

1.4. How might climate change affect the success of salmonid reintroductions, supplementation or recovery efforts, particularly since warmer waters may favor other species, especially non-natives?

1.5. How can understanding future climate conditions help guide restoration actions and ensure their effectiveness over time?

1.6. How could integrated ecological monitoring be used to determine how climate change affects fish and wildlife and the freshwater, estuarine, ocean and terrestrial habitats and ecosystems that sustain them; how can this information inform decisions?

Question 2. What strategic actions could help ameliorate potential effects of climate change including increased water temperatures, decreased summer river flows, changes in upland plant communities, and other ecosystem changes?

Theme K. Human development

Question 1. How are projected changes in society's use of land and other resources likely to affect environmental quality, habitats and fish and wildlife populations?

1.1. What changes in human population levels and their distribution, per capita income and economic activity are expected over the next 20 years?

Theme L. Harvest

Question 1. Do current harvest and escapement strategies provide the expected results in supporting recovery efforts and providing harvest opportunities?

1.1. Are current harvest monitoring tools effective at determining if the results of harvest in supporting recovery efforts and providing harvest opportunities are being met?

Question 2. Are there additional harvest and escapement strategies that would do a better job of supporting recovery efforts and providing harvest opportunities?

2.1. How can fishery interceptions and harvests of ESUs or populations, both hatchery and wild, best be managed to minimize the effects of harvest on the abundance, productivity and viability of those ESUs and populations?

2.1.1. What is the catch-and-release mortality by species and stock, and in relation to environmental variables in the ocean, estuary and freshwater?

2.1.2. What are the impacts of directed (intentional) and incidental (unintentional) harvests on population-specific characteristics and productivity of Columbia River Basin fishes?

2.1.3. Are hatchery harvest rates a reasonable surrogate for wild salmon harvest rates in freshwater and the ocean?

2.1.4. Are there additional strategies that can be employed to increase harvest of certain hatchery fish and benefit both wild fish and harvesters?

Theme M. Monitoring and evaluation methods

Question 1. Are current methods to count fish and measure productivity accurate, reliable and cost effective?

1.1. What are the acute and chronic effects of various tag types on fish survival, for example PIT tag effects on juvenile salmonids?

1.2. Can survival of juvenile salmonids from spawning to estuary be best monitored using PIT tags, acoustic tags, genetic or other tags?

Question 2. Are there better methods for counting fish and measuring their productivity?

2.1. Fish survival is currently estimated using capture/recapture methods. How can advances in genetic stock identification, reductions in sizes of tags, new tag technologies, and other emerging methods be used to improve estimates of survival (better precision and less bias) and/or reduce costs?

2.1.1. What methods can be used to estimate the survival and abundance of lamprey?

Question 3. Are there better methods for determining the response of fish populations to habitat restoration?

3.1. What are the most effective methods for quantitative estimates of changes to abundance, survival, movement and production in response to habitat restoration, and how can these estimates be integrated across a range of spatial scales from individual restoration

treatments to whole watersheds, and temporal scales from annual returns to entire life cycles?

3.1.1. Do the current methods for detecting effects of many small, incremental habitat improvements on fish populations provide answers with sufficient precision and accuracy to evaluate the success of these programs?

3.1.2. Are models used to predict habitat benefits of actions prior to implementation accurate and useful in order to prioritize actions and assess cost/benefit ratios?

3.2. Are there effective methods for fish-in and fish-out monitoring for measuring effects of habitat restoration and other changes?

3.2.1. What statistical methodologies are available for estimating the number of fish (1) entering and then leaving habitat areas or for (2) entering and the number of progeny leaving the habitat area? And how effective are the statistical methodologies for different habitat types?

Question 4. Are there better methods for determining the response of wildlife populations (other than fish) to habitat restoration?

4.1. Can impacts to transient wildlife populations (e.g., waterfowl) and small localized wildlife populations (e.g. bears) be effectively monitored at a lower cost?

Theme N. Public engagement

Question 1. How well does the Fish and Wildlife Program communicate with and engage the public (and its diverse social groups) associated directly or indirectly with the landscape?