



Columbia River Basin Fish and Wildlife Program

2017 RESEARCH PLAN

Pre-publication Version



Northwest **Power** and
Conservation Council

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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.

The research plan, though not a part of the Fish and Wildlife Program, serves as guidance to the federal agencies with legal responsibilities under the Northwest Power Act in implementing the research measures and priorities of the Program. The Bonneville Power Administration has a particular obligation in the Act to use its fund and authorities "in a manner consistent with" the Council's Fish and Wildlife Program, power plan, and purposes of the Act. The Corps of Engineers and Bureau of Reclamation and FERC have a separate obligation to take the Council's Fish and Wildlife Program into account to the fullest extent practicable at every stage of decision-making. With advice from the Independent Scientific Review Panel (ISRP) established under the Act, the Council reviews projects proposed for implementation by state and federal fish and wildlife agencies, Indian Tribes and others.

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 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 and monitoring programs may often be based on scientific principles identified through research. The goal of critical uncertainties research is to either experimentally or observationally test the validity of key assumptions implied or stated in the Program (Study Designs for Research, Monitoring and Evaluation; [ISRP 2005](#)). 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 the critical uncertainties, and proposed end or completion dates (also see section IV below). The Fish and Wildlife Program and this research plan define these research and monitoring terms:

Research term	Definition
Critical uncertainties	Critical research uncertainties are questions concerning the validity of key assumptions implied or stated in the Program.
Critical Uncertainties research	For the purposes of the research plan, research furthers the understanding of critical uncertainties, including action effectiveness, new methodologies and technologies. Consistent with the Program, research projects contain a clearly stated hypothesis, beginning and end dates, and results and conclusions.
Effectiveness	Assesses whether certain actions and projects are having the intended effect and contribute to overall mitigation, protection and recovery efforts in the basin. This may require establishing a causal relationship or a correlation between the action and change observed; i.e. statistical cause-and effect and correlation relationships. This can be at one of two scales -- to detect a localized effect (project or stream reach level effect), and to detect a watershed level effect (intensively monitored effect) -- and can be either research or monitoring.
Monitoring term	Definition
Implementation	Monitoring conducted to determine whether an activity was performed and completed as planned.
Status and trend	Used to assess status over time of fish, wildlife and habitat that informs program evaluation and reporting needs. This type of monitoring is intended to span a time-period adequate to understand the trend and be able to track progress toward program goals and objectives.

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) organize 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 intended to be used to guide 1) projects that are exclusively research, 2) effectiveness monitoring projects, or 3) projects that contain research elements.

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

These 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 the ISAB and ISRP themes of human development, fish harvest, and population structure and diversity; although, references to and 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 [section V](#)) 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 actions 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. Priority themes

One of the important purposes of this research plan is to identify priority areas of research that require near-term and focused science and policy review outside of the regular project review process. These research themes (or topics 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 native species including salmon and steelhead, based on the underlying assumption that improvements in tributary habitat conditions not only boost survival and productivity of fish in the tributaries but also contribute survival benefits at the population scale. There remain uncertainties in the relationships between tributary habitat efforts and benefits to fish and wildlife at the population scale, and the appropriate monitoring and evaluation

needed to determine those relationships. In addition for some habitat actions, it is not yet clear if the current level of understanding about the nature and extent of changes resulting from an action is sufficient to determine whether it has improved habitat conditions and benefited fish. For those habitat actions requiring more effectiveness research, the additional cost and time required has not been determined.

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, modified, significantly reframed, or curtailed. This work is anticipated to be completed in 2017. Section IV- A. below describes important review elements, such as a set of key review questions to be incorporated into science and policy reviews.

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 broader scale (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 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 1) are successfully producing fish for harvest, recovery and conservation and 2) are improving the understanding of the magnitude of benefit or detriment to natural origin anadromous and resident fish from natural spawning of hatchery fish and 3) can be used to maximize benefits to harvest and conservation while managing risks to natural populations. The Council sees working with the states, federal agencies and tribes as described in the Program to identify specific hatchery mitigation indicators for Program hatcheries as an important step.

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 science and policy 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. The Council also received input regarding research priorities from fish and wildlife agencies, tribes and others regarding research priorities during public comment on the ISAB and ISRP Critical Uncertainties Report. 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 contributions and resiliency of cold water to tributary and mainstem habitats and how to identify and protect these habitats
- Non-native and invasive species theme: the relative impact and importance of these species structure and diversity theme: the role of density dependence and carrying capacity generally, and also in understanding population goals
- Population and diversity theme: 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 or 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 critical uncertainties research*

With the help of the ISRP established by the Council under the Act, the Council reviews projects proposed for implementation. The purpose of this review is ensure that all projects are based on sound science, provide benefits to fish and wildlife, and are consistent with the priorities and measures in the program.

1. Administrative check-ins

An annual administrative check-in will provide an opportunity to ensure that all Program research projects have completed an updated research report based on the annual reporting [template](#). 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 for Program research should occur to ensure projects are producing results and progressing toward addressing critical uncertainties. Reviews follow established protocols and typically include solicitation for project reports and proposals; ISRP review;

public review; staff review and recommendations, and final Council decision. Information about these steps and past reviews are available on the Council's [website](#).

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 annual written reports, based on Bonneville's reporting template, and these should be made publicly available. In its 2014 Fish and Wildlife Program, the Council called on Bonneville to require all research projects in their annual report to address hypotheses and critical uncertainties and provide an electronic summary of their results and interim findings, including 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. For projects that include both research and monitoring, sponsors should identify in their report, which elements of the project are research and which are monitoring, along with what critical uncertainty the research is addressing.

Reporting steps:

- Projects sponsors will provide draft reports to Bonneville in January of each year using the reporting template.
- Bonneville will be responsible for ensuring reports meet and include all required information. Incomplete reports will be returned to sponsors to remedy.
- Project sponsors should issue their final annual reports to Bonneville by March of each year.
- 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 all 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. To address this need the Council will use a variety of methods to synthesize and evaluate progress towards addressing critical uncertainties. The Council may hold science-policy forums for review and synthesis of topics, request ISAB synthesis for certain topics, or request syntheses from project researchers, staff or contractors.

V. Critical uncertainties by theme

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 this final set of uncertainties, which are organized into 14 research themes.

The critical uncertainties associated with each theme 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. 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.

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?
- 1.2. 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?
- 1.3. To what extent is an increase in carrying capacity usurped by non-native invasive species, preventing recovery of native fish and wildlife populations?
- 1.4. To what extent do restoration efforts provide resilience to buffer against climate events and recover native species of interest?

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

- 2.1. Are the cumulative suites of restoration actions benefiting populations of fish and wildlife in tributary watersheds?
- 2.2. How can habitat restoration actions support or enhance cold water habitat to provide thermal refuges?

B. Mainstem habitat

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

- 1.1. What are the impacts of hydrosystem construction and operations on mainstem habitats, including the freshwater tidal realm from Bonneville Dam to the salt wedge?
- 1.2. How do hydrosystem reservoirs affect food web, predator-prey interactions, competition, survival and growth?
- 1.3. How might hydrosystem operations be altered to benefit fish, for example enhancing prey production, mainstem habitat and carrying capacity?

Question 2. What additional hydrosystem operations or actions 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 and wildlife including shoreline and riparian habitats?
- 2.3. 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?
- 2.4. 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?
- 2.5. How much spawning and rearing habitat is available to White Sturgeon above and below Bonneville Dam under a range of actual operational conditions?
- 2.6. 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?

C. Fish propagation

Question 1. Are current propagation efforts successfully meeting harvest and conservation objectives while managing risks to natural populations?

- 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?
- 1.2. Can hatchery production programs meet adult production and harvest goals (integrated and segregated) while protecting naturally spawning populations?
- 1.3. What are the interactions, by life stage, between hatchery-origin and natural-origin populations with respect to competition, predation (direct and indirect), and disease including harvest in fisheries targeting hatchery-origin adults; and from hatchery effluent?
- 1.4. 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?
- 1.5. 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, and the proportion of natural origin adults in the hatchery broodstock?
- 1.6. What are the risks and benefits of artificial propagation to wild sturgeon?
- 1.7. What are the potential impacts on wild sturgeon from mixing or not mixing of genetic stocks as part of broodstock and larval fish rearing mitigation efforts?

Question 2. Are there additional fish propagation or related strategies that could be considered to benefit to benefit Pacific Lamprey?

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

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 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 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. 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?
- 1.5. How does the existing hydrograph affect reproductive and recruitment success for sturgeon and burbot and thus conservation aquaculture operation decisions, particularly in the Kootenai River subbasin?
- 1.6. How do dams and recent structural upgrades affect lamprey at all life stages?

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

- 2.1. What is the flexibility of the hydrosystem to be optimized for different species needs (flow, temperature, etc.)?
- 2.2. What additional actions at mainstem dams and reservoirs can be implemented to improve water temperature and fish passage (both juvenile and adults)?

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 are efforts to manage and restore estuarine habitat increasing 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 (e.g. climate change, hypoxia, ocean acidification) 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?
- 2.2. How do nutrient fluxes originated above Bonneville dam, influence hypoxia in the estuary?
- 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 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)?

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?
- 1.2. How effective is genetic assessment for determining trends in population status and population diversity?
- 1.3. What is the goal for spawning escapement for focal fish and wildlife populations including consideration of carrying capacity and nutrient return?
- 1.4. How is diversity distributed among populations within a geographic region or biological grouping?

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

- 2.1. What are the results 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?
- 2.3. What are the potential benefits and risks of re-introducing anadromous fish into blocked areas throughout the Pacific Northwest including impacts to novel native species and competition and predation from non-native species?

- 2.4. 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?
- 3.2. At the population scale how do fish move among rearing habitats, and what is the importance of habitat connectivity and spatial distribution?
- 3.3. How does changing hydrosystem, harvest, hatchery and habitat actions affect salmon and steelhead status and trends given the influence of ocean conditions?
- 3.4. What factors are limiting recruitment of White Sturgeon above and below Bonneville Dam?
- 3.5. 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?
- 3.6. 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?
- 3.7. 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?
- 3.8. 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?
- 3.9. 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.)?

G. Predation

Question 1. Are the current efforts to address predation and reduce numbers of predators effective?

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

- 1.2. What proportion of adult salmon, steelhead and White Sturgeon are killed (immediately or by delayed mortality) by sea lions (and other marine mammals) during their upstream migration below Bonneville Dam and how does predation impact the viability and abundance of native fish and wildlife population?
- 1.3. 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?
- 1.4. 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?

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?

I. Contaminants

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

- 1.1. What are the distributions, sources and concentrations of toxics, including emerging contaminants, in the Columbia River Basin, and what are their trends over time?
- 1.2. 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?
- 1.3. 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?
- 1.4. 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?

- 1.5. 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)?
- 1.6. What levels of chemicals of emerging concern (CECs) impact the health of focal species including Pacific Lamprey, White Sturgeon, and salmonids?

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 hatchery facilities able to effectively respond to rapid changes in water availability and quality; are Program habitat actions mitigating for climate related changes including water availability and quality?
- 1.3. What are the potential effects of climate change on water availability, 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?

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?

- 2.1. How can understanding future climate conditions help guide restoration actions and ensure their effectiveness over time?
- 2.2. 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?

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?

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 fishery monitoring tools effective at determining if fisheries are meeting harvest and conservation objectives?

Question 2. Are there additional harvest and escapement strategies that would support recovery efforts and provide harvest opportunities?

2.1. Do current harvest strategies effectively reduce risk to fish populations, their abundance, productivity population structure and viability?

2.2. Are the release mortality rates for bycatch accurate and do they vary as environmental conditions change?

2.3. Are hatchery harvest rates a reasonable surrogate for wild salmon harvest rates in freshwater and the ocean, and are there ways to improve stock and population specific estimates of harvest impacts?

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

M. Monitoring and evaluation methods

Question 1. Are current methods to identify restoration actions, to count fish, and to measure productivity adequate to cost effectively inform decisions?

1.1. 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?

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

1.3. How can survival of juvenile salmonids from spawning site to estuary be effectively and efficiently monitored?

Question 2. Are there innovative methods for counting fish and measuring their productivity that would better inform decisions?

2.1. 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 and reduce costs?

2.2. 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?

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

Question 3. What methods are effective for determining the response of fish populations to habitat restoration?

3.1. What are effective methods to estimate fish response to habitat restoration, from individual restoration treatments at a site-scale to a suite of actions at a whole watershed scale?

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

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?

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?