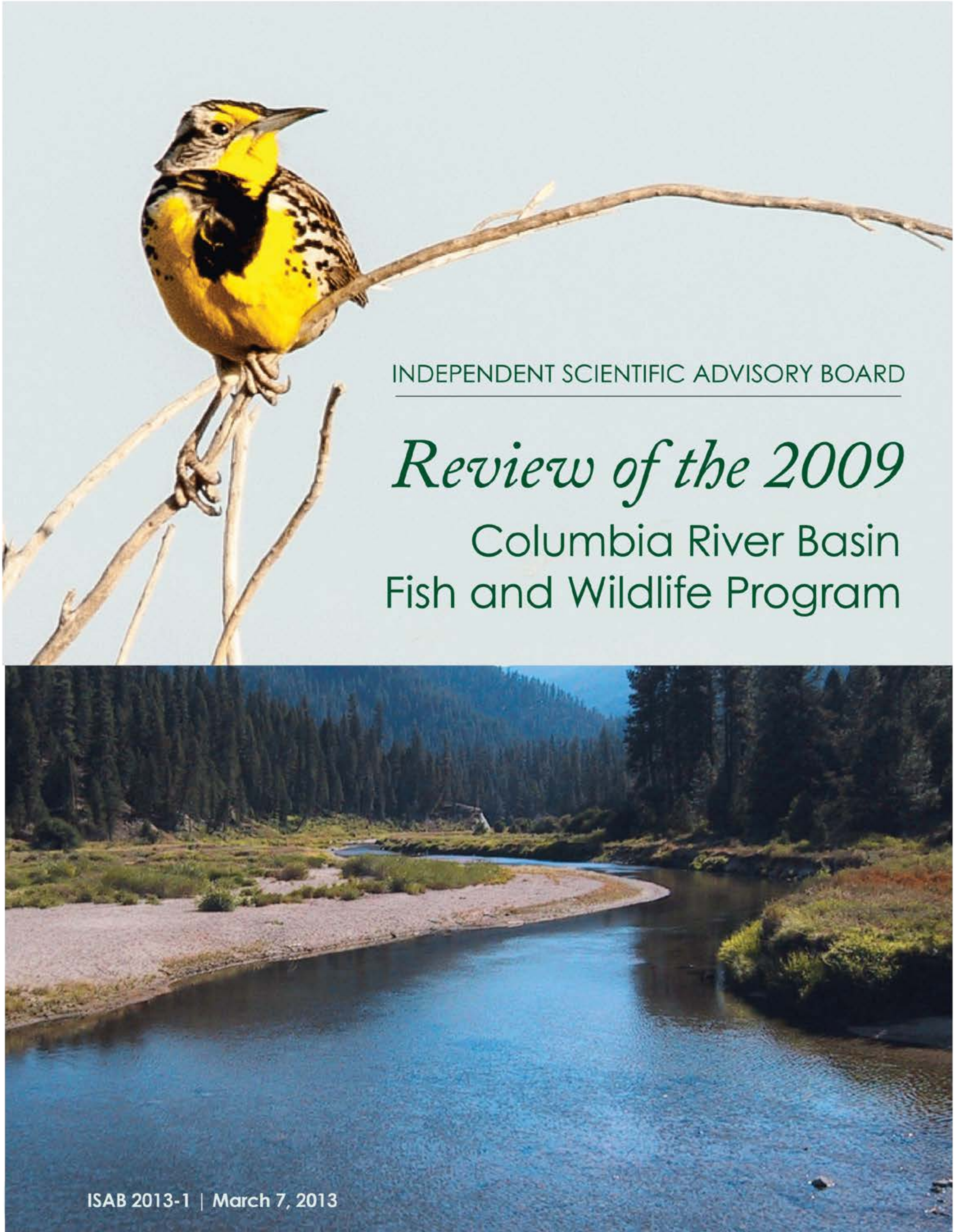
INDEPENDENT SCIENTIFIC ADVISORY BOARD

Review of the 2009 Columbia River Basin Fish and Wildlife Program



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Executive Summary

This report contains the evaluation by the Independent Scientific Advisory Board (ISAB) of the Northwest Power and Conservation Council's 2009 Columbia River Basin Fish and Wildlife Program (Program). In general, the ISAB finds the 2009 Program to have been a useful framework for providing context for the complex issues facing the altered Columbia River Basin ecosystem. In Part I, we revisit the conceptual foundation for the Program, focusing primarily on recommendations for updating the scientific principles based on advances in the sciences of landscape ecology and complex adaptive systems. In Part II, we examine progress in implementing the Program and in monitoring its outcomes; then we consider some major threats to future success and identify potential gaps in the current Program. In Part III, we discuss some general opportunities for improving the effectiveness of the Program.

Sustainability as a conceptual foundation

The concept of sustainability in ecology describes how biological systems remain diverse, robust, and productive over time. Sustainability can be enhanced by building ecosystem resilience and adaptability. Natural systems do not fluctuate within a fixed range of variability. What we have seen historically will not be a reliable indicator of the future, and we must seek to be more flexible and adaptable in our management responses. Uncertainty is inevitable and is an essential feature of resilience thinking, structured decision making, and adaptive management. Success is not a completed state, but a process requiring sustained monitoring, intentional learning, communication, and cooperation. Indeed, the Program amendment can be considered as the learning phase of the adaptive management cycle, and as an opportunity to benefit from 30 years of experience.

Threats to sustainability

In this review, the ISAB has identified major threats to the sustainability of the Columbia River ecosystem and to the success of the Program. This list includes loss of biological diversity, climate change (both directly and indirectly through linkages to the ocean ecosystem), proliferation of chemicals and contaminants within the Basin (including the estuary), the emergence of hybrid food webs due to the spread of non-native and artificially propagated species, and a failure to understand and respect the carrying capacity of the Columbia River ecosystem.

Biological diversity arises naturally within diverse landscapes and habitats, and it provides the redundancy and options for ecological innovation that contribute to resilience and adaptability in the face of environmental variability and change. The capacity to systematically monitor biological diversity at scales relevant to the Basin is limited. Moreover, relatively little effort is being directed at documenting trends in diversity or at understanding how actions implemented across the Basin affect diversity and the consequences of losing diversity. The ISAB recommends that the Program develop quantitative objectives for diversity and promote an active program of research to systematically collect information so that trends in biological diversity can be monitored and reported at the scale of the entire Basin.

Climate change predictions point toward changes in the timing and distribution of water flow, including extreme events such as floods and droughts. The concept of return periods of floods and droughts based on historical data may no longer be adequate for designing and planning for extreme events. Fisheries impacts due to warmer water temperatures include physiological effects such as lower growth rates that can result in higher predation, increased susceptibility to invasive and non-native species, and reduced cold water refuges. Ocean habitat suitable for salmonids in the

Gulf of Alaska is projected to be substantially reduced in extent by the 2080s, due to changes in temperature, salinity, and acidification. Given the importance of climate change to the success of the Program, the ISAB recommends that the amended Program promote development of a comprehensive strategic plan to explore strategies to cope with potential impacts of climate change throughout the Basin. Modeling and analyses are needed to provide guidance for flood control and hydropower operations to enhance ecosystem resilience and adaptability under climate change.

Artificial chemical proliferation in the Basin is a priority for resolution. In addition to contaminants of the past, there is a growing concern about emerging contaminants. The estuary and the coastal ocean communities are particularly vulnerable to the accumulation of contaminants because of their spatial position in the watershed. There is an urgent need to quantify and map the spatial patterns of these chemicals; assess their transfer, accumulation, and persistence; and document their impact on native organisms and on the carrying capacity of the Columbia River ecosystem for juvenile salmonids. The Council has an opportunity to take an active role – through cooperation with regional partners – to ensure that monitoring of toxic contaminants and evaluation of their effects on fish and wildlife are addressed.

Non-native species' spread is a major issue confronting the Program. Well-reasoned policies and procedures are needed to address the risk posed by non-native species, as well as native species spreading outside of their native ranges within the Basin. The Program could play a key role in fostering development of policies and effective methods for monitoring and controlling the spread of these species.

The limitation of the **carrying capacity** for juvenile salmonids is an urgent and specific priority for research, management, and restoration activities in the Basin. It is not clear whether the Columbia River can provide sufficient food in the long term to support the large populations of artificially propagated fishes produced today, as well as natural salmonids and other organisms. The concept of carrying capacity for target species in the Basin must ultimately constrain Program objectives related to the abundance and productivity of those species. The amended Program should explicitly address carrying capacity for juvenile salmonids when integrating and prioritizing plans for hatchery production and habitat restoration. The ISAB also sees a need to conduct empirical investigations and to develop bioenergetic models to estimate trophic demands on food supplies by native and non-native competitors of juvenile salmonids.

Artificial production, used to mitigate for lost harvest opportunities, must be reconciled with the objectives of ESA recovery and threats such production poses to the restoration of healthy natural populations. Implementation of artificial production must consider scientific insights about the need to maintain the diversity of heterogeneous populations and habitats that confer resilience. Hatchery fish provide important benefits to some of the Basin's stakeholders and populations, but the trade-off in costs to natural production and other environmental consequences remain poorly understood. The ISAB recommends that the artificial strategies be revised to incorporate conclusions from the Hatchery Scientific Review Group's review and that supplementation, harvest, and habitat restoration programs must be well integrated to be effective.

Harvest plans need to be scientifically justified and consistent with subbasin and other plans that establish viability parameters for salmon and steelhead populations. It is not clear whether harvest management plans have been scientifically reviewed and analyzed to assess compatibility with the Program. If not, an independent scientific review should be encouraged. The amended Program should also promote development of capability to monitor hatchery and natural-origin fish separately so that the productivity and abundance of the naturally-reproducing stock can be tracked and used to develop escapement goals and harvest rates.

Key advice on moving forward

Three fundamental issues warrant reconsideration in amending the Program. First, it would be timely for the Council and region to re-evaluate the scientific foundation in light of accomplishments of the Program during the past 30 years. A review of the Program's foundation might lead to reassessment of the long-term objectives and the strategies to achieve those objectives. Second, there is a need to move away from qualitative goals toward quantitative objectives with specified timelines. Third, there is a need for increased socioeconomic engagement as part of a landscape approach. The current Program is intended to be habitat-based but in reality, relies heavily on artificial production; the amended Program should be ecosystem-based and fully acknowledge social aspects of the Program that can contribute to its success.

The ISAB believes that the **scientific foundation** should be modified to more explicitly consider the basis of resilience and adaptability, and to include additional emphasis on the landscape approach to fish and wildlife management (ISAB 2011-1, 2011-4). Accordingly, the ISAB proposes six revised principles based on recent advances in scientific knowledge about the nature of ecosystems. These new principles are intended to replace the original eight principles, but they retain most of the original content.

Establishing **quantitative performance goals** both for the biological objectives and restoration strategies is an essential feature of adaptive management and provides measurable thresholds for determining success. True objectives are focused and measurable benchmarks whereas many of the "objectives" identified in the 2009 Program express general intentions as unquantified goals or strategies to achieve goals. The amended Program should include quantitative biological objectives that can be regularly monitored and evaluated as a means to determine whether the Program is on target or in need of change.

Social aspects of the Program should include stronger efforts to foster leadership and to build the structures that provide governance needed for broad collaboration and effective integration across science-management disciplines and social, political, and ecological boundaries. The revised Program should recommit to regional partnerships and explore similar ideas to strengthen regional coordination efforts, and share information and learning among projects with common settings or issues. The Program should be amended to describe techniques for engaging broader public involvement and to explain how socioeconomic engagement will be measured and monitored.

A **primary conclusion** of this review is that continuing to implement the Program on its existing trajectory is highly uncertain to achieve the Council's biological objectives for the Basin. The ISAB suggests a revised focus on sustainability with strategies to protect diversity and resilience, and to build adaptability. The ISAB is concerned that artificial propagation is a risky foundation for restoration, and that adaptive management, long considered an integral component of the Program, has not been conducted in the manner originally envisioned. A landscape perspective, drawing from broader community involvement, could help build consensus on Program objectives and strategies, or if this is not possible, it could at least help to create strategies that keep options open, consistent with a diversity of visions for the future. The ISAB recommends that Council decisions be guided by the precautionary principle and structured decision making, within an adaptive management cycle.

I. Fish and Wildlife Program Amendment as Adaptive Management

1. Introduction and Review Process

A primary responsibility of the Independent Scientific Advisory Board (ISAB) is to evaluate the Northwest Power and Conservation Council's Columbia River Basin Fish and Wildlife Program (Program) on its scientific merits in time to inform amendments to the Program and before the Council requests recommendations from the region. This report contains the ISAB's scientific evaluation of the 2009 Program and is intended to help guide the region as it develops recommendations and the Council as it frames the amended Program. The Council's amendment process is scheduled to begin in April or May 2013.

The ISAB began this review in October 2012, and the content and approach of the review was shaped by the five months available to complete the review before the amendment process formally begins. This review focuses on the scientific concepts and language in the 2009 Program and although the review explores the implementation of the 2009 Program on a number of issues, a comprehensive evaluation of the Program's implementation was not feasible given the time available. The ISAB believes that such an additional evaluation of whether the combined projects are leading to success would be useful, even though the ISRP and Council have reviewed all projects implemented under the Program.

The revised Program should include the Council's review and evaluation of accomplishments to date and resulting decisions on how best keep the Program moving forward. That is, a summary of actions or strategies that have been implemented should be presented in the revised plan, or at least reference what has been accomplished so far in relation to the Program objectives. The amended Program should identify strategies and actions that have not been implemented.

Many past ISAB and ISRP reviews informed the development of the current 2009 Program, but several comprehensive ISAB and ISRP reviews were completed after the last Program amendment, for example, the ISAB's Food Web (ISAB 2011-1) and Landscape-Scale Restoration (ISAB 2011-4) reports and the ISRP Category and Retrospective reports (for example, ISRP 2011-25). Also in recent years, fish and wildlife project sponsors have developed comprehensive summaries of emerging Program areas such as for the ocean, estuary, and lamprey. These recent reports were very informative for this ISAB review.

The Council staff briefed the ISAB on the amendment process, the United States and Canada Columbia River Treaty, the framework process, subbasin planning, and the wildlife section and other aspects of the 2009 Program. The Hatchery Scientific Review Group presented a summary of their review of artificial production in the Columbia River Basin. Several ISAB members attended CRITFC's informative Future of Our Salmon Conference, which examined the science behind hatchery policy. Finally, briefings by the Bonneville Power Administration and NOAA Fisheries on monitoring and evaluating the effectiveness of habitat restoration actions were very useful.

2. Defining Success

Considerable progress has been achieved in understanding what makes restoration efforts successful (e.g., Bernhardt et al. 2005, Palmer et al. 2005, Palmer and Filoso 2009). Many people in the Basin are now well-versed in the science, politics, and industries associated with resource management and habitat restoration. The Tribes have long espoused the need to live in a manner that preserves options and resources for the future (Campbell and Butler 2010). However, the people of the Basin are still working toward a common landscape perspective (ISAB 2011-4), and leadership is needed to develop shared ethics and realistic visions that will promote a sustainable future. A grand challenge for the Council in amending the Program is to provide this leadership.

Recent ISAB reports and publications (e.g., Williams 2006, ISAB 2007-2, ISAB 2007-3, ISAB 2008-4, ISAB 2011-1, ISAB 2011-4, Naiman et al. 2012) point to a future for the Basin that lies outside the bounds of previous experience. Will the strategies and actions forged in recent decades be fully effective going forward? The answer is uncertain. There are, however, ways to prepare for an uncertain future, and to improve the possibilities for positive outcomes by integrating local decisions and actions with the Basinwide vision, objectives, and strategies (ISAB 2011-4). To achieve success, it is necessary to recognize that:

1. Success is a process requiring communication and cooperation, not a state of completion. "*There is no such thing as an optimal state of a dynamic system*" (Walker and Salt 2006)
2. Change is continual: sustained monitoring and active learning will always be required
3. Early and extensive public engagement is needed at all scales of social organization (e.g., homeowners, counties, sub-basins, and larger spatial scales)
4. Sustainability requires the diffusion and adoption of innovative ideas and broad ecological perspectives and adaptability to unexpected changes
5. Socioeconomic and ecological issues must be addressed simultaneously within an integrated approach, keeping in mind that the Basin's natural environments ultimately sustain the economic and personal well-being of its people.

Successful implementation of the Program will require continual learning and adaptation. Indeed, the 2009 Program states (p. 3) that "*decision points should be informed by adaptive management during Program amendment processes and during Program implementation.*" The process of Adaptive Management[1] needs to be practiced in the manner it was originally intended – to improve management actions through intentional learning. The amendment process can be considered as the learning phase of the adaptive management cycle and as an opportunity to benefit from 30 years of experience (NPCC 2009-9).

Accordingly, this review by the ISAB is also structured to follow the adaptive management cycle. In Part I, we revisit the conceptual foundation for the Program, focusing primarily on recommendations for updating the scientific principles based on advances in the sciences of landscape ecology and complex adaptive systems. In Part II, we examine progress in implementing

[1] Adaptive management is defined in NPCC 2009-09 (Appendix A, p. 70): "*A scientific policy that seeks to improve management of biological resources, particularly in areas of scientific uncertainty, by viewing Fish and Wildlife Program actions (projects) as vehicles for learning. Projects that implement the Program are designed and implemented as experiments so that even if they fail, they provide useful information for future actions. Monitoring and evaluation are emphasized so that the interaction of different elements of the system is better understood.*"

the Program and in monitoring its outcomes; then we consider some major threats to future success, and identify potential gaps in the current Program. In Part III, we discuss more general opportunities for improving the effectiveness of the Program.

3. The Program Vision and Sustainability as its Conceptual Foundation

The vision of the 2009 Program (NPCC 2009-09) is to recover an ecosystem that can sustain much of the historical abundance, productivity, and diversity of fish and wildlife, including abundant opportunities for harvest, while satisfying requirements for electrical power from the hydrosystem. The vision is to be achieved wherever feasible, by protecting and restoring natural ecological functions, habitats, and biological diversity. Recognizing that these natural processes may not be sufficient or feasible, the use of non-natural methods such as artificial propagation and non-native species are also permitted as less preferred options. This vision has merit in being comprehensive and ambitious, as well as flexible, depending on the interpretation of "abundance" and "feasible." It is worth noting that the goal of "abundant opportunities" for harvest sets expectations for ecosystem benefits and largely determines whether the fish and wildlife community can possibly be "abundant, productive, and diverse" enough for the vision to be achievable and sustainable.

The Program framework includes a scientific foundation with eight principles to help identify strategies and actions that will be effective in achieving the vision and biological objectives of the Program. The ISAB recognizes that the vision and biological objectives properly reflect cultural values and aspirations whereas the scientific principles summarize current scientific knowledge about the nature of the Columbia River ecosystem. However, the scientific principles warn that the Basin's capacity to produce sustainable benefits will ultimately constrain the potential to achieve the Program's vision and biological objectives. Accordingly, the ISAB recommends that the vision and biological objectives be examined for consistency with the scientific principles.

Since 2000, scientific principles in the Program, and related discussions in the Columbia River Basin Research Plan (NPCC 2006-3), have focused on constraints of the ecosystem and emphasized that restoration of salmonids in the Columbia River must address the entire ecosystem: that salmonid productivity requires a network of habitats that are created, altered, and maintained by dynamic natural processes; and that the ability of salmonids to cope with environmental variation depends on their genetic, life history, and population diversity (Lichatowich and Williams 2009). This theme of moving toward protecting diversity to enhance sustainability is extended in recent reports by the ISAB (ISAB 2011- 1, ISAB 2011-4, Naiman et al. 2012) and in our present proposal to update the scientific principles.

The ISAB is concerned that the vision and objectives do not adequately consider uncertainty about the limits to food webs and fish and wildlife productivity in the Columbia River ecosystem or consider the risk of losing ecosystem resilience (capacity to absorb and adapt to disturbance and change while maintaining essential functions) in the face of increasing threats from human population growth (ISAB 2007-3), climate change (ISAB 2007-2), and non-native species (ISAB 2008-4). For example, the vision seems to imply that abundant opportunities for harvest could be created and sustained by non-natural methods including artificial propagation to supplement natural reproduction. The ISAB is concerned that this option might be pursued uniformly throughout the Columbia River Basin without respecting scientific insights about the need to maintain the diversity of heterogeneous populations and habitats that confer resilience.

__**ISAB recommendation regarding vision and biological objectives**__

1) The Program vision and biological objectives should be consistent with the scientific principles.

4. Updating the Scientific Principles for Sustainability

The 2009 Program charges the ISAB with the "*primary role in reviewing and recommending modifications to the scientific principles.*" The ISAB recommends that the scientific principles be updated to reflect recent advances in scientific knowledge about the nature of ecosystems, which vary in their sustainability and degree of human influence. The eight existing scientific principles were first introduced in 2000 and remain sound. However, consistent with its recent reports, the ISAB believes that the scientific foundation needs to include additional emphasis on the landscape approach to fish and wildlife management. The principles should be modified to more explicitly consider the basis of resilience and adaptability, and to recognize the role of socioeconomic engagement.

The following six revised principles are proposed to broaden the scientific foundation for the Program. These new principles are intended to replace the original eight principles while retaining most of the original content. They are structured to express the theme that sustainability can be enhanced in two ways: first, by building resilience to reduce the probability that an ecosystem will cross a "tipping point" and shift into a new regime; and second, by building adaptability to improve outcomes when such regime shifts do occur. The latter concern is especially relevant in the Columbia River Basin in the face of climate change, human population growth, proliferation of chemicals, hydrosystem development, and the emergence of hybrid food webs due to the spread of non-native and artificially propagated species.

ISAB recommendations for scientific principles

__Principles to enhance resilience__

Principle 1: The abundance, productivity, diversity, and spatial distribution of organisms are sustained by complex and adaptive ecosystems.

Physical and biological components of ecosystems act synergistically to produce the abundance, productivity, and diversity of plant and animal communities. Ecosystems are usefully described as complex hierarchies of nested components distinguished by scales of space and time. Higher-level ecological patterns and processes constrain, and in turn reflect, localized patterns and processes. Ecosystems are also adaptive systems in that they develop over time in response to dynamic internal and external factors. The system we see today is the product of its geological, biological, and human legacy. Natural disturbance and change are normal ecological processes which create, alter, and maintain ecosystems. Management actions to maintain ecosystem services are most effective when undertaken with an understanding and appreciation of the natural limits and underlying structure and function of the ecosystem, and the dominant forces being imposed on the ecosystem.

Principle 2: Biological diversity allows ecosystems to persist in the face of environmental variability.

The diversity of species, populations, genes, and life history traits within biological communities contributes to ecological stability in the face of disturbance and environmental variability by providing a greater range of options to absorb, or respond to change. Populations are the basic units of abundance, productivity, and diversity. Each population has a distinct role that contributes to the structure, productivity, and sustainability of the ecosystem over time. A population that is genetically adapted to its local conditions is more productive in that habitat than would be other populations of the species not adapted to those conditions. Populations with different adaptations are also likely to have distinct responses to changing environmental conditions, such that productivity increases for some and decreases for others. This diversity of responses generally reduces temporal variability in productivity summed across all populations in the landscape (the "portfolio effect"). Loss of locally adapted populations through extirpation or introgression with non-adapted sources lessens phenotypic and life history diversity, overall productivity, and ecological resilience. Introduction of non-native species can increase diversity but disrupt stabilizing ecological interactions that have co-evolved among native species. Management actions are most meaningful when they contribute to long-term maintenance of the diversity of locally-adapted populations of native species and of all the habitats needed to support their full life cycles.

Principle 3: Human health and well-being are tied to ecosystem conditions.
As humans, we often view ourselves as separate and distinct from the natural world. However, we are integral parts of ecosystems. Our actions have a pervasive impact on the structure, function, and resilience of ecosystems, while at the same time, our health and well-being are tied to ecosystem conditions. In the face of such widespread human impacts, a landscape perspective is needed to protect ecosystem processes and guide the restoration of fish and wildlife. A landscape perspective enhances resilience because it protects redundancy and diversity to maintain options, it avoids management that limits ecological variability, and it embraces adaptive management to foster innovation through learning and experimentation. Maintaining redundancy and diversity in landscapes comes at a cost, but that cost must be balanced against the benefits of resilience to unexpected perturbations from human actions.

Principles to enhance adaptability[2]

Principle 4: Biological and cultural diversity provide the raw material for reorganization and adaptability during unexpected transitions to new ecosystem regimes.
Regime shifts have now been observed in hundreds of different ecosystems, including marine, freshwater, and terrestrial ones. Adaptability is the capacity of actors in a system (fish, wildlife, people) to avoid crossing into an undesirable regime or to succeed in crossing into a desirable one. For people, this capacity requires weighing options, keeping options open, and creating new options when old ones close. Once an ecosystem's resilience has been overwhelmed, what matters is the system's transformative capacity to reorganize in ways that will minimize loss and restore beneficial conditions and services. Basic elements critical to adaptability include the biological diversity of fish and wildlife species represented by genes, populations, and species, and the cultural diversity of people and communities represented by learned behaviors, ideas, values, and institutions.

Principle 5: Ecosystem management is adaptive and experimental.
The complexity of ecosystems routinely disables attempts to command and control them. We must seek to be more flexible and adaptable in our management responses to a world in which change occurs continuously and unpredictably. Because our knowledge is limited, the only practical response is one of discussion, modeling, experimentation, and learning. Structured decision making (SDM) combined with adaptive management — the intentional use of experiments to investigate ecological problems and to iteratively test and revise management programs — improves problem solving by clearly articulating current understanding, acknowledging uncertainty and risk, and by

[2] These principles are based in part on text from Walker and Salt (2006), Harris (2007), and Gunderson et al. (2010).

promoting continuous learning and adaptation. Experimental management does not simply mean passive learning by doing but rather deliberate intervening directed at understanding key ecosystem dynamics and creating new knowledge through scientific experimentation and inquiry.

Principle 6: Socioeconomic understanding and engagement is required to make management actions more sustainable.

Effective management actions follow from the cultural values and incentives of people who live in the landscape, who use its land, water, or living resources, or who are concerned about sustaining its habitats and fish and wildlife populations. Societal knowledge is filtered by values to create intentions that may become actions. People respond better to positive incentives than disincentives. Collaboration and partnerships can increase the effectiveness and efficiency of actions. Aligning policies with the appropriate level of governance can also improve effectiveness, recognizing that local actions can affect socioeconomic outcomes at regional, national, or international scales. Developing mechanisms and networks for the communication, sharing, and review of new knowledge can enhance the diffusion and adoption of innovative actions.

II. Current Status of the Fish and Wildlife Program

1. Monitoring, Evaluation and Research

A. Uncertainty and Levels of Evidence

Goodman et al. (2002) state "… *although we can strive constantly to improve understanding, many of the systems we seek to manage need to be treated as knowable only within quite wide bounds, and that management needs to take uncertainty (imperfect knowledge) into account."* Such advice is more critical than ever as it becomes more and more evident that natural systems do not fluctuate within a fixed range of variability and that stationarity is a fallacy (Milly et al. 2008). When future *variability* is unpredictable, a key challenge is to identify thresholds or tipping points and to recognize the risk of shifting into new regimes. What we have seen historically will not be a reliable indicator of the future. Adaptability is needed to adjust options and to manage in an uncertain environment (Rogers et al. 2013).

The 2009 Program poses an interesting question with regard to the level of confidence needed in monitoring and evaluation (M&E) design, and how that level should depend on the size and scope of evaluation. The amount of monitoring required depends on the variability of the attribute being measured, the size of biological differences that need to be detected, and the acceptable risk of Type I and Type II errors (considering both probability and consequence). Type II error often has greater consequences for protecting the environment and its functions in natural systems where variability is high. Increasing statistical power to detect biologically important effects (reducing the probability of Type II error) by accepting a higher level of Type I error to 10 or even 20% should be considered.

Traditional hypothesis testing, with its associated Type I and Type II errors, is only one of the tools that could be used to deal with uncertainty and levels of evidence. An alternative approach is to estimate parameters and show their variability with confidence intervals. For example, parameters of interest might include survival via different routes of hydrosystem passage, adult and juvenile abundance, or abundance and survival after different restoration strategies. To inform management and policy decisions, one can compare the estimated magnitude of the biological parameter, along with its estimated uncertainty, to the level that is considered biologically meaningful.

Model uncertainty and methods to choose one model in preference to another also deserve more examination. Models are simplifications of reality and their output is uncertain due to uncertainties in input data, errors due to model structure, and errors due to model processes (Oreskes et al. 1994, Katz 2002). It is important that these uncertainties be acknowledged and considered in choosing and applying models, and that the impacts of uncertainty be discussed when interpreting model outputs.

<u>ISAB recommendations for addressing uncertainty and levels of evidence</u>

1. **Require all project proposals to acknowledge uncertainty.** Proposals should describe areas of uncertainty and what will be done to deal with the uncertainties. Consideration of uncertainty is essential for effective adaptive management and structured decision making.

2. **Recognize that uncertainty is inevitable and encourage efforts to enhance resilience.** The importance of resilience and enhancement strategies are included elsewhere in this review.

B. Monitoring Strategies to Measure Success

Monitoring plays a crucial role in making less tractable problems more tractable (Goodman et al. 2002). Monitoring and evaluation in the Basin has improved (ISRP 2011-25), but to evaluate program effectiveness, a more comprehensive analysis of progress toward achieving biological objectives for hatchery and habitat efforts is needed. Management strategies should be evaluated within a structured decision approach that combines habitat, hatchery, hydrosystem fish passage, and full life-stage recruitment information. Additional dialogue should be encouraged among habitat managers, scientists, and policy makers so that realistic timeframes can be established to evaluate success.

Further consideration of the Program's monitoring, evaluation, and research reporting (MERR), high level indicators (HLIs), and science-policy exchanges were encouraged in the 2009 Program to focus efforts on performance, reporting of results, accountability, and adaptive management. Discussions continue about how to improve the management and availability of data. An internet web site (MonitoringMethods.org) has been created for meta-data on protocols and to encourage consistency, but it is not clear that MonitoringMethods.org provides a completely satisfactory forum for the presentation and development of monitoring protocols. It is essential to present in clear language a general approach for monitoring, including the kind of framework being developed, where types or categories of projects may be monitored to indicate expected benefits, and where monitoring is needed and where it is not. The type of monitoring required for Program-sponsored activities should be clearly indicated, for example, monitoring of task completion, trend monitoring, statistical monitoring based on probabalistic selection of study sites to allow statistical inferences, or effectiveness monitoring to establish causal links between management actions and biological responses (McDonald et al. 2006).

Computer modeling could be a useful tool for addressing issues related to monitoring, evaluation and research. Specific models are mentioned in a few places in the 2009 Program but comprehensive models are not mentioned explicitly. Modeling can extend and enhance monitoring as well as reveal monitoring gaps because an underlying conceptual model is needed to explain what is being modeled and to clarify assumptions. Goodman et al. (2002) discuss the kinds of models that can be used to represent ecosystem processes. Use of information criteria for model selection and model averaging should be encouraged as modeling strategies. The Program could go further to suggest some guidelines for ways to coordinate modeling that would provide more consistency between modeling efforts, and to note datasets that are available and useful for modeling.

Progress has been made in standardizing evaluations of the effectiveness of habitat restoration. The standards for monitoring in the 2009 Program include appropriate criteria but inadequacies in some past monitoring efforts suggest that revisions may be needed. Standardization of monitoring is needed but should be applied judiciously because advances in physical and chemical measurements and analytical technology will render some approaches to monitoring obsolete. Monitoring protocols must be open to new, more efficient techniques to acknowledge the great strides that are being made worldwide in freely available, automated, low-cost monitoring (Biggs and Rogers 2003). The Council should view habitat action-effectiveness M&E as a work in progress. Consistency is needed to enable broad regional syntheses of status and trends, but a single standardized habitat monitoring approach may not be achievable or desirable. Given that a diverse set of agencies and investigators are measuring a very diverse set of systems, perhaps the goal should be to require collection of a minimum set of data for specific types of projects (e.g., smolt-to-adult return rate

(SAR) for anadromous and migratory fish, basinwide abundance estimates for resident fish, kilometers of habitat restored for habitat projects, etc.), using reasonably standard protocols, while allowing investigators to pursue other information that they deem appropriate. Likewise, advice gained by investigators when presenting research results to the ISRP is likely to be important for improving quality of research and monitoring.

The Program needs to specify the data required for High Level Indicators (HLIs) that will be routinely monitored, updated, and presented to stakeholders; data requirements need to be communicated to those collecting the data to make sure that HLIs can be computed. The ISAB recently identified possible HLIs related to diversity and offered recommendations for moving forward with development of HLIs (ISAB 2012-2). Elsewhere in this review, we emphasize the need for HLIs to demonstrate progress toward specified objectives (II.1.C. Information Sharing, II.2.A Biological Diversity).

Monitoring diversity is an issue to be stressed (ISAB 2012-2). Efficient tools for monitoring comprehensive measures of biological diversity and foodweb status appear to be emerging rapidly. The current Research Plan (NPCC 2006) includes strong support for such research, but it appears that little has been done. Perhaps such research could be strengthened through specific requests for proposals (RFPs) or other mechanisms.

Another important research strategy is to encourage agencies and tribes to reach out to find the expertise needed for efficient and effective projects. If the expertise is not found in-house, then it should be recruited externally. This point has arisen in numerous ISRP and ISAB reviews. In addition support for programs such as extension service, collaboration and communities of practice, science forums, and other incentives to provide technical support and capacity building could be used to enhance research in the region (ISAB 2011-4).

ISAB reccommendations for monitoring strategies

1. **Support development and evaluation of HLIs**.

2. **Implement monitoring to evaluate progress against new quantitative objectives** as recommended elsewhere in this review, for example diversity performance, artificial production programs, and habitat restoration benefits.

3. **Implement social monitoring to better evaluate and improve acceptance of the Program at local scales in the region**, for example, by regular surveying of public opinion about progress and strategies for achieving the vision.

4. **Design monitoring to support adaptive management and structured decision making by providing data to test current knowledge and revise management programs**.

C. Information Sharing

The Pacific Northwest Electric Power Planning and Conservation Act of 1980 (Act) directs the Council to ensure widespread public involvement in the formulation of regional power and fish and wildlife policies. For this directive to be effective, a strong focus on information sharing is required.

Information sharing occurs at all educational, intellectual, and professional levels (e.g., K-12, city and county leaders, landowners, project team members, Council members and staff), and is essential for building adaptability and for developing a common vision among Columbia River Basin stakeholders for the Program. Three main components of information sharing are access to data, education and training, and effective communication. All are essential for successful restoration. Further, in order to be effective, information sharing must be continuous and convey consistent and factual messages.

Access to data

General access to data, as well as information, remains problematic. Despite continuing efforts to improve data availability and sharing through emerging monitoring programs (e.g., Fish Passage Center: www.fpc.org; Data Access in Real Time-DART: www.cbr.washington.edu/dart; Pacific Northwest Aquatic Monitoring Partnership – PNAMP; www.pnamp.org), more effort is needed to develop capabilities to routinely share relevant data and to formalize basinwide analyses. Data do not become information or knowledge without appropriate analyses, and often analyses require specific kinds of data. Indeed, adaptive management is a formal process for establishing beforehand that adequate capacities for data collection and analytical evaluation will be in place when management interventions are initiated.

Information sharing within the Program should also reflect its ecosystem scale. A strong and continued coupling between biophysical and socioeconomic knowledge brings understanding and engagement on social and economic issues, making effective management and restoration possible. For example, it is broadly recognized that effective restoration requires integrated monitoring of physical, biological, and socioeconomic processes, including data that reflect cultural diversity and well-being. Inclusion of data on people, cultures, and economies with the more conventionally considered elements of landscape and biota helps underpin success (Naiman 1992, Rogers 2006, Susskind et al. 2010, ISAB 2011-4, Kareiva and Marvier 2012).

Education and training

Education and training should match the diversity of people, cultures, and skills in the Basin. Workshops, like the semi-regular policy-science exchanges sponsored by the Council, are effective but they do not harness the full potential of educational activities. Additional opportunities for educating and training public and professional participants in the Program could be created by activities such as citizen science programs, training workshops on specific topics, meetings of engineering groups, and other venues to celebrate rivers, fish, and wildlife that include conservation groups, fish and wildlife clubs, or commercial fish organizations. Education and training enhance the adaptability of the Basin's people by helping to build a common vision for restoration and by establishing responsibility for execution of restoration activities.

Citizen science has several important benefits. First, citizen labor can provide more data from more locations at more times. Citizen engagement can also expand the ability to monitor on private property by enabling cooperation from private landowners. Citizen data can provide a large-scale, on-the-ground view to complement data obtained through remote sensing. Citizens also gain experience from participating in monitoring activities, such as mapping habitat characteristics and conditions, or learning the rationale behind the protocols. They come to better understand the reasons for data gathering, how data are gathered, procedures for getting quality data, and they learn something about ecological processes from the observations. Most importantly, citizens become engaged and informed in the discussion, knowledgeable about the issues, and interested in the outcome. In effect, they gain more knowledge to participate in decision making and to ask valuable questions (Buck et al. 2001, Curtis et al. 2002) and are empowered to assume an appropriate level of responsibility to improve the effectiveness of the Program. Citizen science serves as an example of what can be accomplished educationally by working with partners, and without a large budgetary cost (ISAB 2011-4).

Public communication

The ultimate goal of sharing information is to develop a common vision for the future of the Basin and to engage the public – at all levels – to shoulder responsibility and to participate in the discussion of possible solutions. Strong monitoring and communication programs that provide consistent feedback are fundamental for building adaptability. That said, the means by which information is communicated are changing rapidly with the advent of social media sites and the ability to quickly and easily search for and map information. The Council now has an opportunity to engage the public, Tribes, NGOs and agencies by embracing a diverse suite of communication media and exploiting communication tools to their full potential.

The audience dictates how information is best communicated and what format will be most easily understood. Most audiences cannot easily grasp complex scientific and technical information and prefer simple, direct graphics that inform central issues of public or scientific concern, like trends in space and time. Visual graphics are only one form of information sharing; music, theater, and storytelling can also be effective.

ISAB recommendations for information sharing

1. **Accelerate efforts to improve data availability and sharing through emerging monitoring programs to ensure that these tasks are completed in next two to three years and that data access and sharing become functional.** Further, the ISAB or another group should be directed to identify additional basic data that should be acquired and shared, for example, measures of genetic diversity.

2. **Initiate and support a comprehensive citizen science program.** Identify citizen science programs that already exist in the Basin. Promote a comprehensive citizen science program by starting in a few selected subbasins with existing programs with a view to expand these programs to all parts of the Basin within in a few years and linking them to the appropriate agencies and Tribes. Partnerships and mechanisms to guide new efforts can be encouraged through funding or broad recognition.

3. **Organize and support "communities of practice" and support technology transfer and education (e.g., workshops) on issues of importance to the ecological province.** Collaboration at the ecological province scale is essential for effective restoration.

4. **Use HLIs and information from other monitoring programs to engage the public and develop a common Program vision.** Conduct regular press and other briefings; use fact sheets and

message boxes to define the issues. Use of “mobile apps” is one example of effective information sharing.

5. **Convert ISAB, ISRP, and Council reports into short documents, briefings, and other forms of information sharing that can be broadly understood and appreciated by a diverse public.**

2. Threats to Sustainability

A. Loss of Biological Diversity

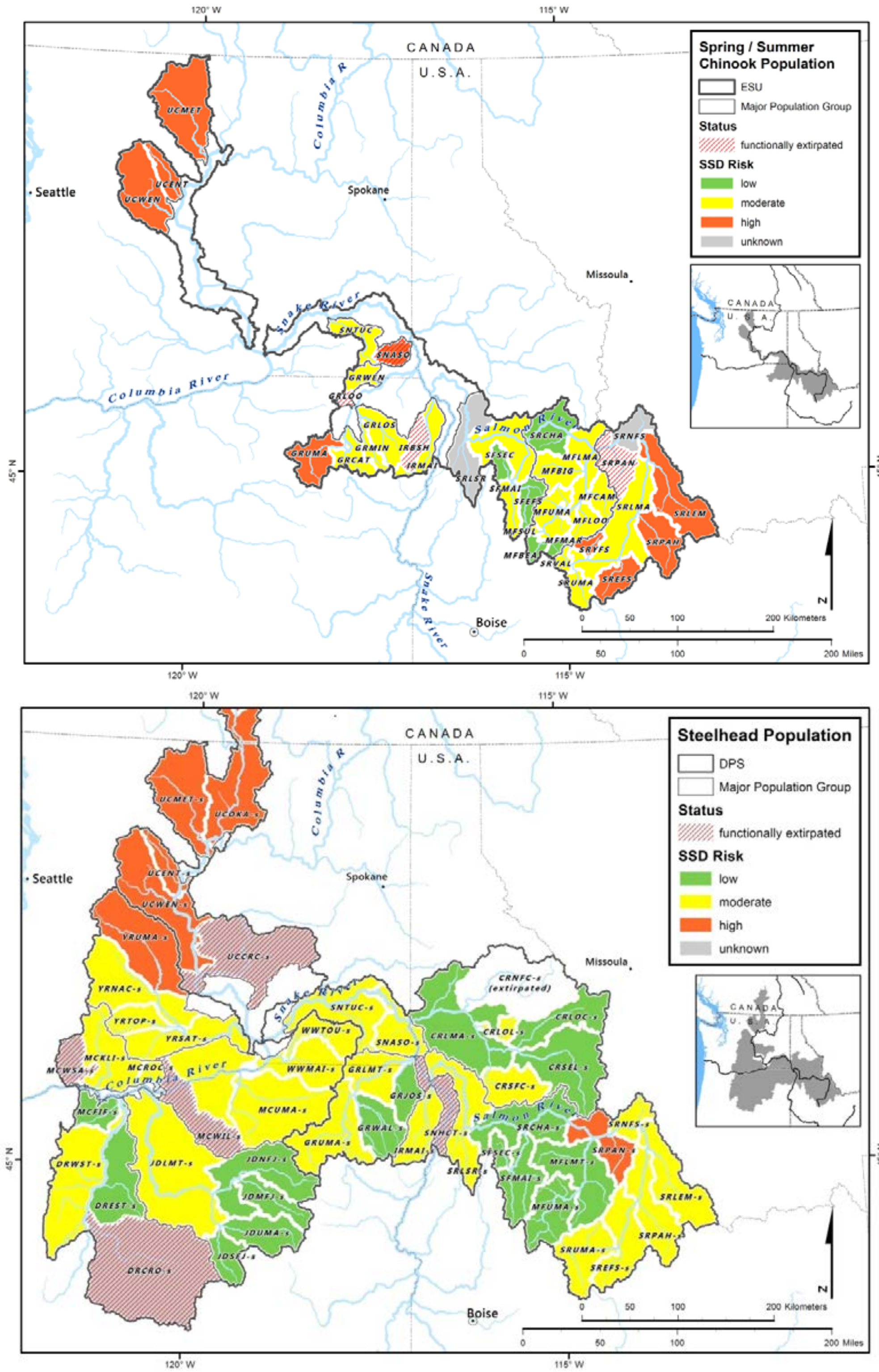
As emphasized in the scientific principles recommended in section I.4, biological diversity arises naturally within diverse landscapes and habitats, and it contributes to resilience and adaptability in the face of environmental variability and change. The value of diversity has been recognized in the Program vision and other discussions since 1994, but the capacity to systematically monitor biological diversity at scales relevant to the Columbia Basin still does not exist. We know that native diversity has been lost within the Basin and in nearby systems based on a handful of comprehensive studies (e.g., Lee et al. 1997, Burke 2004, Bottom et al. 2005, Gustafson et al. 2007, McClure et al. 2008) and from extrapolation of other studies at finer scales (Isaak et al. 2003, Moore et al. 2010). These studies provide important insights, but the fact remains that baseline information on native diversity is limited. Moreover, relatively little effort is being directed at documenting trends in diversity or at understanding how actions implemented across the Basin affect diversity and the consequences of losing diversity. Technical and analytical capacities to document trends in diversity are expanding quickly (e.g., Miller et al. 2011, Campbell et al. 2012), and efforts are being made to develop and monitor “essential biodiversity variables” at regional, national, and global scales (Pereira et al. 2013). It is time to begin systematic collection of the information that is needed in the Columbia Basin.

Potential first steps

The Council has asked the ISAB for guidance in choosing appropriate High Level Indicators (HLIs) for monitoring and discussion of diversity to help meet the fish and wildlife objectives for the Basin (ISAB 2012-2). Unfortunately, it is not a simple task to create such indices because relevant information is often unavailable or inadequately summarized. Current monitoring provides much information on abundance and survival of juveniles and adults (e.g., CBFWA 2011 Status Report), but it does not quantify species, genetic, or phenotypic diversity at scales or in ways that provide a basinwide picture of diversity. Moreover, the broader concepts of ecological and social diversity have yet to be considered in detail.

The ISAB (ISAB 2012-2) suggested that a possible place to start is with information synthesized in the five-year status reviews for salmon recovery (Ford et al. 2010). Viability risk characterized for individual populations include measures of diversity and spatial structure across populations and broader recovery units. Summaries of the number or proportion of populations at risk over all criteria, or at risk specifically based on diversity and spatial structure criteria, could be used to portray trends in diversity across watersheds, subbasins, recovery units, or even the entire Basin (Fig. II.3.A.1).

Figure II.3.A.1. Spatial structure and diversity ratings by population for spring/summer Chinook salmon (top frame) and steelhead (bottom frame) as assessed by the Interior Columbia Technical Recovery Team. (Source: Tom Cooney, personal communication, based on data available from: http://www.nwfsc.noaa.gov/assets/25/7962_01312012_150050_SRUpdateSal&SteelheadTM113WebFinal.pdf)



Development of new capacity and knowledge
Existing work and rapidly expanding technologies can provide an important foundation for new capacity and knowledge. Recent work exploring salmonid life history patterns in the estuary, for example, might be extended to track changes in the representation of life histories in response to hatchery reform and habitat actions across the entire Basin. The infrastructure used to monitor juvenile outmigration and adult returns provides data on spatial and temporal patterns in migration, and on the size, age, and origin of migrants. Those data might be analyzed to define useful measures of life history expression in the river. Analytical capacity to survey genetic markers and to develop baselines of genetic structure and variability has expanded dramatically in recent years making it possible to consider both the diversity and representation of populations across the entire system (Campbell et al. 2012). Efforts to refine habitat monitoring through both traditional and remotely sensed data collection hold promise for a broader and more consistent assessment of habitat conditions. That assessment might be integrated with emerging landscape, watershed, and stream channel classification systems (Whittier et al. 2011) to more effectively characterize and track the representation of habitats and the distribution of restoration actions. It will be important to expand consideration of socioeconomic components of diversity as well (Smith 1994). As restoration progresses, indicators of public knowledge of, and support for the Program planning and revision process may reflect the influence and success of the Program.

ISAB recommendations for diversity

1. **Develop and refine HLI**. The Council should consider revising the Program objectives for biological performance to include quantitative measures of diversity. Council staff and others who are working to develop and refine HLI should explore simple measures of population viability that depend on life history diversity and spatial structure (and are provided in periodic status reviews) as potential HLI to represent population diversity across recovery units.

2. **Develop new capacity and knowledge.** For nearly two decades the Program has recognized the need to understand biological diversity as the critical foundation for resilience and sustainability. It is now possible to develop new measures to monitor biological diversity at the scale of the entire basin. An active program of research implemented through focused RFPs should be initiated.

B. Climate Change

Despite noteworthy efforts to collect relevant data, climate change and the lack of stationarity of environmental variables add another layer of uncertainty to predictions of future impacts of management decisions (Milly et al. 2008; Palmer et al. 2008). For example, the concept of return periods of floods and droughts based on historical data may no longer be adequate for designing and planning for extreme events (Milly et al. 2008). Trends over the past several decades show decreasing April 1 snow water equivalence (Mote 2006); decreasing ratios of snow water equivalence to precipitation (Barnett et al. 2008) and snowfall to precipitation (Feng and Hu 2007, ISAB 2007); earlier spring runoff pulse onset dates (Stewart et al. 2005); decreasing September stream flows (Chang et al. 2012); and increasing winter and spring air temperatures (Stewart et al. 2005) in the Pacific Northwest and the Columbia River Basin. Models for the region predict that trends of decreased snow water equivalence and earlier snowmelt-driven runoff will continue (Hamlet et al. 2005; Rauscher et al. 2008; Stewart et al. 2004), that warming may be decreased with altitude (Bürger et al. 2011), and that wildfire frequency and intensity will increase (ISAB 2007-2).

Such trends and predictions point not only toward changes in the timing and distribution of water, including extreme events such as floods and droughts (Palmer et al. 2008), but also to compounding impacts on fisheries (ISAB 2007 -2, Kuehne et al. 2012). Warmer water temperatures, increased salinity, and acidification will affect fisheries through physiological effects such as lower growth rates that can result in higher predation (Kuehne et al. 2012, Steel et al. 2012), increased susceptibility to invasive and non-native species (Fausch et al. 2001, Lawrence et al. 2012), and reduced cold water refuges (Donley et al. 2012, ISAB 2007-2). Sharma et al. (2012) conclude that a 1°C increase in sea surface temperature (SST) during the period April through July could result in decreased survival of Chinook salmon populations in the Pacific Northwest. Ocean habitat that is thermally suitable for all species of salmonids in the Gulf of Alaska, the primary ocean rearing area for Columbia River Basin salmon and steelhead, is projected to be substantially reduced by the 2080s, with potential complete losses of summer (July) habitat for Chinook salmon and winter (December) habitat for sockeye salmon (Abdul-Aziz et al. 2011). New genetic analyses suggest significant northward shifts in the ocean distribution of Chinook populations (California to Southeast Alaska) into the southeastern Bering Sea in June (Larson et al. in press). In addition, empirical evidence now exists that warming can lead to new species interactions exacerbating the anticipated effects based on habitat availability alone (Wenger et al. 2011, Milazzo et al. in press).

The 2009 Program briefly addresses climate change in the Mainstem Strategies section of the Mainstem Plan and acknowledges the potential for significant effects of climate change in the Basin. The 2009 Program recommends improving forecasting techniques; assessing the effects of climate change on flows and fish and wildlife, and subsequent impacts on mitigation efforts; and evaluating alternative water management scenarios including changes in flood control operations, selective withdrawal and other changes in hydrosystem operations. The 2009 Program recommends investigating impacts in the estuary and plume as well as the mainstem.

The ISAB (2007-2) noted that climate change impacts on fish and wildlife species' ranges have already been observed, with latitudinal and elevational changes in habitat, and pointed out that subbasin plans have generally not adequately addressed future impacts of climate change on fish and wildlife habitat. To address climate change concerns, the ISAB (2007-2) recommended that locations sensitive to climate change be identified, reserve areas established, and that hydrosystem operations might be changed to mitigate some of the flow impacts. However, Payne et al. (2004) also note that current constraints on operational policies limit the effectiveness of such mitigation and that it might be necessary to reconsider flood control and hydropower needs under climate change.

More analyses are needed to investigate the effectiveness of management actions under potential climate change scenarios. One example is the examination of options to restore instream flow in the central Columbia River as a way to manage risk to sustainable fisheries (Donley et al. 2012). The amended Program should include more explicit directives to consider climate change impacts and associated uncertainties in subbasin plans or other broad assessments, and to plan for habitat restoration and population conservation so that limited resources are prioritized effectively. New analytic capacity to anticipate hydrologic, temperature, and species responses (Wu et al. 2012, Isaak et al. 2010, Wenger et al. 2010), and new tools to support decision making should help managers to consider vulnerability and restoration options for adapting to climate change (Peterson et al. in press). Continued monitoring can be integrated with adaptive management strategies by using computer models at local to basinwide scales to explore management options. Beyond flow management, such models can assess water quality and species responses to changes in flow quantities, timing, and climate.

ISAB recommendations for addressing climate change

1. **Develop a comprehensive strategic plan on the potential impacts of climate change on the entire system, including the estuary and ocean, and develop a suite of strategies within the amended Program.**

2. **Provide guidance for potential revisions to flood control and hydropower operations to enhance ecosystem resilience and adaptability under climate change.** Management options considered in experiments and modeling should not be limited to current operating constraints.

3. **Examine management options under climate change scenarios by using monitoring data and modeling tools where possible**

4. **Assess and appropriately revise ongoing monitoring to optimize collection of data regarding species responses, interactions and production under climate change**

5. **Require project proposals and management plans to consider the potential impact on project outcomes of climate change and its associated variability and uncertainty.** Create a resource of references to the current science that can be shared with project designers and managers.

C. Proliferation of Chemicals and Contaminants

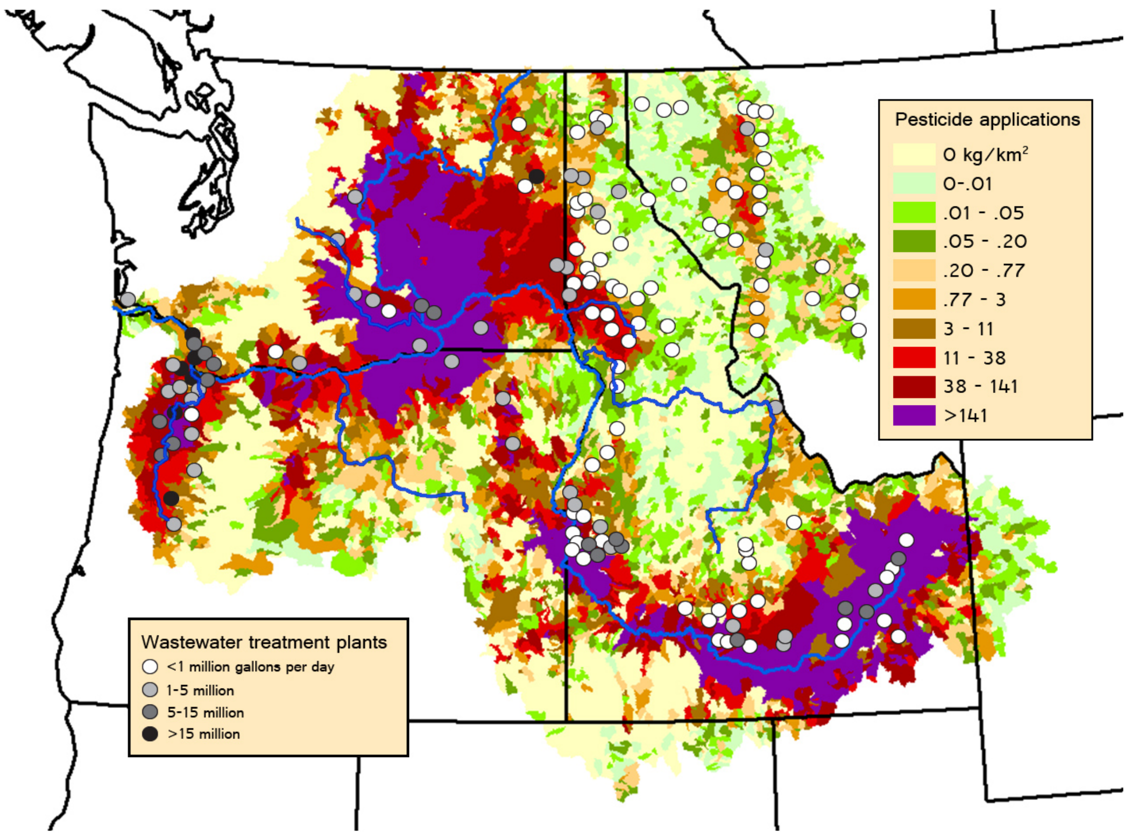
Fish, wildlife, and human populations in the Columbia River Basin and elsewhere in the United States are exposed to an ever-growing variety of pollutants as a result of increasing urbanization, industrialization and agricultural development.[3] Human communities use and dispose of literally thousands of chemicals, and many end up in aquatic systems where they persist, affect organisms and food webs and, in some cases, accumulate in consumers near the top of the food web. It is well documented that the lower Columbia River and its tributaries contain concentrations of toxic pollutants that are harmful to fish and wildlife. Contaminants of greatest concern in the late 1980s and early 1990s included dioxins and furans, heavy metals, polychlorinated biphenyls (PCBs) and organochlorine pesticides such as DDT (Tetra Tech 1996). Today there is continuing and growing concern about persistent pollutants coming from a wide variety of sources, especially those that

[3] The amounts and diversity of chemicals in use are both stunning and a matter of great concern, with almost 454,000 mt/year of pesticides applied in the United States since 1980 (Gilliom et al. 2006, Grube et al. 2011). A great diversity of pesticides is used (http://water.usgs.gov/nawqa/pnsp/usage/maps/) and pesticides have been detected in every region of the United States where surface water has been analyzed, including the Columbia Basin (Larson et al. 1997). In watersheds with agricultural or urban land use, stream organisms are likely to be exposed to mixtures of multiple pesticides (Gilliom et al. 2006). Besides pesticides, numerous studies have reported a variety of manufactured and natural organic compounds such as pharmaceuticals, steroids, surfactants, flame retardants, fragrances, and plasticizers, especially in waters in the vicinity of municipal wastewater discharges and livestock agricultural facilities (Focazio et al. 2008). In addition, of the more than 6,350,000 mt of sewage sludge (dry weight) produced in the United States. in 2004, about 50% was applied to land as fertilizer or soil amendment, and 45% was disposed of in landfills or as landfill cover (NEBRA 2007). Terrestrial environments can offer effective biological, physical, and chemical attenuation of manmade pollutants, but they also act as routes of chemical migration into both surface and groundwater from biosolid runoff and leachate (McClellan and Halden 2010).

linger in the environment and are known to affect the health of humans or the aquatic community. Further, there is also growing concern about "emerging contaminants," a group of potentially harmful chemicals for which only limited information is available.

The proliferation of artificial chemicals in the Basin was recently identified by the ISAB as one of the highest priorities for resolution (ISAB 2011-1, Naiman et al. 2012). The most recent tally of pesticide use (average for 1999-2004) lists 182 chemicals, with an aggregate application rate of ~46,000 mt of active ingredients annually; these are concentrated mostly in agricultural lands along water courses (Figure 3.C.1; ISAB 2001-1, Naiman et al. 2012). In addition, there are a variety of manufactured and natural organic compounds such as pharmaceuticals, steroids, surfactants, flame retardants, fragrances, and plasticizers detected, especially in waters in the vicinity of the >169 municipal wastewater discharges and uncounted livestock agricultural facilities (Focazio et al. 2008, Morace 2012).

Figure 3.C.1. The Columbia River Basin has undergone substantial transformation through the application of pesticides (246 compounds evaluated; average 1999-2004; data obtained from USGS, National Water Quality Assessment Project) and construction of >169 wastewater treatment plants.



Surprisingly little attention has been paid to the effects of contaminants on fish production and survival, even though pollutants have been recognized for many years as a problem in the Columbia River and its tributaries, especially for species positioned higher in the food web (ISAB 2011-1). The vulnerability of the estuary and the coastal ocean communities to the accumulation of the contaminants is especially worrisome because of their spatial position in the watershed.

Contaminant-related declines in populations of fish-eating species often lead – after the fact – to further study of contaminants in the prey fish species. However, studies of contaminants in invertebrate species, many of which are the first components of the food web to accumulate contaminants, are extremely rare in the Basin. The collective impacts of contaminants continues unabated, and there is an obvious need to quantify and map the spatial patterns of these chemicals; assess their transfer, accumulation, and persistence; and document their impact on native organisms and on the carrying capacity of the Columbia River ecosystem for juvenile salmonids. The Council has an opportunity to take an active role – through cooperation with regional partners – to ensure that monitoring of toxic contaminants and evaluation of their effects on fish and wildlife are addressed.

ISAB recommendations for addressing chemicals and contaminants

1. **Actively investigate the impact of chemicals on restoration activities by fully implementing a water quality program.** This initiative will require working partnerships with the Federal Action Agencies (e.g., EPA, Bureau of Land Management, U.S. Forest Service and others) as well as initiating modeling of climate-temperature effects for all parts of the Basin.

2. **Work diligently with other regional agencies to implement the interagency Columbia River Basin Toxics Reduction Action Plan**. Update the plan regularly, so that current and future chemical insults to the system can be addressed in timely fashion, before they become even more serious problems. The nature of the issue dictates that this will be a large, ongoing, and collective regional effort.

D. Novel Hybrid Communities: Non-native Species and Predation

A major issue confronting the Program in the coming decades will be how to manage non-native species and the hybrid or novel aquatic, riparian, and terrestrial communities in which they exist (Simberloff et al. 2005). The Program can play a key role in fostering cooperation among co-managers in developing approaches encouraging research on non-native species and hybrid and novel communities; in leading and encouraging communication and education of the public (ISAB 2008-4); and facilitating cooperative approaches to policy development.

The non-native challenge

Effective policies are needed to address the risk posed by non-native species, as well as native species spreading outside of their native ranges within the Basin. Although the ISAB has reviewed the role and status (ISAB 2008-4) and food-web impacts (ISAB 2011-1, Naiman et al. 2012) of non-native species in the Basin, no comprehensive set of policies currently exists for dealing with non-native species nor for continuously monitoring the status of non-native species (Sanderson et al. 2009). Policies should be formal, transparent, and defensible, even if they cannot be applied uniformly across the Basin. For example, the Program might allow policies tailored to specific areas of the Basin where non-native species are favored by local communities, provided these actions are consistent with a landscape perspective and do not jeopardize options to protect native species in other areas.

The Columbia River Basin now contains 85 non-native fish species, numerous other vertebrates, and a host of poorly documented non-native plants and invertebrates in aquatic, terrestrial, and riparian habitats (ISAB 2008-4, Sanderson et al. 2009, Carey et al. 2012, Naiman et al. 2012). How these species affect food webs and ecosystem function is largely unknown. In amending the Program, the

Council has an opportunity to encourage and support the development of research on these critical uncertainties, to better understand species interactions, and ultimately, to develop well-reasoned procedures and methods to categorize and address the risk posed by non-native species. Risk categories include:

1. non-native species that have not yet arrived in the Basin.
2. non-native species present in the Basin but whose effect is poorly understood
3. non-native species present in the Basin and identified as “invasive”
4. non-native species present in the Basin and identified as “problematic” because they are known to cause damage but also provide benefits in some instances or localities
5. native species that are expanding their historical range and moving into new habitats within the Basin

An effective program to prevent introduction of non-native species is the first, the most critical, and the most cost-effective measure (ISAB 2008-4). Species profiling can be used to forecast probable future non-native introductions and possible entry pathways (Kolar and Lodge 2002). A non-native detection and monitoring system is also needed within the Basin (Graham et al. 2007), including an up-to-date database to map and track their status, distribution expansion or contraction, as well as locations where they are cultured (e.g., hatcheries rearing bass). New genetic techniques can aid in prevention and detection, including understanding the genetic characteristics of successful invasive species (Lee 2002) and the use of environmental DNA for detecting non-native species in water samples (Ficetola et al. 2008). Environmental assessment protocols are needed to anticipate the entry and spread of undocumented, newly documented, and inconspicuous species. Well-reasoned and consistent policies, wherever possible, are needed to guide management of problematic species.

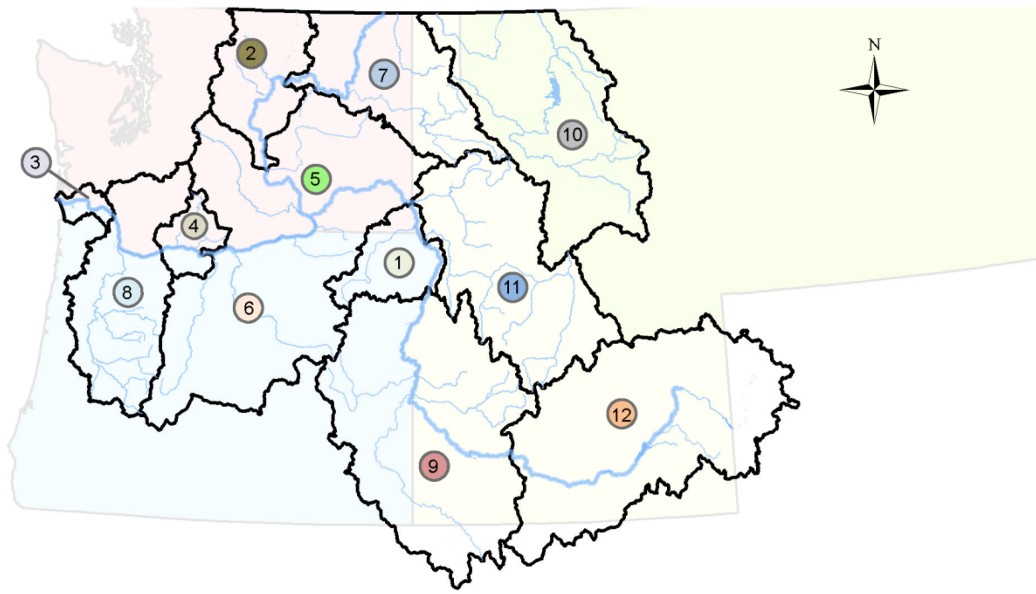
An active program to control known invasive non-native species is also needed. Complete removal of invasive species might be the preferred option, and should be considered, but it is seldom possible. Where eradication is not possible, emphasis should be placed on implementing policies and control measures that effectively reduce or prevent the spread of invasive species. Habitat protection and restoration remains a primary strategy to prevent introduction and establishment of most non-native species and to limit their expansion (Marchetti and Moyle 2001, ISAB 2008-4), even while recognizing that habitat protection will not be sufficient to prevent the spread of some highly invasive non-natives.

The most problematic category in terms of policy development includes non-native species already present in the Basin that have been shown to cause damage but which are also viewed as providing benefits, such as to fisheries in some locations (see Fig. II.3.D.1). For example, in fish substitutions allowed under the Program, agencies and tribes have sometimes selected non-native species known to impact native fauna over less desirable or less economically valuable native species. This situation is problematic because it can compromise an effective native fish strategy and send the message to the public that surreptitious, illegal introduction of non-natives is tolerable or accepted practice (Johnson et al. 2009). In this respect, the 2009 Program non-native strategy seems inconsistent and inadequate.

The 2009 Program identifies the need for a formal risk assessment process for non-native fishes and refers to the procedure described in ISAB 2008-4 regarding non-native fish substitutions. However, the assessment presented in ISAB 2008-4 focused on assessing non-native substitutions of salmonids, and to be effective, such an assessment must be part of a more comprehensive set of policies, procedures, and methods for dealing with the different categories of non-native species and their hybrid and novel communities. Because of its basinwide scope, the Program could play a key role in fostering development of those policies, procedures, and methods. The Program should also encourage expansion and coordination of state and tribal control programs that already exist. The Program can also "*encourage revisions in the subbasin plans* [or other collaborative planning efforts] *for addressing non-native species and impacts.*" (ISAB 2008-4).

Figure II.3.D.1. Total releases of resident fishes (both native and non-native) into the Columbia River Basin in 2011 by province and agency

Species	Number	Native / Non-native	Agency / Tribe	FWP Funded
BLUE MOUNTAIN (1)				
Rainbow Trout	175,139	N/NN	State	
COLUMBIA CASCADE (2)				
Brook Trout	537,402	NN	State	
Brown Trout	365,230	NN	State	
Cutthroat Trout	367,830	N/NN	State	
Kokanee	38,700	N/NN	State	
Rainbow Trout	1,136,189	N/NN	State	
Tiger Trout	22,500	NN	State	
COLUMBIA ESTUARY (3)				
Rainbow Trout	3,096	N/NN	State	
COLUMBIA GORGE (4)				
Brook Trout	30,756	NN	State	
Brown Trout	13,972	NN	State	
Cutthroat Trout	17,870	N	State	
Rainbow Trout	161,452	N/NN	State	
COLUMBIA PLATEAU - NORTH (5)				
Brook Trout	9,083	NN	State	
Brown Trout	147,677	NN	State	
Cutthroat Trout	273,774	N	State	
Golden Trout	4,512	NN	State	
Kokanee	703,767	NN	State	
Rainbow Trout	2,428,342	N/NN	State	
Tiger Muskie	300	NN	State	
Tiger Trout	26,151	NN	State	
COLUMBIA PLATEAU - SOUTH (6)				
Bluegill	325	NN	State	
Brook Trout	94,747	NN	State	
Brown Trout	39,047	NN	State	
Cutthroat Trout	62,084	N	State	
Kokanee	182,443	N	State	
Largemouth Bass	800	NN	State	
Rainbow Trout	648,673	N/NN	State	
INTERMOUNTAIN (7)				
Arctic Grayling	3,700	NN	State	
Brook Trout	177,833	NN	State/Tribe	Part
Brown Trout	212,050	NN	State	
Channel Catfish	11,552	NN	State	
Cutthroat Trout	428,696	N/NN	State	
Golden Trout	2,100	NN	State	
Kokanee	1,262,684	N	State/Tribe	Part
Rainbow Trout	3,034,217	N/NN	State/Tribe	Part
Tiger Muskie	1,450	NN	State	
Tiger Trout	75,000	NN	State	
Walleye	20,000	NN	State	
White Sturgeon	3,990	N	State	Yes
LOWER COLUMBIA (8)				
Bluegill	100	NN	State	
Brook Trout	89,547	NN	State	
Brown Trout	67,575	NN	State	
Channel Catfish	3,755	NN	State	
Cutthroat Trout	83,356	N	State	
Kokanee	311,743	NN	State	
Largemouth Bass	325	NN	State	
Rainbow Trout	2,259,251	N/NN	State	
Tiger Muskie	3,050	NN	State	



Species	Number	Native / Non-native	Agency / Tribe	FWP Funded
MIDDLE SNAKE (9)				
Arctic Grayling	11,471	NN	State	
Black Crappie	51	NN	State	
Bluegill	2,951	NN	State	
Brown Trout	52,425	NN	State	
Channel Catfish	12,460	NN	State	
Cutthroat Trout	91,891	N/NN	State	
Golden Trout	21,979	NN	State	
Kokanee	838,023	NN	State	
Largemouth Bass	655	NN	State	
Rainbow Trout	2,499,402	N/NN	State	
Smallmouth Bass	849	NN	State	
Tiger Trout	1,600	NN	State	
MOUNTAIN COLUMBIA (10)				
Arctic Grayling	135,000	N	State	
Brook Trout	58,643	NN	State	
Brown Trout	5,002	NN	State	
Channel Catfish	8,663	NN	State	
Golden Trout	1,800	NN	State	
Kokanee	11,856,694	NN	State	
Largemouth Bass	95,700	NN	State	
Rainbow Trout	939,058	N/NN	State/Federal	Part
Rainbow Trout x Westslope	36,000	NN	State	
Smallmouth Bass	31,500	NN	State	
Westslope Cutthroat Trout	355,353	N	State/Federal	Part
White Sturgeon	14,000	N	Tribe	Yes

Species	Number	Native / Non-native	Agency / Tribe	FWP Funded
MOUNTAIN SNAKE (11)				
Arctic Grayling	4,544	NN	State	
Channel Catfish	4,177	NN	State	
Cutthroat Trout	135,318	N/NN	State	
Golden Trout	11,420	NN	State	
Rainbow Trout	651,318	N/NN	Tribe	Yes
UPPER SNAKE (12)				
Arctic Grayling	7003	NN	State	
Brook Trout	100,007	NN	State	
Brown Trout	40,793	NN	State	
Channel Catfish	42,993	NN	State	
Cutthroat Trout	1,353,659	N/NN	State	
Golden Trout	1,507	NN	State	
Kokanee	224,387	NN	State	
Rainbow Trout	2,946,302	N/NN	State	
RainbowTrout x Cutthroat Trout	221,419	NN	State	
Walleye	1,050,000	NN	State	

Data source and graphic: Neil Ward and Binh Quan, Columbia Basin Fish and Wildlife Foundation

The predator issue
In the Columbia Basin, there is a particular need, noted by McMahon and Bennett (1996), for more research to better understand how non-native predators shape their hybrid fish communities. It is imperative to evaluate how well predator control is working, based on metrics such as increased abundance of species of interest or improved smolt-to-adult survival (SAR) of salmonids. In addition, the Council, through the Program, is encouraged to focus research on ways to understand or mitigate the ecological changes associated with the hydrosystem that have created conditions favoring the proliferation of predators and their concomitant impacts on salmonids, sturgeon, lamprey, and other native species. Documented benefits from suppressing predators to increase abundance or survival of salmonids or other valuable native species might have to be weighed against the loss of predator species that are also valued by some members of society. The Program should recognize the divergent public views regarding the value of many predator species, including non-native species (García-Llorente et al. 2008).

Novel approaches for novel aquatic, riparian and terrestrial communities
Although some non-native species, many from introductions, have inhabited the Columbia River Basin for more than a century, much remains unknown about their current ecological roles. For example, despite their abundance, we still lack an adequate understanding of the ecological role of non-native American shad, and whether they contribute positively or negatively to the sustainability of the Columbia River ecosystem.

The Program should explicitly address expectations for hybrid and novel communities, their changing food webs, and how these systems should be scientifically evaluated with respect to meeting both ESA requirements and maintaining abundant, productive, and diverse communities of native species. More effort is needed to understand and manage the ecological roles that newly established species will play basinwide (Seastedt et al. 2008). Future efforts should emphasize the linkages between terrestrial, riparian, river, and reservoir segments, their rapidly changing habitat and fauna, and other relevant landscape features (Moyle and Light 1996, Miranda 2008). Scientific methods of risk assessment are needed to evaluate community resilience before and after non-native introductions (McMahon and Bennett 1996, Wilcove et al. 1998, Gozlan et al. 2010).
The Program may need to foster policies tailored not only to cope with different threat categories of non-natives but also to consider specific areas of the Basin where local stakeholders favor hybrid communities including non-native species over degraded native communities. However, such policies should first and foremost protect landscape-scale options involving native species by requiring that proponents for local hybrid communities bear the burden of proof in establishing that these experiments pose a low risk to native communities in other subbasins.

<u>ISAB recommendations for addressing non-natives and predation</u>

1. **Develop, with basin co-managers, a process for dealing with non-natives.** Lead development of a non-native prevention program as the first, the most critical, and the most cost-effective approach to avoid introductions of non-native species. Develop well-reasoned procedures to deal with non-native species that are already present.

2. **Develop a system for regularly monitoring the status of non-native species across the entire Basin.**

3. **Support research to understand or mitigate past ecological changes created by the hydrosystem that have lead to current conditions fostering the proliferation of predators and their impacts on salmonids, sturgeon, lamprey, and other species.**

4. **Support research to understand trophic interactions involving non-native species in hybrid and novel ecosystems with reference to improved diversity, abundance, and productivity.**

5. **Recognize and develop methods for addressing divergent public views regarding many non-native (problematic) predator species.** Play a proactive role informing and educating the public abaout non-native species issues in the Basin.

E. Uncertainty about Carrying Capacity

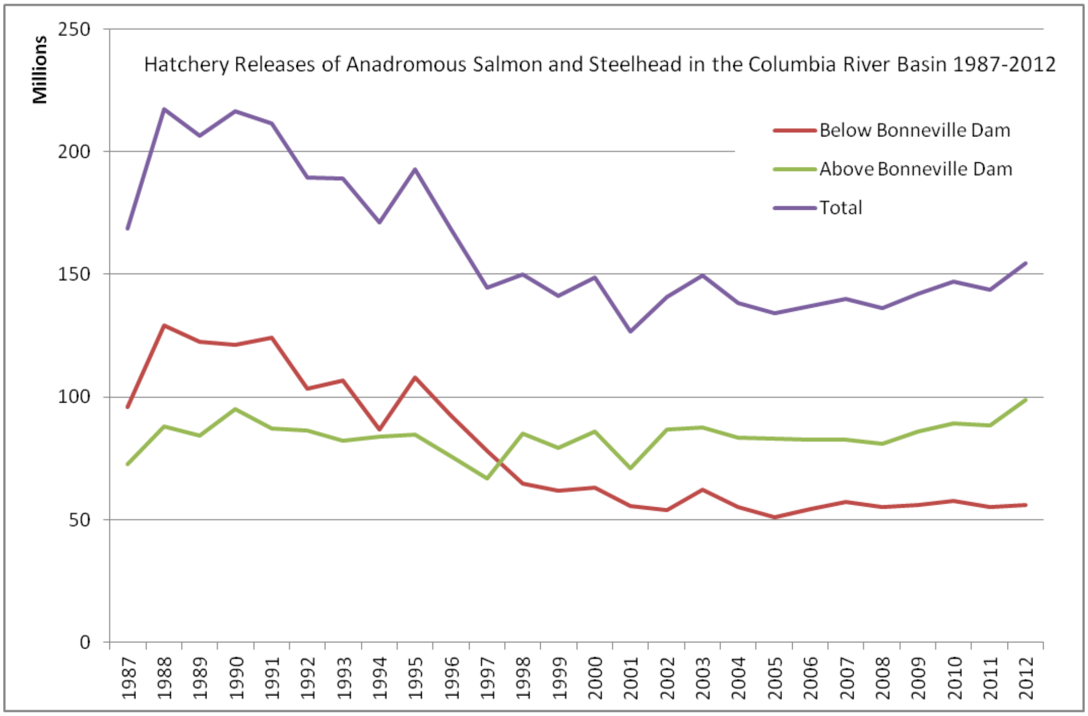
A recent ISAB review identified uncertainty about the aggregate carrying capacity for juvenile salmonids as the highest priority for research, management, and restoration activities in the Basin (ISAB 2011-1, Naiman et al. 2012). Carrying capacity, the maximum abundance or biomass of a population of concern that can maintain itself under specified conditions (i.e., mortality rates and the quantity and quality of habitat and food available), has rarely been considered explicitly by Program managers and biologists. However, the Basin's carrying capacity for target species must ultimately constrain Program objectives related to the abundance and productivity of those species and should be addressed when prioritizing restoration activities.

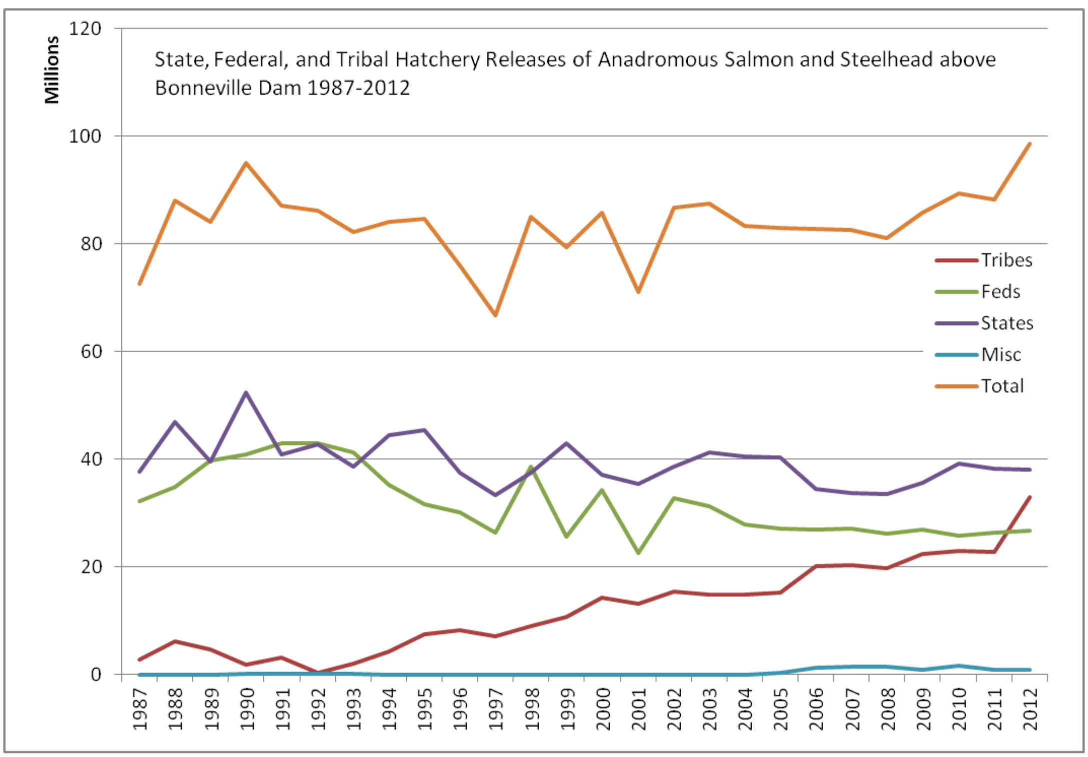
The Program could be improved by explicitly considering carrying capacity as an integral component of the Four H's. Are food, thermal, and other environmental conditions (e.g., contaminant levels, competition from non-natives) adequate to support growth and survivorship in juvenile salmonids? To what extent do pesticides and other chemicals impact food supplies or reduce the ability of juvenile salmonids to adequately function (e.g., altered behaviors, slower growth, increased disease susceptibility)? To what extent are non-native species or hatchery fish competing for prey with native fishes? These questions are rarely addressed systematically, yet failure to do so could hamper recovery of federally listed species and derail the success of many habitat, harvest, and hatchery programs.

Hatchery production and the natural food supply

It is not clear whether the Columbia River can provide sufficient food to support large populations of artificially raised fish and other organisms, including natural salmonids, for the long term. Consider the massive annual releases of juvenile fish from Columbia River hatcheries and how they potentially affect food webs and populations of wild fish. Approximately 130-150 million hatchery salmon and steelhead are added to the river annually from more than 200 hatcheries, at a cost of over $50 million (Fig. II.3.E.1). Basinwide releases have decreased significantly from 200 million fish annually in the 1980s, driven by a reduction in releases below Bonneville Dam by WDFW and ODFW. Since 1998, more hatchery fish have been released above Bonneville Dam than below; the highest release above Bonneville Dam was 99 million in 2012. The increase in fish releases above Bonneville Dam has been driven by a steady increase in releases from tribal hatcheries which receive funding from the Program as well as other sources (e.g., LSRCP, Mitchell Act). In 2012, considering only releases above Bonneville Dam, tribal hatcheries released more than 30 million fish, more than was released by federal hatcheries (primarily the USFWS), and nearly as many as released by state hatcheries.

Figure II.3.E.1 Hatchery releases of anadromous salmon and steelhead in the Columbia River from 1987-2012 showing trends above and below Bonneville Dam (top frame) and by hatchery management entity (not funding source) for releases above Bonneville Dam (bottom frame). Releases below Bonneville are primarily from ODFW and WDFW hatcheries. Data include total releases of eggs, fry, smolt, and adults, and are preliminary for 2012. Source: Fish Passage Center.





The food used to raise these hatchery-origin fish mostly originating from outside the Basin, as well as the thousands of metric tons of natural foods required to sustain them in the river, must affect the capacity of the Columbia River to support naturally-produced native fish. Studies show that larger salmon smolts tend to have higher survival rates at sea (Groot and Margolis 1991, McGurk 1996, Moss et al. 2005, Quinn 2005). Therefore, it is important to ask how much additional growth natural-origin juveniles might have achieved and how much higher their survival might have been had fewer hatchery fish been released. This issue may be especially important in years when food availability in the ocean is relatively low (Levin et al. 2001). Available evidence suggests that nearly twice as many salmon smolts (mostly hatchery fish) are produced in the Columbia Basin today than were present historically prior to major hatchery and mainstem dam construction (ISAB 2011-1).

Modeling food webs and carrying capacity

Food web modeling, like habitat modeling, is needed to develop alternative hypotheses that can be tested empirically. Linked trophic and population models have been essential for understanding the impacts of competition and predation in a variety of situations (Sidebar II.2.E.1). Trophic modeling can also help to understand and predict relationships among smolt size and measured stage-specific survival rates or adult returns, within various thermal regimes. As well, a comprehensive food web model, general enough that the inputs can be changed to accommodate variability in thermal regime, feeding, diet, and growth at appropriate temporal and spatial scales, can help forecast “what-would-happen-if” scenarios and to update model inputs as accumulating experience reveals that key components are missing.

The ISAB sees a need to investigate the sustainability of food web structures and to estimate carrying capacity for broad habitat types (e.g., tributaries, main stream, lakes, reservoirs, wetlands, estuary, and ocean). Such investigations by habitat type, including both healthy and degraded examples, could provide the blueprints for what to protect and what to restore to maintain carrying capacity. Establishing reasonable and measurable targets of carrying capacity for key species would also provide benchmarks against which to gauge the success of conservation actions. In this regard, it is important to recognize that the concept of carrying capacity is based on specified conditions which might vary temporally (seasonally) or be impacted by climate change and shifts in ocean regimes. Some of this information is being collected, but general access to data remains problematic.

ISAB recommendations for addressing carrying capacity for juvenile salmonids

1. **Explicitly address carrying capacity for juvenile salmonids when integrating and prioritizing plans for artificial propagation and habitat restoration**.

2. **Conduct empirical investigations and develop bioenergetic models to estimate trophic demands on food supplies by native and non-native competitors of juvenile salmonids.**

Sidebar II.2.E.1. Density dependence and carrying capacity in the Umatilla River
The investigation of steelhead supplementation in the Umatilla River provides a relevant example of how salmon density-dependence can and should be examined within watersheds. Steelhead productivity (smolts per spawner) typically declines as parent spawner abundance increases, and this density-dependence can be attributed to a limiting food supply (rather than spawning habitat) because the length-at-age of steelhead smolts decreases and the average age of smolts increases with increasing parent spawner abundance (Hanson et al. 2010). These and other targeted approaches can identify which interactions or environmental conditions impact restoration goals, allowing managers to focus on critical processes at relevant locations and times.

F. Artificial Propagation: Loss of Productivity in Natural Populations

The 2009 Program vision establishes a priority for recovering ESA-listed species and providing fishery benefits through the restoration of natural production but permits artificial production from hatcheries to meet remaining mitigation and conservation obligations. The Artificial Production Strategy section of the 2009 Program incorporates contemporary understanding of scientific risks of using artificial production as a tool to rebuild wild populations and/or to provide for harvest while minimizing adverse impacts of hatchery fish on natural stocks. However, the ISAB is concerned that this strategy is not being adequately informed and implemented.

A key scientific uncertainty in the 2009 Program is whether the objective of using artificial production to mitigate for lost harvest opportunities can be reconciled with the dual objectives of ESA recovery and restoration of healthy natural populations. Often, there is little information to demonstrate that hatchery fish intended for harvest are having negligible adverse impacts on natural populations or that hatchery fish intended for conservation are benefiting natural production. In recent years approximately 1.5 million adult salmon and steelhead pass Bonneville Dam annually, and the ISAB understands that nearly 80% of these are hatchery fish, although the composition of the aggregate salmon runs is not known precisely (Sidebar II.2.F.1). These hatchery fish provide important benefits to some of the Basin's stakeholders and populations, but the trade-off in costs to natural production remains poorly understood.

At the heart of reconciling the value of harvest opportunities versus sustaining natural populations are two unresolved questions:

1. If the scale of artificial production were curtailed would natural populations increase in abundance and productivity?
2. If artificial production continues at the current scale will natural productivity and diversity be eroded to the point that natural reproduction is no longer sustainable?

The ISAB recognizes that NMFS provides Biological Opinions for harvest activities related to ESA-listed species and only approves harvest activities if their analysis indicates no appreciable increase in risk of extinction or reduction in probability of recovery. Even so, a key question is whether the sustainability of ESA-listed species would be maintained or enhanced if large-scale artificial production were curtailed (Sidebar II.2.F.1)

Individual hatchery projects are typically evaluated for their performance within the hatchery setting, including their contributions to harvests and natural spawning, but the cumulative effect of multiple hatchery projects on natural production and ecosystem processes has yet to be adequately quantified at the population, subbasin, or basin levels. Such comprehensive evaluation would require coordination and meta-analysis of projects across watersheds and management jurisdictions. A Columbia River Hatchery Effects Evaluation Team (CRHEET) was proposed to address this challenge, but it has not yet been formally established. The ISAB believes that this broad-scale evaluation is required to evaluate interactions of hatchery and wild salmon and to provide a basis for deciding on alternative restoration priorities.

HSRG recommendations

When the Program was written, the technical and scientific recommendations of the Hatchery Scientific Review Group (HSRG) were not yet available (Review of Hatchery and Wild Stocks, p. 19). Now that they are, the ISAB recommends that the artificial production strategies be revised to incorporate conclusions from the HSRG (2009) review, making it clear which recommendations from the HSRG are "standards" to be followed and which recommendations are optional suggestions. If HSRG suggestions are not incorporated into the Program, an explanation of alternative options should be provided. Artificial production involves trade-offs with natural production, and these tradeoffs need to be explicitly described and acknowledged so that they can be adequately evaluated. Revising the existing artificial production standards (section 3.a.) to be consistent with the HSRG principles and recommendations would provide useful guidelines for reforming existing hatchery programs.

Integrated and segregated strategies

The first of the primary strategies for artificial production ("*1) in an integrated manner to complement habitat improvements by supplementing native fish populations up to the sustainable carrying capacity of the habitat with fish that are as similar as possible, in genetics and behavior, to wild fish*") requires knowing the sustainable carrying capacity of the habitat but does not identify data requirements (e.g., the number of wild and hatchery fish smolts and adults). Without these basic data, the foundation for a successful integrated strategy is weak. The HSRG did not explicitly address carrying capacity or ecological interactions (direct predation, competition, disease), but recent work cited in the ISAB food web and landscape reports suggests that large releases of artificial production fish may compromise habitat capacities for wild fish (ISAB 2011-1, ISAB 2011-4). Hatchery supplementation projects, which are intended to boost natural salmon production, can lead to reduced growth of juveniles and reduced productivity (smolts per spawner) even though overall abundance is low compared with historical periods when habitat was less degraded. Additionally, large hatchery releases may enhance or concentrate key predators, such as birds, pikeminnow and walleye, leading to significant predation and mortality on natural populations. Carrying capacity and ecological interactions between artificial production and wild fish in the ocean also need to be addressed (see below, section 4.B.). Effective integration of hatchery projects, harvest management (section II.2.G), and habitat improvement projects (section II.2.I) requires stronger emphasis in the Program. The integrated strategy applies to both supplementation (conservation) and to integrated harvest projects, which are distinct programs, each requiring their own standards for operation.

The second of the primary strategies for artificial production ("*2) in a segregated manner to maintain the genetic integrity of the local populations in order to expand natural production while supporting harvest of artificially produced stocks*") should be revised to clearly indicate that active removal of hatchery fish from the natural spawning grounds is required to maintain genetic integrity. The statement that segregated projects intend to expand natural production is probably not realistic. In any case, it would be worth emphasizing that natural production is expanded by spawning of Natural-Origin-Return (NOR) adults, not Hatchery-Origin-Return (HOR) adults (i.e., adults straying from hatcheries). A critical uncertainty is how to implement a segregated strategy, and specifically, how to ensure that fisheries fully utilize all of the hatchery fish that are produced for harvest (see Section II.2.G).

Supplementation for conservation

Regarding the benefits of artificial production supplementation of wild fish, the 2009 Program states: "*The science on this issue is far from settled*" (Primary strategies, p. 18). This statement is still accurate (ISRP 2011-25). The ISAB concludes that benefits to natural population abundance and consequences to productivity and diversity are not sufficiently quantified to show that supplementation can boost production of natural origin salmonids.

The 2009 Program states: "…*supplementation of natural runs with artificially produced fish may be used to preserve and rebuild the natural runs*" (Restoration, p. 19). Generally, ISRP reviews of artificial production programs have found little empirical evidence of success from this approach. Supplementation benefits will be affected by the capacity for spawning and rearing in freshwater and ocean habitats. The ISRP concluded in their review of Snake River spring Chinook projects that supplementation projects are not well integrated with existing habitat conditions or efforts to increase freshwater habitat productivity and capacity (ISRP 2011-14). Integration is essential for supplementation in which the primary goal is conservation. The Program should be amended to emphasize the importance of evaluating limiting factors by life-stage and of considering artificial production-driven density dependence that limits production of natural-origin fish. These issues necessitate better coordination of hatchery operations and habitat restoration activities within the subbasins, as well as adaptive management strategies to address changes in climate and ocean conditions.

Supplementation is typically used in streams where the natural spawning population has declined to low abundance because its productivity has been compromised relative to historical levels. Because few natural-origin adults are available for hatchery broodstock, these projects are likely to be initiated with a small Proportionate Natural Influence (PNI), which quantifies the proportion of selection occurring in the natural versus hatchery environment. A small PNI implies that the population will evolve primarily in response to selection in the captive (hatchery) environment, which has the potential to further reduce its productivity in the natural environment, thereby aggravating the original problem.

The ISAB recommends that the Program implement a broad-scale hatchery effects monitoring program, such as CRHEET, to provide a comprehensive evaluation of supplementation across projects and species. Supplementation evaluation needs to progress from evaluating only abundance to estimating the proportional level of gain or loss from supplementation. An increase of total salmon abundance on the spawning grounds due to greater straying from hatcheries is not a measure of success. Likewise, an increase in natural-origin spawners may not be a sign of success of supplementation if abundance has also increased in nearby control streams without supplementation.

The 2009 Program addresses uncertainty regarding risk from interbreeding between artificial production and natural fish: "*What is not so clear is the extent to which artificially produced fish can be mixed with a wild population in a way that sustains and rebuilds the wild population.*" (Primary strategies, p. 18). Recent studies of relative reproductive success suggest that harmful effects from interbreeding vary in magnitude by species and populations (Araki *et al.* 2009, Hess *et al.* 2012).

However, few of these relative reproductive success evaulations have compared supplemented streams with unsupplemented reference locations. Only a few streams, like the Hood River, are conducive to studies that assess parentage for the entire population to evaluate genetic, environmental, and carryover effects. Alternative experimental designs are needed to separate genetic from ecological effects where these conditions do not exist. Equivalent relative reproductive success of artificial production and natural fish within a stream cannot be used to assess long-term deleterious effects from interbreeding because only hatchery versus stream rearing differentiates the fish. Similarly relative reproductive success of artificial production and natural fish within a stream cannot be used to assess benefits to abundance because habitat capacity may limit population abundance.

In everyday usage, "supplementation" is often synonymous with "hatchery production." The ISAB thinks that the 2009 Program definition of supplementation (Appendix A, p. 76) which states, "*increase the abundance of naturally reproducing populations*" might be interpreted to include increases from natural plus hatchery fish spawning in the natural environment. The appropriate objective is an increase in the natural-origin adult abundance.

Reintroduction

The artificial production Strategies section of the Program should include guidelines, benchmarks, and a basin-level experimental framework specifically for reintroduction of salmon and steelhead into watersheds in the anadromous reaches where they have been extirpated. Currently the Program identifies that reintroduction should lead eventually to a "*self-sustaining*" natural population (section d. Restoration, p. 19). The ISAB believes this end-point is essential for consistency with first principles of restoration science, and the Program's vision. The Program needs to establish a time frame for achieving this self-sustaining status, biological objectives or benchmarks for identifying success, and methods for tracking progress. Otherwise, projects that are not achieving threshold performance have no adaptive-management path to termination.

Step and categorical reviews of reintroduction projects by the ISRP have revealed the importance of choosing the correct metric for evaluation. Releasing a large number of smolts produced from non-local hatchery broodstock may result in slower adaptation to local conditions than releasing a smaller number of smolts produced from local-hatchery and natural-origin fish because fewer are available as broodstock. Across the Basin, alternative approaches are amenable to experimental evaluation.

Monitoring and evaluation

A monitoring section should be added to the artificial production strategies to be consistent with the monitoring section in harvest strategies. Artificial production monitoring should be closely aligned with the habitat strategy, acknowledging the need for the Program to address the scale of artificial production at the subbasin, province, and basin levels (see John Day Subbasin example in Sidebar II.2.F.1). The artificial production strategies might be better viewed as an integrated program with a mission, instead of each entity and geographic area necessarily having its own hatchery or hatcheries, particularly in light of mixed-stock ocean and freshwater harvests.

An integrated basin-level adaptive management experiment is needed to evaluate the ecosystem and landscape consequences of cumulative hatchery smolt releases and hatchery adult returns. For both salmonids and non-salmonids, it is often not clear how many distinct hatcheries are needed to meet Program goals. It may be informative to compare the basinwide objectives for natural and hatchery salmon smolts and adult returns with the sums of the corresponding subbasin objectives; any discrepancies would have to be reconciled or justified. A series of maps, such as in the ISAB's food-web publication (ISAB 2011-1) showing recent hatchery releases and returns by province for each species and race, would be a useful addition to the revised Program. Additionally, maps could be used to show the percentage of spawners in each watershed that are hatchery fish (e.g., pHOS).

<u>ISAB recommendations for artificial production strategies</u>

1. **Evaluate whether the multiple objectives of recovering ESA-listed species, establishing healthy natural populations, and mitigating harvest opportunity using artificial production can be reconciled and address any trade-offs explicitly.**

2. **Recognize and address the need to quantify the cumulative impacts of artificial production on natural production and ecosystem processes at population, subbasin, and basin scales.**

3. **Revise artificial production strategies to incorporate HSRG advice**. Recognize and address the need to develop quantitative objectives for each artificial production program based on HSRG recommendations.

4. **Treat integrated supplementation (for conservation) and harvest as distinct programs requiring their own standards of operation.**

5. **Specify that segregated artificial production requires removal of hatchery fish before they reach spawning grounds to maintain the genetic integrity of local populations.**

6. **Commit to establishing more empirical evidence concerning the effect of supplementation on rebuilding natural populations and improving integration between artificial production supplementation and habitat restoration programs.** Address the importance of evaluating limiting factors by life-stage, including density-dependent effects of artificial production fish on production of natural-origin adult fish.

7. **Adopt guidelines, benchmarks, and a basin-level experimental framework specifically for reintroduction of salmon and steelhead into watersheds from which they have been extirpated.**

8. **Develop quantitative goals and basin-scale monitoring for artificial production**.

Sidebar II.2.F.1. Artificial propagation

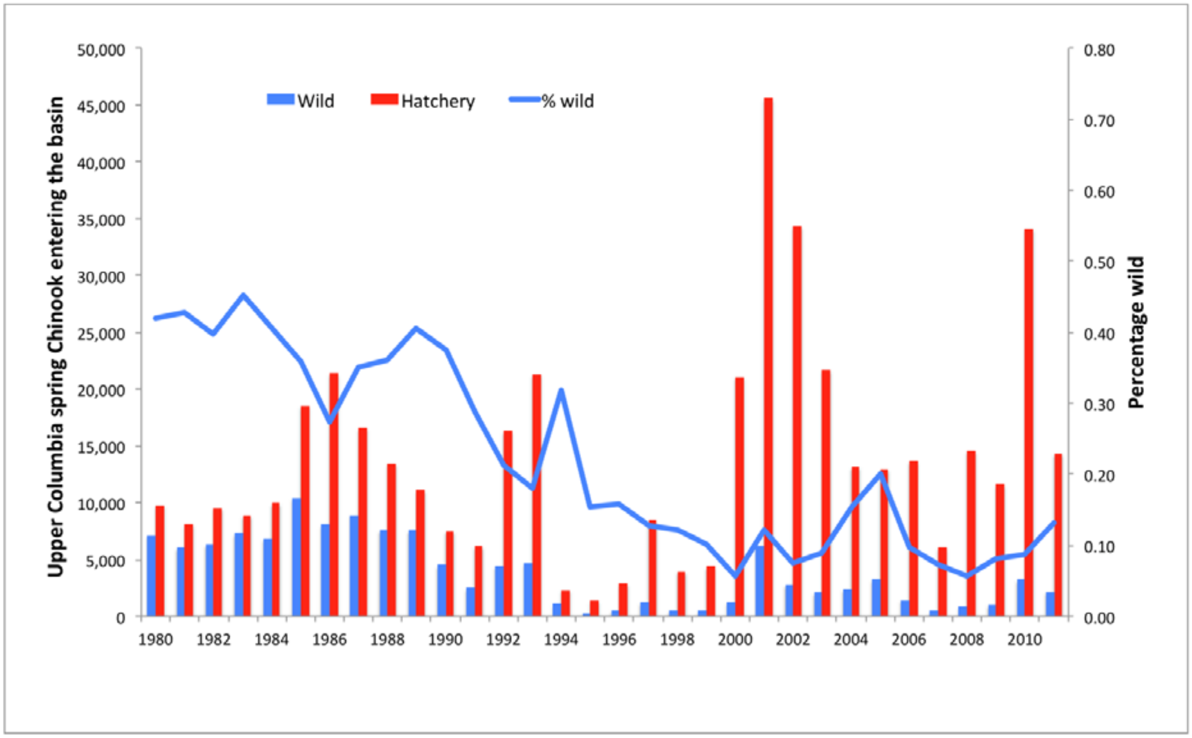
Total numbers of hatchery versus natural-origin salmon and steelhead returning to the Columbia River are not estimated (see CBFWA: http://www.cbfwa.org/), but management agencies have monitored the hatchery versus wild composition of particular stocks.[4] The upper Columbia spring Chinook ESU is ESA-listed as endangered, yet the wild component of the upper Columbia run has declined since 1980 and now represents only 10% of the aggregate hatchery/wild run (Sidebar Fig. 1). The Snake River spring/summer Chinook ESU is ESA-listed as threatened and the wild component has declined to only 25% of the aggregate run (Sidebar Fig. 2).

Upriver summer steelhead include the upper Columbia River, middle Columbia River, and Snake River ESUs, all of which are ESA-listed as threatened. Ten-year average abundances have increased for both hatchery and natural-origin steelhead, and the proportion of natural-origin steelhead has remained relatively unchanged over time at 15-40% (Sidebar Fig. 3). Lower Columbia River coho salmon are ESA-listed as threatened. Hatchery coho salmon have been re-introduced into upriver watersheds, such as the Yakima River. The proportion of natural-origin coho returning to the Columbia River is very low (7%) (Sidebar Fig. 4).

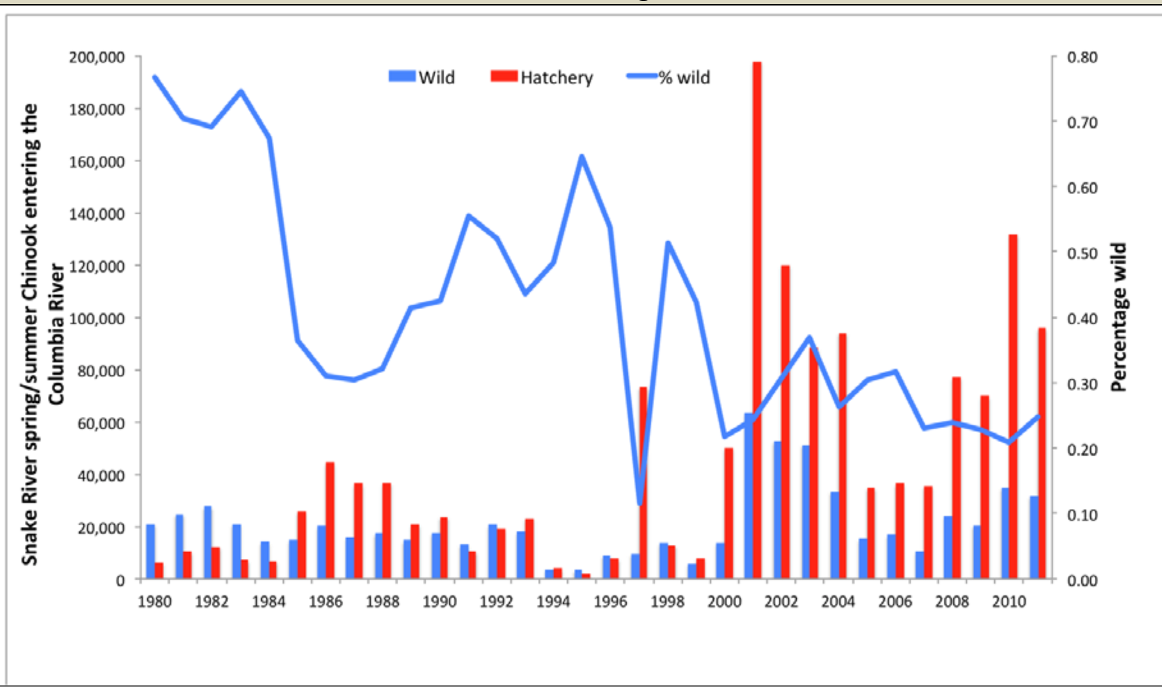
No hatchery fish are released in the John Day Subbasin; salmon and steelhead populations there are enhanced through habitat restoration actions only. Yet after more than 20 years of restoration, steelhead redd counts have declined by 68% and hatchery-origin steelhead (strays from other subbasins) account for up to 30% of spawners (average 14%) (Sidebar Fig. 5). The straying rate into the John Day River is positively correlated with transportation of hatchery steelhead smolts past dams, likely because of reduced opportunities for imprinting. This example shows how seemingly distant factors can affect the success of restoration efforts, and underscores the need for a landscape perspective.

[4] Graphs presented in this sidebar include data from the three stocks assessed for stock composition in the spring/summer management report (Joint Columbia River Management Staff 2012, www.pcouncil.org/salmon/background/) plus reconstructed abundances of natural and hatchery coho salmon provided by WDFW (A. Hagen-Breaux, personal communication). For some watersheds, NOAA Fisheries (www.webapps.nwfsc.noaa.gov/apex/f?p=238:1:0::NO) has estimated the percentage of stream spawners that are hatchery strays, and their database indicates that strays are often present in proportions that exceed maximum levels recommended by the HSRG (5% for segregated, 10% for integrated hatcheries). Estimates of hatchery strays were removed from the Chinook and steelhead graphs but not the coho graph (T. Cooney, NMFS, personal communication).

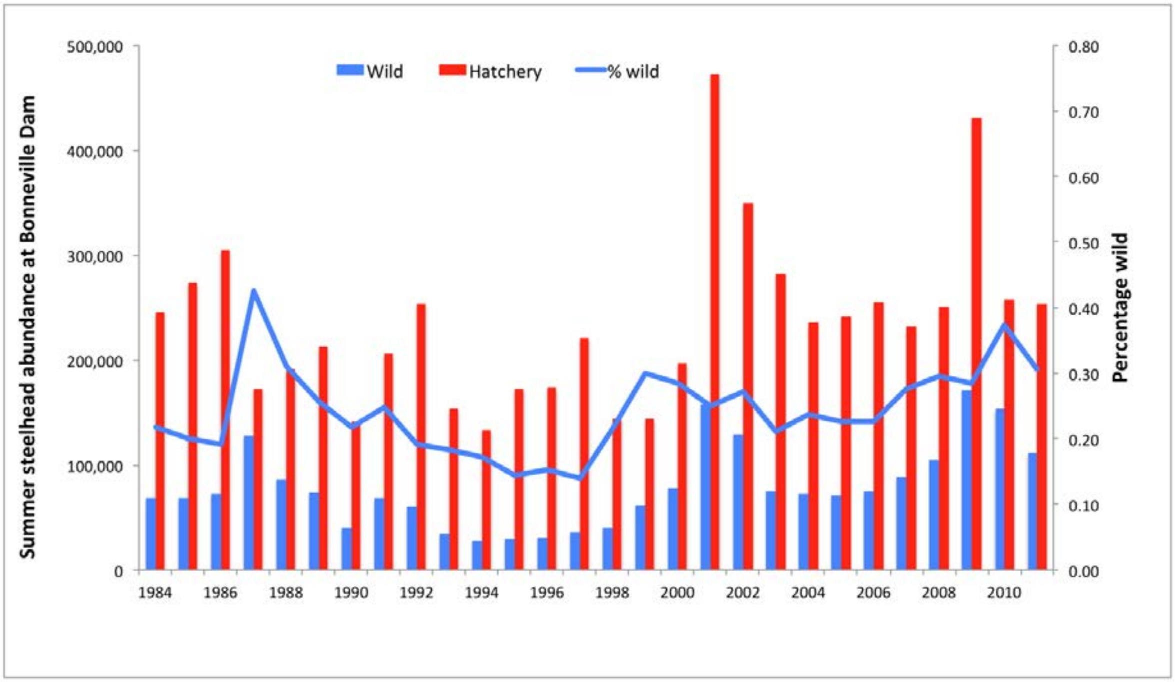
Sidebar Figure 1. Numbers of wild and hatchery upper Columbia spring Chinook salmon entering the Columbia Basin, 1980-2011. Upper Columbia spring Chinook are listed as endangered under the ESA. Data source: Joint Columbia River Management Staff 2012, Table 9.



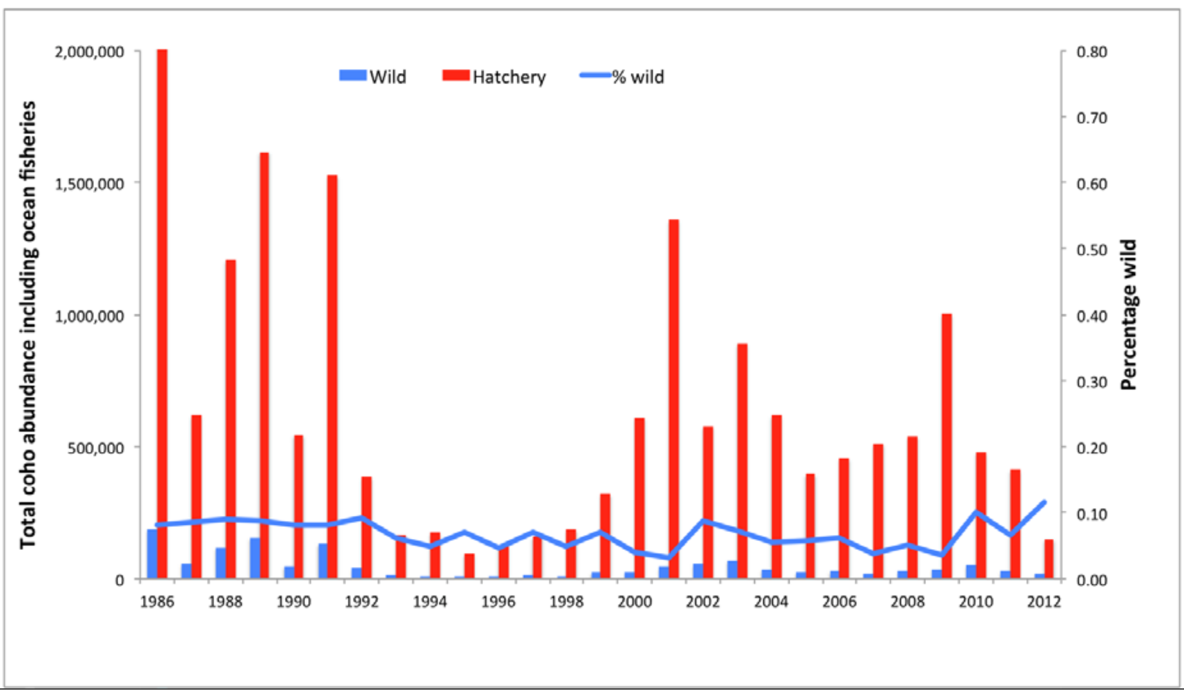
Sidebar Figure 2. Numbers of wild and hatchery Snake River spring/summer Chinook salmon entering the Columbia Basin, 1980-2011. Snake River spring/summer Chinook salmon are listed as threatened under the ESA. Joint Columbia River Management Staff 2012, Table 8.



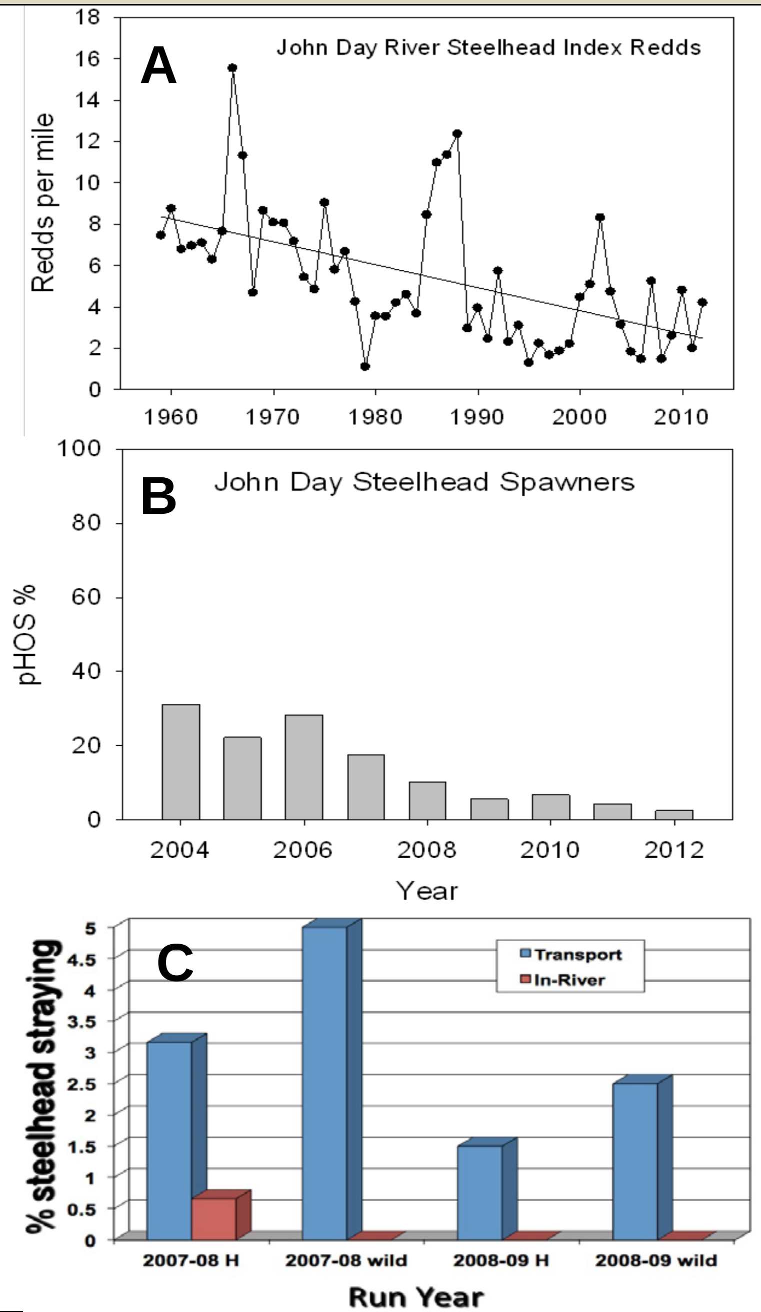
Sidebar Figure 3. Numbers of wild and hatchery summer steelhead counted at Bonneville Dam during April-October, 1984-2011. Columbia River summer steelhead are listed as threatened under the ESA. Data source: Joint Columbia River Management Staff 2012, Table 12.



Sidebar Figure 4. Numbers of wild and hatchery coho salmon returning to the Columbia Basin, 1986-2012. Values include ocean harvest mortalities, inriver harvests and escapement. Wild run may be slightly over-estimated because escapement counts include hatchery strays. Columbia River coho salmon are listed as threatened under the ESA. Data source: A. Hagen-Breaux, WDFW, personal communication.



Sidebar Figure 5. John Day steelhead trends illustrate why a landscape approach is needed in the Columbia Basin. A) natural steelhead redds have declined in the John Day MPG since 1959 despite actions to improve habitat; B) the proportion of natural spawners that are stray hatchery steelhead (pHOS) has been high even though no hatchery fish are released in the John Day watershed; and C) steelhead transported in barges consistently stray into the John Day River more than steelhead that migrated inriver. Stray hatchery steelhead are considered a major factor contributing to the decline in wild steelhead (panel A). Declining pHOS in recent years (panel B) is correlated with the reduction in the transportation of steelhead. Graph and information source: R. Carmichael and J. Ruzycki, ODFW.



G. Harvest Strategies

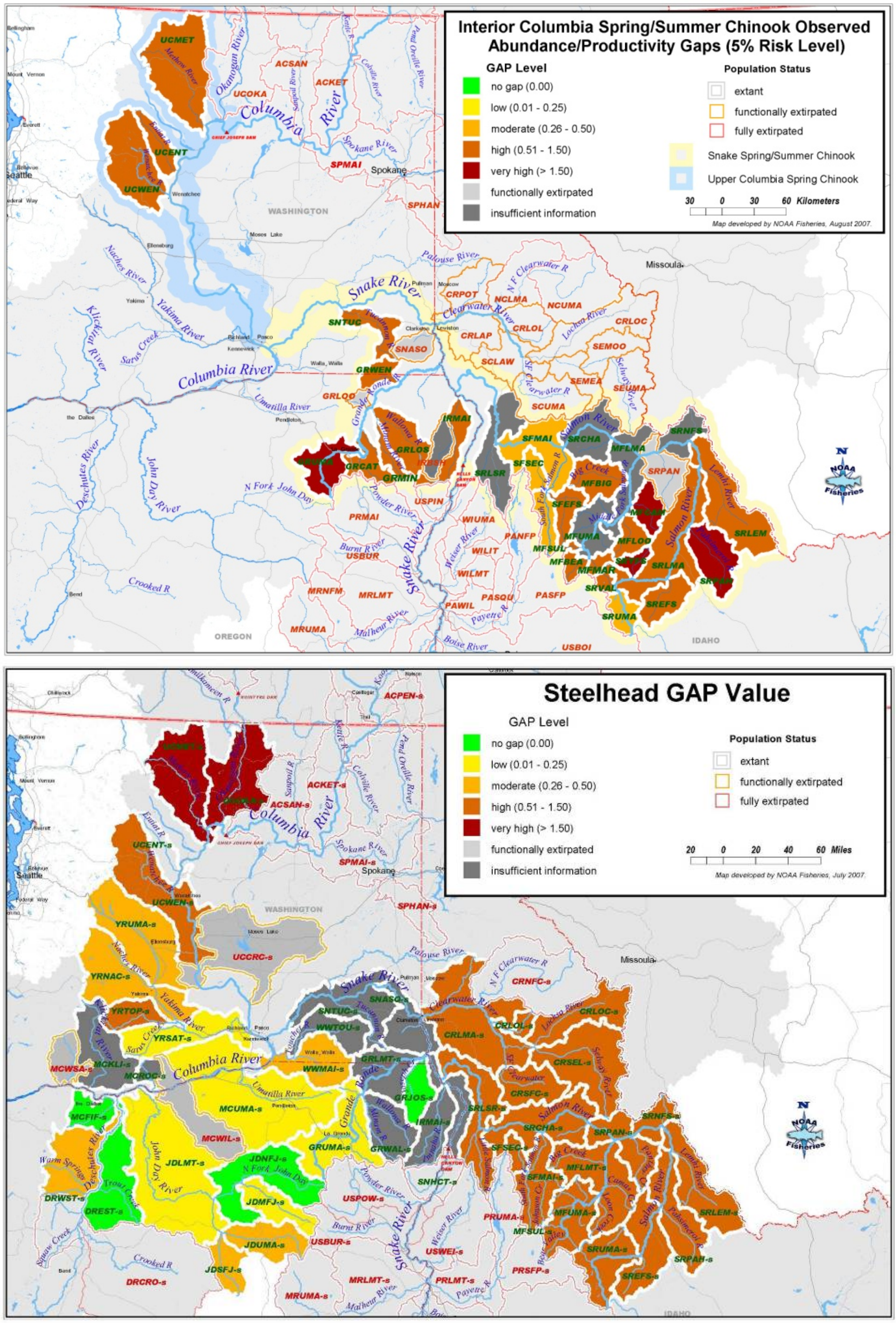
The Program vision emphasizes the importance of harvest, and the Program's hatcheries provide a means to augment harvest. But the Council is not responsible for harvest *management* in the sense of determining an allowable harvest level and then allocating that harvest among fishers. However, the 2009 Program harvest strategies do reflect harvest obligations established in other management domains (United States v Oregon, PFMC, United States and Canada Treaty, ESA). Accordingly, a useful conceptual framework for the Program might be to consider harvest activities, including non-consumptive cultural and recreational uses, as part of a complex food system (e.g., Ericksen 2008) that determines food security, ecosystem services, and social welfare both inside and outside of the Basin. The complex interactions within the food system become apparent by realizing that a Program decision to reintroduce wildlife or increase hatchery fish production for harvest in one location will affect the intensity and distribution of harvest activities, and thus the status of fish and wildlife populations, elsewhere in the Basin. The effects of harvest activities reverberate throughout the ecosystem, and harvest management decisions have the potential to affect the resilience of the entire ecosystem. A better understanding of the entire food system could improve harvest-related decision making within the Program and enhance sustainability.

Human fisheries account for more mortality of large fish in the Columbia River Basin than any other predator (ISAB 2011-1, p.67). Fishing mortality affects nutrient cycling, metabolism, genetic selection, wildlife abundance, and a host of other important biological parameters. Harvest management is needed to achieve spawning escapement goals that will sustain natural communities. Ecosystem-scale considerations need to be acknowledged in the Program's harvest strategies and acted upon, as for example, when hatcheries are recommended to artificially enhance harvests.

New evidence indicates that fishing can cause detectable evolution in salmon characteristics like body size, migration timing and age of maturation within ten or fewer generations (Hard et al. 2008). Although the mechanism is not clear, interactions between hatchery propagation and fishing also seem to lead to a younger age distribution. Such fisheries-induced evolution could affect both productivity and carrying capacity (the spawner–recruit relationship), and adversely affect sustainable harvest rates and the long-term viability of natural populations (Hard et al. 2008, Eldridge et al. 2010). Accordingly, the Program should encourage experimental testing of evolutionary responses to harvest. Tactics that might reduce evolutionary responses to fishing include (1) reducing size-selective fishing gear and practices that prevent sufficient numbers of larger, older individuals from spawning and (2) shifting intensive fisheries closer to the spawning grounds to reduce directional selection on maturation.

The Program should also include provisions to curb the tendency to harvest too many fish before restoration goals have been met. Although the Program vision includes abundant opportunities for harvest, it will be important to ensure that the pursuit of this long-term objective does not slow ESA recovery and the establishment of healthy natural populations (see viability gaps in Fig. II.3.G.1). To this end, the Program should develop indicators to show trends in the number of hatchery versus natural-origin salmon (by species) harvested in the Basin, for comparison with quantitative biological objectives (e.g., figures in Sidebar II.2.F.1).

Figure II.3.G.1. Abundance and productivity gaps by population for spring/summer Chinook salmon (top frame) and steelhead (bottom frame) as assessed by the Interior Columbia Technical Recovery Team. Color coding represents the proportional increase in productivity required to achieve a low risk of extinction (assuming conditions similar to 1980-2007). Source: Tom Cooney, personal communication, based on data available from:
www.nwfsc.noaa.gov/trt/col_docs/ictrt_gaps_report_nov_2007_final.pdf



The 2009 Program primary strategy for harvest (p. 19) states, "*Ensure subbasin plans are* consistent *with harvest management practices…*" This strategy implies that harvest management could be a major external factor constraining achievement of the Program vision and biological performance objectives. Harvest plans need to be scientifically justified and consistent with subbasin and other plans that establish viability parameters for salmon and steelhead populations. It is not clear that harvest management plans have been scientifically reviewed and analyzed to assess compatibility with the Program. If not, an independent scientific review should be encouraged. Also, where the strategy states, "*increase opportunities for harvest wherever feasible,*" the word "sustainable" should be inserted before harvest, and "*feasible*" needs to be clarified, e.g., with respect to areas, times, and quantities that protect and sustain natural-origin salmon.

Hatchery Scientific Review Group (HSRG)
The ISAB strongly endorses the HSRG's recommendation to explicitly link hatcheries and harvest (HSRG 2009, Paquet et al. 2011), and urges the Council to consider adopting the HSRG recommendations, as stated in the 2009 Program (section a., p.2). The 2009 HSRG recommendations diverge from past ISAB advice on the issue of selective harvest. The HSRG recommends selective fisheries to more fully harvest hatchery fish, whereas the ISAB (ISAB 2005-4) previously concluded that selective harvest of hatchery fish could not be assumed to have an overall conservation benefit to naturally-reproducing populations and that a conservation benefit had not yet been established. CRITFC has also expressed reservations about selective harvest in its presentations to the ISAB and Council. A particular concern about selective harvest is that unmarked cohorts of fish would sustain additional but unknown mortality as a result of fish being caught and released, perhaps repeatedly; this additional unknown mortality could compromise their viability and would complicate the assessment of harvest rates on indicator stocks. Further work is needed to quantify conservation benefits and losses, and it may be worth pursuing methods for selective harvest in terminal areas to fully exploit hatchery fish while allowing natural populations to spawn. If new evidence provides a reason to reconsider the ISAB's (2005-4) conclusion, the justification should be developed in the harvest strategy.

Artificial production
Presently, many hatchery fish go unharvested due to concerns about overexploiting wild stocks. In some instances, ISRP reviews have revealed that hatchery production intended for harvest is not being exploited. For example, adult returns of Umatilla hatchery spring Chinook and Imnaha hatchery steelhead were not being fully harvested in terminal fisheries. Since the Program is producing these fish to meet obligations to provide harvest, it is potentially a vehicle for adaptive management experiments to explore other options to meet the harvest objective and to improve this mitigation aspect of the Program. Important questions to be asked include: Are harvest rate data readily available for each hatchery? Are hatcheries being terminated, as recommended in the 2009 Program (section b., p. 20)? Is artificial production being reduced in watersheds where hatchery fish are not being fully harvested?

Monitoring and reporting
Continuation of stock monitoring and data management programs is essential. Stock monitoring should separate hatchery from natural-origin fish so that productivity (e.g., R/S) and abundance of the natural stocks can be documented and used to develop escapement goals and manage harvests accordingly. Spawning escapement goals should be developed, as recommended in the 2009 Program.

<u>ISAB recommendations for harvest strategies</u>

1. **Assess the extent to which harvest slows recovery of naturally-reproducing populations that are below the replacement level (R/S <1) and delays the objective of establishing healthy naturally-reproducing populations.**

2. **Recognize and address ecosystem-scale effects of harvest and potential fisheries-induced evolution**. Address whether harvest management plans have been scientifically reviewed and analyzed to assess compatibility with the Program.

3. **Consider revising harvest strategies to reflect HSRG conclusions**. Determine the circumstances in which selective harvest confers a conservation benefit to wild populations.

4. **Evaluate the impacts that limitations in the extent of hatchery fish harvest have on natural spawning populations through factors such as overexploitation and straying.** Address whether hatcheries are being terminated as recommended in the 2009 Program.

5. **Develop the capability to monitor hatchery and natural-origin fish separately so that the productivity and abundance of the naturally reproducing stock can be tracked and used to develop escapement goals and harvest rates**. Recognize that this monitoring has been an important "term and condition" in some NMFS hatchery Biological Opinions.

3. Knowledge Gaps

A. Hydrosystem Impacts

The Mainstem Plan has received much attention and has been one of the most successful components of the Program, especially as it relates to improving salmonid passage. Accordingly, in this review, the ISAB focuses on issues that have received less attention, and where knowledge is still rudimentary or seriously lacking.

The infrastructure in the hydrosystem provides special opportunities for experimental management to test hypotheses related to system operations and factors affecting fish movement, passage, and spawning response and success. Important innovations in hydrosystem design and operations to improve salmonid passage can be attributed to the successful small-scale application of adaptive management principles. The Program should continue to foster application of adaptive management to examine hydrosystem impacts on other important species such as lamprey, sturgeon, and shad. For example, experimental manipulation of the pulse shape and duration of water releases, compatible with power needs, might contribute useful knowledge about how water flow attracts these fish or affects their spawning behavior.

Of all fish species in the Basin, the status of white sturgeon is most strongly tied to conditions in the mainstem, which are directly affected by the hydrosystem. The white sturgeon has declined greatly in abundance throughout most of the Columbia Basin. Only the population segment below Bonneville Dam still shows substantial natural recruitment, despite the fact that it is affected by hydrosystem operations at all dams upstream. It is anticipated that diminished natural recruitment will be a major factor influencing sturgeon status and the sustainability of harvest fisheries. Natural recruitment of sturgeon is potentially affected by hydrosystem operations directly, through blocked passage or inundation of preferred spawning areas, and indirectly, through the effects of water flow and sediment release on spawning success. In addition, recently documented predation on adult sturgeon by Steller sea lions just below the Bonneville Dam may threaten that population (www.cbbulletin.com/406133.aspx).

The relationship between hydrosystem operations and sturgeon passage and reproductive success needs more investigation. Studies to date indicate that only the east fishway at The Dalles Dam provides moderately efficient passage for sturgeon. More information is also needed on mortality associated with downriver passage. Without adequate passage and recruitment, natural recruitment and population abundance will continue to decrease, leading to a dependence on hatchery stocking programs as the only option to maintain abundance.

Lamprey recovery efforts have progressed greatly since the 2009 Program was written, and many different groups (the tribes, the Corps of Engineers, the U.S. Fish and Wildlife Service, state agencies, and universities) are now conducting studies aimed at improving mainstem passage, reintroducing lamprey into depleted areas, and better understanding the life history and population biology of lamprey. The ISRP recently recommended (ISRP 2012-19) that these diverse research efforts should be coordinated within a recovery plan. Efforts are also needed to develop a comprehensive database and to foster data sharing.

Addressing mainstem passage needs of sturgeon, lamprey, and other non-salmon species will require new approaches to accommodate species with different requirements. In particular, it will be necessary to identify situations where strategies benefiting those species may conflict with well-established approaches for improving salmon passage.

Steelhead kelt reconditioning research is continuing within the Basin, but the work has not been evaluated comprehensively in terms of its potential effectiveness and feasibility. More coordination among investigators would be beneficial. Undoubtedly this work, if successful, would create some benefits by maintaining diverse life histories within and among populations, and by improving knowledge of steelhead physiology. However, it seems worthwhile to evaluate the potential cost- and biological effectiveness of the kelt reconditioning approach for improving run sizes and life history diversity of returning adults through the hydrosystem.

It also seems important to learn (1) how short–term fluctuations in water release affect fish access to main channel and connected side channel habitat, and stranding rates, especially of larval and juvenile fishes (including lamprey) that use the margin areas for rearing and (2) how reservoir conditions might be improved to increase SARS, and to generally provide better habitat for juvenile salmonid rearing. More information is also needed on the role that mainstem reservoirs play in providing rearing habitat for native salmonids and other fishes, and how conditions might be improved.

ISAB recommendations for addressing hydrosystem impacts

1. **Continue to foster and support more formal adaptive management experiments designed to provide information on hydrosystem operations and their effects on salmon and other species.**

2. **Foster and support efforts to monitor and improve white sturgeon passage through lower mainstem dams and conduct research on factors in the mainstem hydrosystem (including aspects of reservoirs) that affect natural spawning, reproduction, and recruitment success**

(Consistent with Council direction to the 2012 Columbia River Basin White Sturgeon Planning and Passage Workshop).

3. **Develop a unified plan for lamprey restoration efforts conducted under the Program, The U.S. Army Corps of Engineers' Anadromous Fish Evaluation Program (AFEP), as well as by tribal, state, and federal entities** (Consistent with ISRP 2012-19).

4. **Evaluate the feasibility and cost-effectiveness of steelhead kelt reconditioning, particularly in relation to mainstem hydrosystem operation and passage issues.**

5. **Investigate the potential impacts of short-term fluctuations in water releases and of reservoir habitat and water levels on access to habitat, growth and survival of larval and juvenile fishes and other species.**

B. Freshwater Habitat Restoration Requirements

Habitat restoration is the central element of the current Program and a major focus of current implementation funding. While the success of that effort remains critical to the program, it is also highly uncertain that habitat restoration will be successful as presently configured. Section D of the 2009 Program (p. 5) states that "*The Program has identified the basin's biological potential and the opportunities for improvements.*" As indicated in other sections of this review, quantitative objectives for habitat, an unambiguous assertion of biological potential, and a route to achieve the potential through habitat restoration actions, are not yet available. Under the Basinwide Provisions section, Planning Assumptions, Habitat (p7), it is stated that "*This is a habitat-based program. The Program aims to rebuild healthy, naturally producing fish and wildlife populations by protecting, mitigating, and restoring habitats and the biological systems within them*." The ISAB believes that it is important to further state that the biological potential is uncertain (see discussion of carrying capacity above) and that the scope of restoration and improvement required to achieve the vision remains unknown. It is unknown how many stream miles need to be restored or reconnected, where the additional capacity or habitat quality needs to be located, and how that will link to mid-scale and basinwide measures of success. It is important to keep the limited success of past efforts clearly in mind if the stakeholders in the Program are to have a common understanding of the challenges being faced. Further, it must be recognized that habitats are components of the landscape and depend on patterns and processes with a broader context.

In an important sense, the Habitat Strategies and other discussion in the Program create something of a split personality. On one hand, the Program is described as a habitat-based program, but also one that must focus on ecosystem-scale components and some processes. In general, the Habitat Strategies section of the existing Program is well written, but it could be revised to be more consistent with a landscape perspective. The ISAB has identified three general areas where the discussion of habitat restoration and appropriate strategies for implementation should be strengthened.

Habitat as a component of ecosystems and landscapes

The ISAB believes the Program needs to be *ecosystem-based* with habitat restoration being just one important component. Success will come by protecting ecosystem or landscape-scale processes, such as biological and hydrologic connectivity, and the broader conditions underpinning resilience, such as diversity and more effective public engagement (ISAB 2011-4). The 2009 Program focuses on subbasin plans as context and then lists a series of strategies (p.15) or rules of thumb (*i.e., build from strength, restore ecosystems, use native species*). This guidance is important, but the direction could be strengthened by explicitly acknowledging the landscape approach and the four primary recommendations from ISAB 2011-4 (p. 87): broaden socioeconomic engagement; build from landscape ecology; organize for integration and collaboration; and foster adaptation through adaptive management. Rules of thumb for prioritization of habitat restoration can be useful to help managers develop a common foundation, but a more complete set associated with a landscape perspective are also available from the recent ISAB 2011-4 (Table VII.1, pages 94-96). The ISAB encourages the incorporation of a more complete context into the rules of thumb for habitat restoration strategies in the revised Program.

Emerging issues constraining habitat restoration
The emerging issues identified at the end of the section Habitat Strategies in the 2009 Program and those mentioned in other parts of the Program (e.g., non-native species, climate change, toxics, carrying capacity, artificial production) need to be addressed directly and aggressively. These issues are huge and could limit the success, and even derail the overall effectiveness of habitat restoration if not embedded in habitat strategies, monitoring, and evaluation (e.g., unexpected influence of hatchery strays in the John Day Subbasin, Sidebar II.2.F.1). The Council's leadership is needed to assess and understand these emerging issues and to allow managers to determine whether habitat restoration can be successful, where it is currently most important, and how these determinations may change in the future. Administrative and scientific review in the Program should encourage or require proponents of funded projects to explicitly consider the degree to which changing socio-ecological conditions might compromise or overwhelm any benefit from efforts to restore habitat.

Evidence of successful habitat restoration
There is still insufficient evidence that the "*most common habitat protection and improvement activities implemented under the program*" (2009 Program p.16) are actually producing important biological benefits. This conclusion is unlikely to change in the immediate future because the core of the Program's habitat-improvement activities is unlikely to change, and strategies for comprehensive and consistent monitoring of fish populations and habitat are still being developed. The conclusion will only change when consistent, quantitative evaluation within an appropriate framework for strong inference about the effectiveness of habitat actions is used to justify and refine or redirect continuing efforts. In the past, monitoring has been broadly discussed but rarely implemented well. Actions have been justified based on broad assessments or conventional wisdom, with little documentation or quantification of specific successes, and virtually no broad analysis to suggest that habitat restoration, as currently implemented, has been effective at the scale of subbasins or entire populations. This is not a problem unique to the Columbia Basin (Palmer et al. 2005, Palmer 2009), but it is one that remains critical to success.

The substantial investment in the ISEMP and CHaMP projects to develop consistent and comprehensive monitoring and analytical assessment is promising. These kinds of projects are needed to effectively evaluate and guide habitat restoration, and they have the potential to revolutionize the generally ineffective and inconsistent approaches that have existed in the past. Many in the Basin have already taken note and are beginning to follow or implement some of the methods. The ISAB believes that it will be important to see these projects through to their logical conclusions and to require a full and critical evaluation of the results. If these projects are successful, new opportunities for technology transfer, analytical support, and coordination of monitoring across similar ecological settings may be possible. If they are not, the reasons for failure will reveal the next steps. Either way, future efforts will build on a stronger foundation in this critical area of the Program.

<u>ISAB recommendations for freshwater habitat requirements</u>

1. **Uncertainties concerning the success of habitat restoration efforts should be addressed.** There is a need to view habitat restoration as an experimental process that will require much better sampling designs at multiple scales. The ISRP has commented that the effectiveness of habitat restoration will depend not only the success of a specific action (e.g. planting riparian zones, fencing, flood plain reconnection) but also on how those actions are arranged within a watershed. For example, in many subbasins, actions are implemented through willing landowners, not through a prioritized strategy – and the success of such an opportunistic approach is questionable (ISAB 2011-4).

2. **Consider habitat restoration as a long-term effort focused on creating the landscape and ecological conditions that underpin resilience.** The Program should encourage project sponsors to recognize that habitat restoration may take a long time to show positive effects, particularly if it is focused appropriately on processes constraining or degrading habitat rather than on the structure or condition of the habitat itself (i.e., the symptoms; ISAB 2011-4). Incorporation of the rules of thumb from the landscape report in the revised Program could help emphasize a broader perspective.

3. **Establish quantitative objectives and timelines and require detailed evaluations, or formal reviews to evaluate whether habitat restoration efforts are really providing the anticipated benefits.** Quantifiable objectives are required to provide clear direction and context. An audit/review process involving experts (such as was done for hatcheries by the HSRG), but with a focus on habitat and landscape restoration, could be used to explore the current state of restoration actions in the Basin. A formal review of the results from ISEMP and CHaMP should be highlighted and shared broadly with all engaged in Program projects.

4. **Consider the potential for conflict among the diverse efforts at conservation and restoration in the Basin.** The Program is not the only habitat restoration program in the Basin, and as pointed out in the ISAB Landscape Report, many other entities have authority over actions that lead to degraded watershed conditions. For example, Program project participants might be removing roads to improve salmon habitat while other stakeholders in the same subbasin might be adding new roads at faster rate (e.g., Forest Service mitigation efforts for fuels). Successful habitat restoration requires integration and collaboration among all actors in the landscape.

5. **Encourage the sharing of experience and information among programs engaged in similar actions.** Innovation and diffusion of ideas, successes, and failures across the Program can strengthen the capacity to adapt and refine restoration actions. By supporting "communities of practice" (Rogers 2006), the integration of information across projects becomes a basic principle of effective habitat protection and restoration activities.

C. Terrestrial Wildlife Restoration Strategies

The primary wildlife strategy included in the 2009 Program is "*Complete the current mitigation program for construction and inundation losses and include wildlife mitigation for all operational losses as an integrated part of habitat protection and restoration*." The Program establishes wildlife losses in terms of habitat units. Use of habitat units for mitigation accounting and the Habitat Evaluation Procedure for estimating habitat units lost and acquired should be reconsidered in light of the possibility that other methods may better account for habitat quality and quantity. The wildlife program defines key species yet has taken a habitat unit approach to track mitigation credits. It is important to validate the relationship between the HEP habitat units and some real measure of value of the habitat, such as abundance, productivity, diversity, and spatial extent for key species. The Wildlife component of the Program would benefit by shifting emphasis from habitat units toward an ecosystem strategy.

The 2009 Program also states "*the Council believes that the wildlife mitigation projects should be integrated with the fish mitigation projects as much as possible*." Such integration should be strongly encouraged and rewarded as part of an ecosystem approach. For example, research in Hokkaido revealed that about one third of the diet of summer migrant songbirds in riparian zones of small streams can come from emerging aquatic insects (Nakano and Murakami 2001; Uesugi and Murakami 2007). Thus, restoring healthy stream habitat can support riparian migrant songbirds, because these habitats are tightly linked within the ecosystem.

One point concerning wildlife losses that seems to be missing is that the anadromous and resident fishes that have been lost might also have supported diverse and abundant wildlife including bears, wolves, eagles, ospreys, and mink. Have these losses also been accounted for? The section on Wildlife Strategies indicates that these "secondary" losses may be specifically excluded, which seems unwise. For example, loss of spawning runs of Yellowstone cutthroat trout by lake trout invasion in Yellowstone Lake has resulted in loss of a seasonal food source for hundreds to tens of thousands of bears, otters, eagles, osprey, and pelicans (Gresswell 2011).

ISAB recommendations for terrestrial wildlife restoration strategies

1. **Validate the relationship between the HEP habitat units and some real measure of value of the habitat, consistent with an ecosystem approach, such as abundance, productivity, diversity, and spatial extent for key species.**

2. **Encourage integration of wildlife mitigation projects with fish mitigation projects, consistent with an ecosystem approach.**

D. Estuary Strategies

Considerable progress has been made on the estuary component of the Program since the last review. Methods recently developed by the estuarine research community have improved our understanding of this dynamic ecosystem and the new information suggests that a number of modifications are required to the estuary component of the Program.

The Mainstem Plan does not address linkages with the estuary, below Bonneville Dam. After about 40 years of research we now realize, from a landscape point of view, that the estuary can have profound effects on salmonid and ecosystem restoration, below *and* above Bonneville. Processes in the estuary such as predation affect the survival of salmonids (e.g., Roby et al. 2003) after they have passed mitigation efforts upstream. At the same time, reservoir operations affect food webs in the estuary (Simenstad et al. 1990) which in turn could affect the survival of subyearlings with concomitant implications for major efforts at wetland restoration. Consideration should be given to developing an Estuary Plan that could be coordinated with the amended Mainstem Plan.

A fundamental aspect of estuarine ecology is how processes in the estuary interact with ocean and river ecosystems. Upwelling offshore and penetration of the salt wedge, for example, can influence factors such as the spread of invasive copepod species (Cordell et al. 2008), nutrient supply (Roegner et al. 2011a) and dissolved oxygen (Roegner et al. 2011b). River and reservoir ecosystem processes can influence salmonid food web functioning in the estuary as described above. The interaction of the river, estuary, and ocean has been stressed in ISAB reports (e.g., ISAB 2012-6), but these intimate connections are not always recognized in management processes. To improve the linkages, an amended plan should also emphasize coordination of estuary and ocean strategies.

We now know that subyearling fall Chinook and coho from lower river populations benefit from estuary restoration, based on their feeding, residency patterns, and habitat use (Roegner et al. 2010, 2012; Weitkamp et al 2012). Significant areas of their habitat in the shallow-water wetland areas have been restored by breaching dikes and other methods. The results of the Columbia Estuary Ecosystem Restoration Program (CEERP) show that upriver Chinook and steelhead use the increased food supplies resulting from restoration. We also know that the estuary, especially its channel habitat, is dominated by hatchery released fish (Weitkamp et al. 2012).

The potential benefits of estuary restoration are not currently measured in terms of fish survival and this is inconsistent with the following statement in the 2009 Program (p. 32): "*Recent scientific research suggests that survival improvements for habitat actions taken in the Columbia River Estuary have the potential to improve survival benefits for fall Chinook salmon by 9 percent and spring Chinook, sockeye, and steelhead by 6 percent, a survival improvement possibly unequaled by tributary habitat actions.*" New methods are needed to measure the potential for increasing survival of Chinook and steelhead that benefit from estuary restoration. The metrics currently being used (habitat opportunity, habitat capacity, and salmon performance) by CEERP require clarification, as suggested in a recent ISAB review (ISAB 2012-6) of the draft synthesis of CEERP's recent work.

Evaluating the success of restoration in the estuary in terms of benefits to salmon is a challenge because of the complexity of the estuary ecosystem. The Council should consider adopting alternative evaluation methods such as experimental or modeling approaches to supplement the valuable life history and basic biological studies being conducted. New information on Chinook and steelhead smolt survival in the lower estuary channels (Harnish et al. 2012, Rechisky et al. 2012) should be reviewed for its application to estuary management and concerns about bird predation. Experiments to evaluate the effects of hydrosystem operations on changes in fish survival in the estuary should be used in conjunction with modeling to guide hydrosystem actions.

Another important finding relates to diversity. The estuary is unique among subbasins (Bottom et al. 2005; ISAB 2012-2) in that the entire diversity of anadromous salmonids in the Basin passes through the estuary as juveniles and adults. "Smolt diversity" seems localized in estuarine channels and "fry-parr" diversity in the estuary wetlands margins. Smolt diversity in the estuary channels may be reduced by the prevalence of hatchery fish and losses due to heavy bird predation whereas fry-parr diversity has been affected by habitat loss and food web changes in the estuary. It has been estimated that >90% of juvenile Chinook and coho salmon and steelhead are of hatchery origin in the channel, open-water habitats of estuary, a rate higher than previously reported (Weitkamp et al. 2012). Increased proportions of hatchery fish suggest correspondingly lower genetic diversity in the channel habitat. The diversity issue is an overarching concern for the Columbia River Basin (see II.3.A, above) and the estuary may be an efficient location to assess diversity representative of all anadromous species including salmon, lamprey, and sturgeon. Genetic, life history, population, provenance (hatchery or wild) and species diversity are some of the metrics that could be considered. Projects to develop methods to monitor diversity metrics in the estuary should be considered in an amended Program.

The draft CEERP report identified problems with the time frame for monitoring restoration projects in the estuary. Long-term effectiveness monitoring for representative habitat restoration projects is essential for evaluating impacts and for adaptive management, but a long term plan has not been developed for the estuary. This gap warrants attention in amending the estuary component of the Program. It may also be useful to incorporate other findings from the final synthesis report, possibly after further review. For example new insights into factors limiting production in the estuary may lead to reassessment of those previously identified in the Estuary Module (NMFS 2011a). The Estuary Module may need to be updated and peer reviewed as suggested by the ISAB (ISAB 2012-6).

New information indicates that tidal freshwater habitat in the estuary may be critical for juvenile salmon survival and therefore should be included in estuary subbasin planning. It seems appropriate to include the tidal zone and lower reaches of major tributaries, for example the Willamette and Grays rivers, now that this type of habitat has been found to be important to salmonids in the estuary (Teel et al. 2009, Roegner et al. 2012). Rising sea levels related to climate change (ISAB 2007-2) are also likely to change estuary boundaries in the future.

ISAB recommendations for estuary strategies

1. **Develop detailed strategies for the estuary in conjunction with the mainstem and ocean.** Consider developing a coordinated Estuary Plan that meshes with amendments to the Mainstem Plan and Ocean Strategies.

2. **Develop methods to measure the potential increase in survival of Chinook and steelhead that benefit from estuary restoration.**

3. **Develop methods to monitor diversity in the estuary to track diversity in time.**

4. **Develop a comprehensive plan for monitoring estuary restoration**. Long-term effectiveness monitoring of representative habitat restoration projects will be essential for evaluating outcomes as part of adaptive management.

5. **Reassess factors limiting production in the estuary, including contaminants, in light of new research.** As suggested earlier by the ISAB, it may be appropriate to update and peer review the Estuary Module.

6. **Consider redefining the boundaries for the estuary subbasin to include the tidal regions at the mouth of tributaries draining into the estuary.**

E. Impact of Ocean Conditions

The recent synthesis of 1998-2011 ocean research under the Program (Jacobson et al. 2012) and the ISRP's review of the synthesis of results (ISRP 2012-3) point to a larger role for considering the impact of ocean conditions on the Basin's fish and wildlife than is encompassed by the ocean strategies in the 2009 Program. The productivity of anadromous populations in all subbasins of the Columbia River Basin is affected by physical, biological, and ecological conditions in the ocean. The primary ocean strategy would be improved if expanded beyond survival to include growth (that affects size and age at return), and spatial structure and life history diversity of all anadromous fishes important to the Program (salmon, steelhead, lamprey, sturgeon, and smelt). Managing for variability in life-history traits and distinguishing ocean from freshwater effects continue to be important strategies. However, more attention should be given to understanding how growth, survival, and diversity is limited by ocean conditions and competitive interactions among species; to identifying critical thresholds of smolt size and migration time; and to predicting adult returns of both wild and hatchery fish.

To maximize benefits to all fish and wildlife populations in the Basin, the strategies should include greater emphasis on discovering the linkages between freshwater, estuarine, and ocean survival and growth, and on understanding how ocean conditions might limit restoration potential and action effectiveness in the Basin. Coordination of ocean strategies and associated management actions across subbasins and ecosystems might be accomplished through periodic ocean policy meetings of the Council and formulation of an expert team led by Council staff comprising project managers and scientists. The amended Program might also be improved by including graphics to illustrate linkages between freshwater and ocean ecosystems, ocean effects and management actions, and ocean life history patterns of anadromous species important to the Program.

Primary ocean strategy

The ISAB suggests revising the 2009 Program's concept of how the ocean environment is related to the Columbia River ecosystem. In the opening sentence of the Ocean section (p. 31, initially stated on p. 3), the ocean environment is considered as an "integral component" of the Columbia River ecosystem. Instead, the Columbia River Basin and the ocean should be considered as separate geographically delineated ecosystems with strong linkages that determine the survival and growth, and consequently viability (abundance, productivity, spatial distribution and diversity) of anadromous fishes in the Basin and ocean. The ISAB also suggests defining ocean conditions to include physical and biological factors and their interactions. It is worth emphasizing that poor ocean conditions can reduce survival for most if not all salmon species and life-history strategies. For example, despite their high life history diversity, virtually all wild populations of sockeye salmon in Bristol Bay, Alaska, collapsed in the early 1970s when ocean conditions were unfavorable (Rogers 1987; Ruggerone et al. 2007).

The ocean section in the 2009 Program should also be updated to reflect important recent advances in scientific understanding of the effects of ocean conditions on salmon survival – information that was synthesized for the Council by Jacobson et al. (2012). The ocean section in the 2009 Program seems to disregard processes at smaller spatial and shorter temporal scales that can affect ocean survival of anadromous fishes. For example, the first paragraph of this section (p.31) recognizes only "large-scale" atmospheric and oceanographic processes that link freshwater and marine environments, and the second paragraph recognizes only annual- or decadal-scale variations in ocean conditions. The Program also needs to recognize meso- (10-100 km) and local-scale oceanic processes and habitat conditions such as sea surface temperature, salinity, upwelling intensity, and plume variability that vary at seasonal and shorter (monthly, diel) time scales. Ideally, in-river actions should anticipate ocean conditions at the appropriate spatial and temporal scales.

The opening sentence of the third paragraph states "*we cannot control the ocean*," but in fact, human society already controls many physical and ecological factors within the Basin, including hydrosystem operations, hatchery fish production (abundance, size and time at release), harvest rates, ocean acidification, and pollution levels (see section II.3.C), all of which are potentially significant to the ocean ecosystem, particularly in the Columbia River Plume and coastal ocean habitats in the vicinity of the river mouth. Recent studies are confirming that increased densities of hatchery and wild salmon in the ocean can adversely affect ocean conditions for salmon growth and survival, leading to reduced productivity and size at return (e.g., Ruggerone et al. 2003, Holt et al. 2008, Ruggerone et al. 2010, Connors et al. 2012). This density dependence could be exacerbated by climate change impacts and hatchery release practices.

The number of adult returns to the Basin is a measure of success for human activities such as harvest, hatchery broodstock, and escapement goals, which are often not available; however, survival and growth rates, productivity (R/S), stock composition and distribution (diversity and spatial structure), and biological characteristics such as age and body size at maturation and fecundity are better indicators of ocean success conditions for anadromous fishes. More consideration should be given to how ocean environmental conditions such as prey availability, predation, coastal upwelling, and temperature support abundant, productive, and diverse populations. Daily early ocean mortality rates are likely higher than those in the river (e.g., see POST/COAST project results; Porter et al. 2011), and this large early ocean influence on SARs needs to be considered when setting biological objectives. A list of populations to be assessed by the Program, along with their status and SAR trends should be included as an appendix.

Ocean strategies

The ocean strategies in the 2009 Program focus on single species rather the ecosystem with its complex array of potential species interactions and ecosystem services. The opening sentence of this section (Ocean strategies, p.31) identifies three habitats: the freshwater plume, the near-shore ocean, and the high seas. This section could be expanded to describe the importance of these specific ocean habitats with respect to ocean survival of anadromous fishes and potential interactions with hydrosystem operations, hatchery production, and harvest management. The text of the Program should note that anadromous species, and even populations within species, differ in their use of plume, near-shore, and high seas habitats, and it should avoid sweeping statements about common effects in all ocean areas.

The boundaries of the ocean habitats should be defined more explicitly so that management decisions, actions, and strategies can be appropriately scaled and efficiently and effectively implemented, monitored, and evaluated. The Columbia River Plume seems to be identified as the appropriate spatial scale for achieving basinwide biological performance objectives (p.13, Objectives for Environmental Characteristics) and is defined as extending up to 500 miles (805 km) beyond the mouth of the river (Appendix A). Defined in that way, the plume considerably exceeds the scale of 350-450 km recently estimated as the threshold for statistically significant spatial co-variation in SARs among Chinook salmon populations in the Pacific Northwest and Southeast Alaska (Sharma et al. 2012). The implication here is that the plume is large enough to generate response diversity among populations within the Basin, and so metrics are needed to track individual populations as they migrate through the plume, coastal ocean, and high seas habitats. It should be noted, however, that stock identification technologies and analytical procedures are currently too limited to track variability in ocean survival for every population in the Basin.

Manage for variability

The "Manage for Variability" section (p.31) focuses on management actions that help anadromous fish and other species accommodate a variety of ocean conditions by providing a wide range of life history strategies. The Program should be more explicit about the management actions, species, and range of life-history strategies under consideration. Biological diversity (mentioned twice on p.6) and ocean effects (considered on p.7) are linked and more important than is indicated in the 2009 Program. To update and revise this section, the Council should refer to ISRP's programmatic comments on the importance of marine life history diversity of anadromous fish (ISRP 2010-44). The Council should consider developing HLIs for anadromous species that measure ocean life history diversity and spatial structure (see II.2.A.), as heterogeneity of anadromous populations and habitats in the ocean is likely to enhance the resilience of the Columbia River ecosystem.

Distinguish ocean effects from other effects

A single sentence in the 2009 Program understates the benefits of monitoring and evaluation to separate the effects of ocean- and freshwater-related mortality. Ocean and estuarine effects on the growth and survival of anadromous fishes are large and variable enough to obscure the effectiveness of smaller, but still important, effects of restoration actions taken in fresh water. Thus, the ability to isolate ocean effects from freshwater effects significantly increases the power of statistical analyses to detect the benefits of changes in hydrosystem operations or activities elsewhere in the Basin. As a guide to revision, the ISRP's review of the ocean synthesis report (ISRP 2012-3) includes several recommendations for focusing efforts to obtain the most critical information for understanding how ocean effects combine with hydrosystem effects to influence salmon survival (p.4).

Ocean research is needed to develop more reliable pre-season forecasts of ocean survival and adult salmon returns (ISRP 2010-44). Much of the current forecasting effort is geared toward predicting opportunities for harvest. However, there is also a need to explore the potential to forecast ocean conditions for salmon survival further into the future so that hydrosystem operations, transport, and hatchery production could be adjusted in time to improve outcomes.

Coordination of ocean strategies across subbasins and ecosystems will increase benefits from research, monitoring and evaluation in the Program. A concerted RM&E effort and sustained cooperation from government agencies and foundations will be required to understand the complexities of ocean effects on the survival, growth, and viability of the Basin's anadromous species. By demonstrating leadership and taking responsibility, the Program could catalyze an appropriately scaled effort in cooperation with other programs and agencies conducting ocean research relevant to the Program (p.65, Coordination with Other Regional Programs).

<u>ISAB recommendations for ocean strategies</u>

1. **Emphasize that the productivity of anadromous populations in all subbasins of the Columbia River Basin is affected by physical, biological, and ecological conditions in the ocean.** Expand the primary strategy beyond survival to include ocean effects on growth and viability (abundance, productivity, spatial structure and diversity) and recognize interaction effects among these processes.

2. **Revise and reorder the ocean strategies** as follows:
   a) first priority, to understand and isolate effects of ocean conditions on anadromous fish survival and growth to increase the power of analyses to detect the effects of restoration actions in the Basin;
   b) second priority, to determine limits to restoration potential or the effectiveness of actions taken in the Basin given the variability of ocean conditions that affect anadromous fishes;
   c) third priority, to predict future ocean conditions with a view to adjusting actions in the Basin to achieve greater benefits and/or efficiencies.

3. **Emphasize coordination of ocean strategies across subbasins and ecosystems to increase benefits from research, monitoring, and evaluation in the Program**.

III. Moving Forward

1. Biological Objectives

The Biological Objectives section of the 2009 Program includes many good ideas, but considerable refinement is needed to identify quantitative objectives or benchmarks that implementation strategies can target and that monitoring programs can use to evaluate progress of the Program. More quantitative objectives would facilitate development of HLIs that can be used to inform government officials and the public. It is also important to include metrics for less quantifiable goals like diversity, spatial structure, and ecosystem processes (integrity) so that implementation of the Program is not biased in favor of efforts to achieve more easily quantifiable objectives like abundance and productivity.

Quantitative versus qualitative objectives

Establishing quantitative performance goals both for the biological objectives and restoration strategies is an integral part of adaptive management and provides measurable thresholds for determining success. Despite the statement that "*The Program has identified the basin's biological potential and the opportunities for improvements*" (NPCC 2009-9, p.5 and elsewhere), an unambiguous assertion of biological potential or route to achieve the potential through restoration actions does not appear. It would be better to state that the biological potential remains uncertain and that the scope of restoration and improvement required to achieve the vision is unknown.

True objectives are focused and measurable benchmarks. Many of the “objectives” identified in the Program express general intentions as unquantified goals or strategies to achieve goals. Such goals are important because they help to refine the vision, but the Program needs true biological objectives or benchmarks to refine the strategy to achieve the vision and to evaluate progress through monitoring. Goals and objectives should be stated in a positive manner, rather than highlighting losses of fish and wildlife, e.g., as shown in some headers of the 2009 Program.

Biological objectives should also be realistic and consider the highly altered state of the environment in the Basin. When reviewing the biological objectives in the 2000 Program, the ISAB concluded that explicit linkages between the scientific foundation and biological objectives and strategies were not sufficiently established and that the general nature of the objectives and strategies would not be particularly useful in developing subbasin objectives and management plans (ISAB 2001-6). These criticisms of the objectives and strategies still apply. For example, some of the objectives (e.g., achieve full mitigation, reintroduction of salmon into subbasins where they have been extirpated) are constrained by the existing environmental baseline – the biological community, the hydrograph in both the mainstem and tributaries, water quality, and upland and riparian influences. These constraints are reflected in the scientific foundation as basic principles but are not acknowledged in the biological objectives of subbasin plans, implementation of projects, and decision points by management and Council. Examples of projects mismatched with the existing environment include efforts to provide kokanee in reservoirs that are dominated by non-native predators that may not be feasible to control and therefore prevent sustainable kokanee populations, and to reintroduce salmon into watersheds where habitat conditions have not been restored and probably will not be.

Performance objectives for biological populations

The Program should include quantitative biological objectives that can be regularly monitored and evaluated as a means to determine whether the Program is on target or is in need of change. Biologists familiar with the Basin should be consulted to ensure that objectives can be readily monitored. Quantitative benchmarks should be developed through stakeholder consultation so that the benchmarks are not set too low, or too high. Development of complex or controversial objectives or benchmarks might be phased in over a three-year period, for example. However, this consultation process should not delay the identification and development of objectives, which are needed as a template for measuring progress in the Basin. Time frames for achieving the objectives (a specific year, not "within X years") should be established, as well.

A few quantitative biological performance objectives were stated in the 2009 Program, largely involving abundance and productivity. As discussed below, biological performance objectives should also include population diversity and spatial structure. The ISAB suggests that the Council consider the following modifications of existing objectives for salmon as an example of desirable quantitative objectives:

1. **The objective of 5 million salmon and steelhead by 2025 should be made more specific.** The current objective attempts to address the abundance portion of the viable salmon population criteria (abundance, productivity, spatial distribution, diversity). However, as written, this objective could be achieved with 100% hatchery salmon, which is not consistent with the Program vision. This basinwide objective should be split into at least two objectives, one for natural-origin salmon and one for hatchery fish. The basinwide objectives should be developed from objectives for each species and for each region of the Basin, such as below Bonneville Dam, Snake River, Columbia River above the Snake River, and Columbia River between Bonneville Dam and the Snake River. Furthermore, an obvious abundance objective from the perspective of salmon harvest management is a spawning escapement goal for each species in each watershed. Escapement goals could then be summed to provide the basinwide escapement goal. Alternatively, dam-based escapement goals could be defined for upriver stocks (e.g., see www.pcouncil.org/salmon/stock-assessment-and-fishery-evaluation-safe-documents). The ISAB assembled data and created a graph to evaluate the existing goal of 5 million salmon (Fig. III.1.1); however, the lack of specificity about composition (species, hatchery or wild) leads to many questions about the reasons for increased abundance during the last 10 years. The high contribution by hatchery-origin salmon, including the contribution of hatchery strays to spawning escapements in recent years, raises concerns that are described in section II.2.F of this report.

2. **The Program needs quantitative and realistic objectives for harvest, set with stakeholder input.** This objective is linked to the previous abundance objective, and is a key metric for many stakeholders in the Basin. However, the Program has no quantitative objectives for harvest. Lost harvest estimates in response to human actions in the Basin have been developed and these values, in conjunction with the abundance objectives, could be used to establish harvest objectives for each species, stock origin (hatchery, wild), and region of the Basin. Similarly, the HSRG recommended that harvest objectives be developed for each hatchery. Hatchery harvest objectives should be consistent with sustaining natural populations in terms of genetics, habitat capacity, and harvest levels. Harvest objectives should be established for periods of low, average, and high marine survival since it is unrealistic to expect "abundant opportunities for harvest" during periods of low productivity (e.g., the mid-1990s; Fig. III.1.1). Stakeholder input is

needed to set harvest objectives. Harvest objectives must be developed in conjunction with ecosystem, hatchery, and harvest strategies; they should be realistic and reflect expectations from anticipated improvements in the Basin.

3. **The Program should develop productivity objectives that reflect differences by species and populations.** This objective involves the productivity criterion for viability of salmon populations. Presently, the Program includes an objective to achieve smolt-to-adult return rates (SAR) of 2-6% for ESA-listed Snake River and upper Columbia River salmon and steelhead. Realistic survival rate goals that reflect self-sustaining salmon populations should be developed for each species and stock where feasible. Ideally, the Program would have productivity objectives for key life stages of anadromous salmonid populations, e.g., smolts per spawner, in-river survival, SAR, and adult return per spawner (R/S). Objectives should explicitly consider life-stage productivities needed to maintain a stable population (e.g., R/S = 1) during periods of low survival at sea and objectives needed to provide some level of harvest (e.g., R/S = ~3). Development of objectives should consider stocks and types of data that are presently collected and will be consistently collected in the future, so that key objectives can be evaluated many years into the future. In other words, benchmarks should be developed for indicator stocks that reflect the productivity of stocks throughout the Basin.

4. **Establish quantitative biodiversity objectives for focal species and habitats that can be achieved by 2025.** Diversity is identified in the Program as an important characteristic, but its importance is often overshadowed by abundance and productivity (ISAB 2011-4, ISAB-2012-2). Life history diversity typically reflects the diversity of habitat types and environmental conditions across the respective landscapes (see Ecosystem Objectives below). The basinwide diversity of populations has undoubtedly declined over time, but only limited baseline information is available to track trends in diversity (see section II.3.A). An important first step should be to explore comprehensive measures of biological diversity at the basin scale that can be used to quantify further losses or identify potential issues.

5. **Quantitative objectives should be developed for other species of fish and wildlife in addition to salmonids.** As for salmonids, quantitative objectives should be developed for lamprey, white sturgeon, anadromous smelt, wildlife, and other focal species. For example, objectives for lamprey might involve specific abundance levels for lamprey reaching Bonneville, Willamette Falls, and other specific locations where lamprey can be counted. Given the low abundances of lamprey, these objectives could include targets for lamprey abundances in the future, e.g., 20% increase in 10 years, or whatever seems reasonable to experts. Objectives for white sturgeon and smelt were not identified in the 2009 Program, but the ISAB believes they are important focal species and should be included. It should also be noted that monitoring these species need not be expensive or overly time consuming. South African scientists and managers developed a very effective approach called "Thresholds of Probable Concern" for the national parks and, as well, "Strategic Adaptive Management" (Biggs and Rogers 2003; Rogers and Biggs 1999; Venter et al. 2008). An analogous approach could be used initially in the Columbia River Basin.

Ecosystem objectives

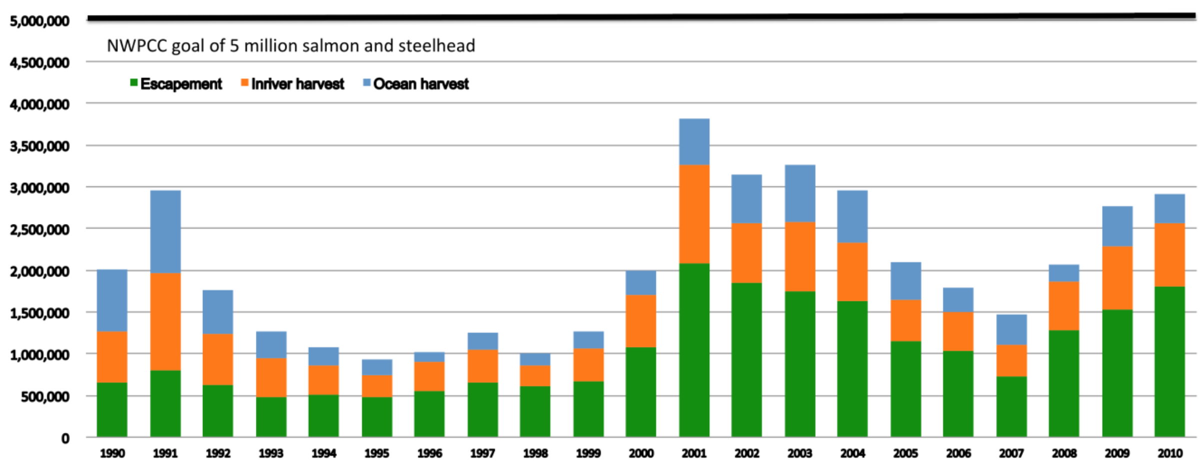
Quantitative objectives are also required to describe the environmental (ecosystem) characteristics of the Basin that are needed to achieve biological objectives for population performance. The current Objectives for Environmental Characteristics seem more like goals and strategies rather than ecosystem objectives. As an example, quantitative objectives for protection of key habitat might include “no loss of key habitats” or “protection of a specific amount of habitat (miles of stream, or acres of habitat)” such that the key habitats must be identified, quantified, and monitored. The ISAB believes that it is essential to have an ongoing census of environmental conditions throughout the Basin for key parameters (e.g., riparian cover and condition, water temperature, turbidity, land cover/use) so that progress can be documented and evaluated. Quantitative objectives might stem from an environmental census and could include recovery of stream flows, stream temperatures, and turbidities that have been impacted by human activities, or targeted reduction in the amount of toxic chemicals discharged into the basin each year. Furthermore, it is noteworthy that the loss of many anadromous and resident fishes in the Basin has likely impacted previously diverse and abundant wildlife; this connection through the food web should be recognized in the Program. Additional discussion is needed to develop quantitative objectives or benchmarks that reflect ecosystem status and can be monitored and evaluated for progress over time.

ISAB recommendations on biological objectives

1. **Develop quantitative biological objectives that can be regularly monitored and evaluated to determine whether the Program is on target or in need of change.** Recommended modifications to existing objectives include:
    a) Make the objective of 5 million salmon and steelhead by 2025 more specific with respect to wild and hatchery fish.
    b) Develop quantitative and realistic objectives for harvest based on stakeholder input.
    c) Develop productivity objectives that reflect differences among species and populations.
    d) Establish quantitative biodiversity objectives for focal species and habitats that can be achieved by 2025.
    e) Develop quantitative objectives for other species of fish and wildlife in addition to salmonids.

2. **Develop quantitative objectives for the environmental (ecosystem) characteristics needed to achieve biological objectives for population performance**.

Fig. III.1.1. Escapement from fisheries, inriver harvests, and harvest related mortalities at sea of Columbia River salmon and steelhead, 1990-2010, in comparison with the Program goal of 5 million salmon and steelhead. Note the large increase in escapement from fisheries beginning in 2000. Harvests include treaty and non-treaty fisheries (commercial, sport, subsistence, non-ticketed treaty sales, and ceremonial). Ocean fishery harvests include Columbia-bound Chinook and coho salmon and non-landed mortalities in commercial and sport fisheries ranging from Southeast Alaska through California (adult equivalent values). Very few Columbia-bound chum, sockeye, pink, and steelhead are taken in ocean fisheries. Approximately 78% of ocean Chinook harvests occurred in British Columbia and Alaska; only 3% of ocean coho harvests occurred in British Columbia and Alaska. Chinook bycatch in offshore groundfish fisheries is not shown. Escapement (all species combined) was calculated by subtracting inriver harvests from the total number of salmonids entering the mouth of the Columbia River, including jack salmon.



<u>Data sources:</u>

ODFW and WDFW. 2003. Status Report on Columbia River Fish Runs and Fisheries 1938-2002.

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WDFW. 2012. Total mortalities of Columbia River-bound Chinook and coho salmon in ocean fisheries. A. Hagen-Breaux, personal communication.

2. Social Engagement and Fostering leadership at Larger Scales

"*For scientists and managers, success will depend on how well they can engage each other and society not as 'experts' but as co-learners and interactive players who are willing to change."* Rogers 2006

The recent ISAB landscape report (ISAB 2011-4) recommended broader social engagement and collaboration as key steps for more effective restoration. That report also recommends stronger efforts to foster leadership and the structures that provide the governance needed for broad collaboration and effective integration across social, political and ecological boundaries, and science-management disciplines (see ISAB 2011-4, Table VII.1 for "rules of thumb").

Engagement in the planning process

An important element in Program planning has been to request public comment at the start of the process. This is a critical step, but in the case of the Program "public" has generally meant the tribes, agencies, managers, and others that have been traditional stakeholders in the Basin programs through funding or direct interests with ongoing projects. There is a broader public reflecting diverse conditions and ecological awareness across the Basin that should also be actively engaged and informed. Conscious efforts to recognize broader interests, concerns, and skepticism can help avoid costly delays in restoration projects, lack of support, or a political impasse later. Effective landscape restoration must include articulation of what matters to people in that landscape, that is recognition of their needs and concerns. By examining the benefits and costs that are expected to follow from landscape restoration, planners can more effectively identify actions and benefits that represent and work within the fabric of the regional culture, and build a common vision for the future. An effective education and outreach process will require a breadth of activities including public meetings as well as print, radio, TV, and social media or web based tools that the Council Public Affairs staff already uses. Engagement that encourages debate and discussion of alternatives, however, will need to occur early in any new efforts. Planning and implementation will require identification of individuals or groups that may be positively and negatively affected by potential actions and not just those currently following the Program. They should include the general public, private landowners that may encompass important habitats or watersheds, and County and City governments or others that influence local decisions, land use, and development.

Building support for implementation

Beyond the planning process, the current Program contains little discussion of public outreach as a critical part of implementation. There is a brief reference under Program Coordination (NPCC 2009-09:64), but no specific measures are included. A section should be added to the Program to explain how socioeconomic engagement will be measured and monitored. It would also help to describe techniques for engaging a broader public through citizen science and community based monitoring, active outreach highlighting and telling good stories, efforts to engage children and adults with scientists and water professionals or through programs like "water or fishing festivals." Active discussion and exploration of real world examples of concepts like biological diversity and other common issues could communicate scientific findings and build awareness, and ultimately yield better support for the Program (see section II.1.C).

One example where more effort to educate participants could be effective is the current tension associated with artificial production. As discussed above, the vision and objectives associated with harvest opportunities, abundance, productivity, diversity, and resilience outlined in the 2009 Program are potentially at odds. The fishing public and the fishery and hatchery managers in the Basin understand the benefits of more abundant fish, but they may not understand the risks when abundance is increased through artificial production at the expense of natural production. The notion that protecting biological diversity, maintaining natural productivity, and respecting the Basin's carrying capacity are the keys to sustainability will require broader understanding and support (ISAB 2011-4; 2012-2). An active education and outreach program that speaks to the entire vision of the Program could provide a better foundation and the public support needed to help move beyond the established management and issues of the past.

The Program should include a mechanism for clear feedback and internal learning. Outreach should be experimental and adaptive just as salmon management should be. Regular surveys of the general public can determine the level of recognition of the program and measure the success of social engagement. The Program should also provide feedback to the traditional stakeholders *and* the general public on how well the Program is achieving its vision. Current efforts to develop High Level Indicators and more comprehensive Basin level monitoring and reporting for the Program are important. Those efforts should include a discussion of progress toward the vision and objectives of the Program, and a clear discussion of how success may be constrained by conflict or inconsistency in implementation.

Fostering leadership and governance for integration and collaboration

Integration and collaboration emphasize relationships across traditional boundaries of ownership, science-management disciplines and responsibilities, and organizations. Better integration and collaboration will be critical to more effective landscape restoration and adaptive management. Cosens and Williams (2012) offer a recent critique of adaptive management in the Columbia Basin and suggest that "adaptive governance" with strong local involvement will be critical to further progress. Those relationships are encouraged and strengthened when there is effective leadership to provide a vision and direction, but also a structure to resolve the tradeoffs that invariably emerge (Cosens and Williams 2012). The 2009 Program mentions the need to support more collaboration and integration, but new or redoubled efforts are needed to ensure continual advancement of this goal. For example, the research plan linked to the Program speaks to the need for a "Regional Research Partnership" and notes that *"The Council is strongly positioned to convene the Regional Research Partnership as the framework …,"* but that has yet to happen. Renewed energy and emphasis on refining scientific guidance for the regional coordination proposals would also be valuable (ISRP 2012-6). The notion of a partnership that would coordinate efforts and facilitate "diffusion" of sound scientific information is critical to learning and innovation (ISAB 2011-4). The revised Program should recommit to Regional Partnerships and explore similar ideas to strengthen regional coordination efforts and share information and learning among projects with common settings or issues.

There are two options for improving leadership and governance at larger scales. One option is to provide leadership directly (e.g., by setting the course and prescribing the forums and structures such as the Regional Partnerships). The other is to foster and support leadership in others. While the two options are not entirely exclusive, the first requires an understanding of issues, actors, and environments and a level of control that may be impossible to achieve beyond the research program. The second requires a capacity to recognize and champion efforts that are innovative and effective even though they may not follow a common or prescribed structure. "Systematic bright spot analysis" (Kareiva and Marvier 2012), where unusually successful examples are highlighted may be particularly useful. Funding strategies that specifically support local governance structures and capacity for collaboration and integration have proven effective as well (McKinney et al. 2010; Johnson et al. 2010). These ideas are considered further in the following discussion of subbasin planning.

ISAB recommendations for social engagement

1. **Actively engage the general public, landowners, county planners, traditional stakeholders, and other groups**, early in the Program planning process.

2. **Strengthen outreach to citizens, landowners, and other groups** with diverse and non-traditional interests to engage in the implementation of the resulting Program (e.g., citizen science and monitoring).

3. **Measure the effectiveness of social engagement** as part of an evaluation of Program success

4. **Create positive incentives for the general public to engage.** Use narratives and stories linking personal well-being and personal commitment to landscapes. Emphasize benefits that come from ecological goods and services beyond simple numbers of fish. Develop financial incentives to support restoration and conservation (i.e., provide tangible support for efforts that help achieve the Program vision).

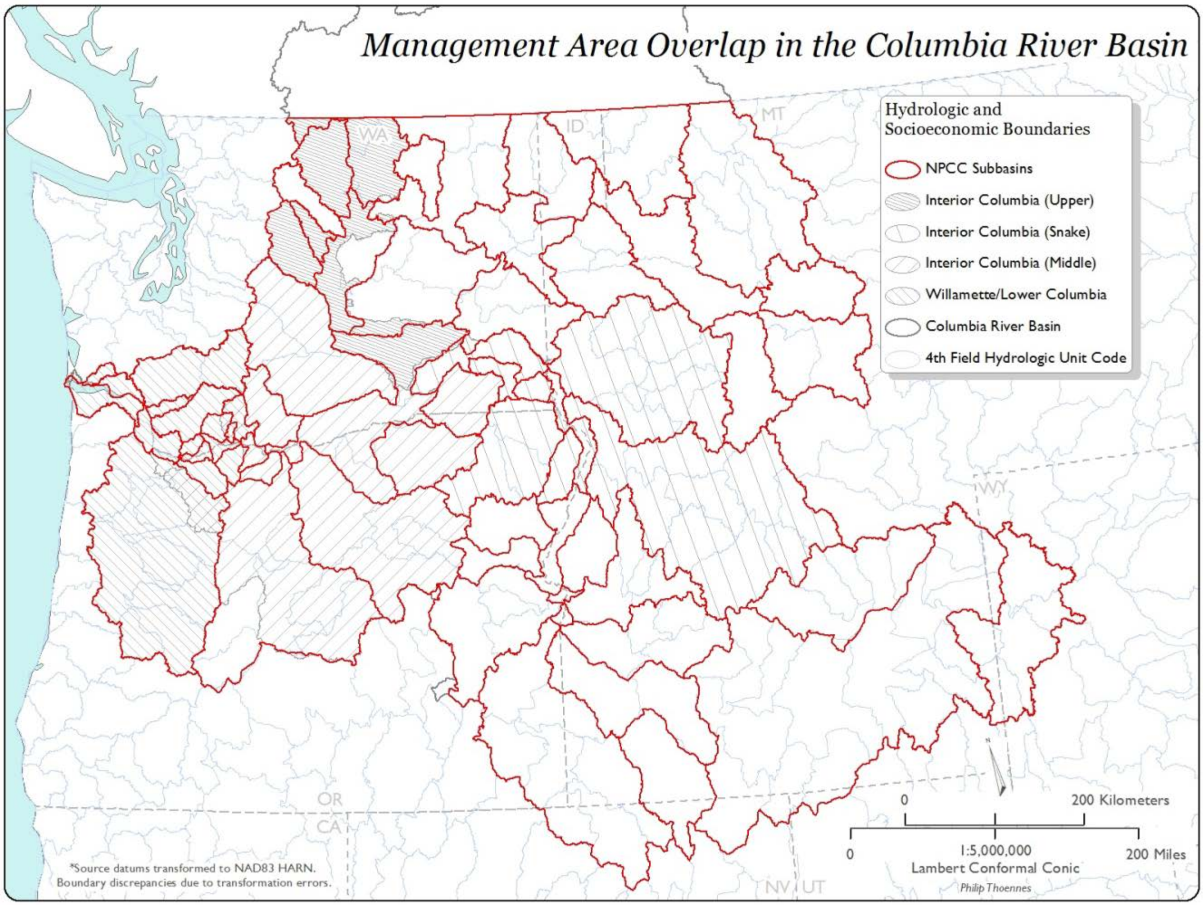
5. **Support and champion organizations that provide effective governance and support productive partnerships** among the relevant sciences, between science, management and the public, and across social and ecological boundaries. Facilitate and support non-traditional organizations and approaches that can bring new capacity and vision to landscape and ecosystem approaches.

3. Landscape and Subbasin Scale Planning

Subbasin planning has provided an important mid-scale framework for current restoration efforts that is consistent with a landscape perspective. How and whether subbasin planning should continue, however, are open questions. Mid-scale planning (like subbasin efforts) is critical, but should not be wedded to a single notion, scale, or prescriptive direction of how that should happen (ISAB 2011-4). The social and ecological boundaries in the Basin are complex (Fig. III.3.1) and are continually evolving with new knowledge and governance structures. An example is the relatively new Southwest Crown of the Continent Collaborative (www.swcrown.org) which focuses on integrating landscape restoration across portions of several of the Council-defined subbasins. The point is to embrace whatever mechanisms and processes actually foster the collaboration and integration of science and people needed to support a true landscape perspective – a "community of practice." The precise scale or boundaries are not set, but the perspective must be broad enough to encompass and support fully functioning aquatic ecosystems and the landscape processes and patterns that support them.

The subbasin planning process was a great idea that has been diminished by the lack of support or continued engagement of the original stakeholders in recent years. The original process was an important attempt to engage local stakeholders and provide a broad context for proposed projects. The usefulness of the plans is now limited because the original versions of many are partially out of date and many of the original participants are no longer active. Continued inclusion of the subbasin planning process in the Program should be reconsidered unless the Council can quickly revive the process to make these plans living documents and unless the stakeholders in those subbasins can retain an effective structure for collaboration and governance.

Figure III.3.1. Overlap of existing subbasins and other management and hydrologic unit boundaries in the Columbia River Basin showing that the subbasins are mid-scale units (from ISAB 2011-4, Fig. V.3). The subbasin units (dark red lines) are at a level that is bigger than the typical watershed (light blue watershed lines) used to organize Oregon and Washington local watershed involvement in salmon conservation and restoration. The four Columbia Basin NOAA recovery domains are hatched. The watershed is the basis for many types of management areas. Many state and federal management and socioeconomic engagement organizations have a watershed focus. These include Oregon watershed councils and recovery regions, and Washington watershed resource inventory areas and recovery areas. The NOAA recovery domains are larger than the Council's subbasin units and most other watershed decision making units.



The ISAB believes that it is critical to support mid-scale planning and assessment that meet the four basic criteria of more effective landscape conservation and restoration (i.e., socioeconomic engagement; landscape ecology; integration and collaboration; adaptation and learning). More effective partnerships may emerge from non-traditional alliances that bridge the capacities and authorities of existing or emerging groups, particularly those that are effectively engaging the public in the process of planning and adaptive management. Useful examples of collaborative planning may cover multiple subbasins such as the Upper Columbia while others focus on one subbasin such as the Grande Ronde Model Watershed project.

One issue relevant to any mid-scale planning effort will be the effective integration of artificial production and habitat restoration (see section II.2.F and ISRP 2005-14). Clear objectives for natural and artificial production that consider existing and expected habitat capacity at population (e.g. mid-scale planning) scales will be required to effectively resolve some of the critical issues surrounding artificial production and habitat restoration (see section III.1).

The challenge of developing effective mid-scale conservation strategies and the governance structures is not unique to the Columbia Basin. As suggested above, "systematic bright spot analysis," which examines especially successful cases with a view to duplicating the conditions that created them, could be useful. A "community of practice" engaged in mid-scale planning might evolve by sharing progress, encouraging innovation, and highlighting both successes and challenges (Rogers 2006). Modeling, analysis, and other tools are important to highlight and share. Electronic and social media developments are important to ensure engagement and rapid updating, for publications and new projects. The Subbasin Dashboards recently implemented by the Council staff are a promising approach that may help current or future mid-scale planning efforts and should help alert managers, biologists, and interested citzens to new developments. The expanding use of social media by the Council Public Affairs staff should also be helpful to maintain a collection of influential contacts in each of the existing subbasins or other planning structures that emerge, to facilitate sharing and communication. These efforts should be maintained and even expanded as possible. It could be particularly useful to resurvey stakeholders across the Basin periodically to determine how well these communication efforts are working and to guide refinements in the process.

ISAB recommendations for landscape and subbasin planning

1. **Actively encourage and support a mid-scale planning process** that provides the context for a more complete landscape approach, but not necessarily with physical boundaries of the established subbasins. A strict reliance on subbasins as the formal structure for mid-scale planning should be reconsidered if other structures exist. Benefits of engaging collaborative structures that already exist or develop through local efforts may be better adaptive learning, communication, and trust.

2. **Actively highlight particularly effective planning efforts**, and the partnerships and organizations that support them, as outlined in the discussion of social engagement and leadership. This would step beyond the summary of existing subbasin coordination to publicize unique approaches in the implementation of landscape and ecological restoration. The intent is to share and focus attention of all planning groups on specific efforts that demonstrate particular success and innovation.

3. **Require proposed and continuing projects to demonstrate their relevance in the broader context of mid-scale social and ecological conditions**. This requirement was basic to the original subbasin planning efforts, but understanding of habitat capacity and the physical and biological processes relevant at the scales of entire watersheds and riverbasins are continually being refined. Proponents should clearly demonstrate the anticipated benefits of any project relative to the scale of the problem being addressed.

4. **Evaluate how effectively mid-scale planning efforts articulate objectives for artificial and natural production and integrate supplementation and habitat restoration efforts.**

5. **Conduct periodic surveys of stakeholders to determine the effectiveness of communication and coordination efforts and to identify the most influential pathways for new information.**

4. Concluding Remarks

Is the Fish and Wildlife Program on a trajectory to be successful?

A primary conclusion of the ISAB review of the 2009 Program is that continuing to implement the program on its existing trajectory is highly uncertain to achieve the Council's biological objectives for the Basin. The ISAB suggests a revised focus on sustainability that emphasizes habitat conditions sufficient to maintain natural populations and strategies to protect diversity and to build adaptability. A landscape perspective, drawing from broader community involvement, could help build consensus on Program objectives and strategies, or if this is not possible, it could at least help to create strategies that keep options open, consistent with a diversity of visions for the future.

The ISAB appreciates that changing the course of a 30 year-old program will be challenging for the Council. For example, CBFISH.org lists approximately 400 active Program projects with contracts. Many projects have been operating since the early 1980s and now have an established constituency in terms of management agency funding support, technical team careers, and end users such as tribal and sport harvest. Consequently, there is enormous inertia to maintain the status quo. However, a broader landscape perspective becomes possible if a consensus can be reached that minor modifications to the existing program will not achieve success. Achieving that consensus is a sociological task, strongly supported by management and science. Once achieved, management and science could re-invent or mold existing projects into a new suite of projects more consistent with a landscape perspective. Assessments by state and tribal co-managers as to the success of the Program to date could be useful in providing justification for continuing or modifying existing strategies, or their priority in implementation.

The current institutional structure could be improved in two important ways to better incorporate science into management and recovery planning: 1) revise the Program to emphasize the attainment of quantitative objectives and timelines (implementation); and 2) adopt a broader perspective to identify, design, and implement projects in accordance with science-based priorities to restore natural populations by protecting natural processes and habitats on which they depend. The ISAB recommends that Council decisions be guided by the precautionary principle and structured decision making (SDM) within an adaptive management cycle.

The ISAB is particularly concerned about two aspects of Program implementation: the widespread reliance on artificial production and the incomplete use of adaptive management. These concerns are described in detail below.

Artificial propagation is a risky foundation for restoration

Concerns about artificial propagation have been described in depth previously by the ISRP, ISAB, and others (e.g., Lichatowich and Williams 2009, HSRG 2009). While artificial production has maintained and improved fisheries in specific cases, no documented cases are known to the ISAB where the original obligations for mitigation have been achieved. Further, there are no documented cases where a natural population's status has materially improved because of supplementation, such that the return of natural origin salmon has increased relative to an unsupplemented control population. The Program's artificial production strategies do incorporate contemporary understanding of scientific risks of using artificial production as a tool to rebuild wild populations and/or to provide for harvest while minimizing adverse impacts of hatchery fish on natural stocks, but the ISAB concludes that the artificial production strategies are not being adequately informed and implemented. The ISAB is concerned that the heavy reliance on supplementation may be counterproductive to the success of the Program and, in the case of production hatcheries, may be driving the ecosystem in directions that will reduce the viability of native populations and foreclose options for the future (see Sidebar II.2.F.1.). The ability of the Program to affect hatchery management in the Columbia River Basin hinges on cooperation and coordination with the management of hatcheries funded and implemented outside of the Fish and Wildlife Program (Fig. II.3.E.1, Fig. II.3.D.1). For example, Mitchell Act funded hatcheries produce about 50% of the hatchery fish released in the Columbia River Basin (NMFS 2011b). In addition, Lower Snake River Compensation Plan hatcheries, although funded by Bonneville and reviewed by the ISRP, are mandated by Congress independent of the Fish and Wildlife Program.

The amended Program should incorporate the following five major recommendations from the ISRP's review of artificial production activities within the Columbia Basin (ISRP 2010-44). Implementing these recommendations could improve the balance between artificial production programs and restoration activities.

1. *Use supplementation as an experiment*. Projects recently reviewed in the Council's Three-Step Process have improved experimental designs, but subsequent analyses from some project proponents remain incomplete and the effects of supplementation are inconclusive. The analyses and application components of adaptive management need to be completed for the adaptive management cycle to be effective; otherwise, supplementation is no longer an experiment.

2. *Require technical design and risk assessment*. Most projects funded by BPA require appropriate ecological, disease, and genetic risk assessments as part of the design phase before approval, and most ongoing BPA-funded projects are conducting retrospective risk assessments prior to the approval of additional funding.

3. *Require rigorous monitoring and evaluation*. While most projects have sufficient data for evaluating performance in hatcheries and contributions to fisheries and adult escapements, an evaluation of ecological effects on natural populations is missing. Such evaluations are needed at multiple levels (i.e., specific drainage, subbasin, province, basin, and ocean for anadromous species) and should be based on appropriate performance metrics. A basinwide program like the previously proposed Columbia River Hatchery Effects Evaluation Team (CRHEET) would be highly beneficial.

4. *Use ecosystem management principles*. In the Three-Step Process, project proponents must show that their proposal is consistent with the Council's artificial production principles and the Program framework. However, in many cases, these responses do not adequately consider uncertainty. There is a need to better address carrying capacity and its variability over broad spatial and temporal scales and, as well, to understand the capacity of existing habitat to support focal species, including natural-origin salmonids.

5. *Require programmatic-level evaluation and reform*. The HSRG report is a step (not the conclusion) in this process. Importantly, there is no mechanism to initiate substantive reconsideration of project or program goals and approaches, or even to conclude that a project or program is not achieving its biological objectives. Effective programmatic-level evaluation and reform will promote a paradigm shift within the region and the Program regarding the appropriate use of, and expectations from artificial production. Further, reform on issues

related to impacts of artificial production on ESA-listed natural populations in the step or project reviews is constrained by legal decisions.

While considerable progress has been made on implementing these recommendations, more is needed. The ISAB believes that hatchery production poses considerable risk to self-sustaining natural populations and that alternative strategies are needed for sustainability in the face of change. An opposing view is that self-sustaining natural populations would require restoration efforts and constraints on land use that are beyond political and practical reality. A landscape approach is needed to resolve the struggle between these opposing viewpoints and to determine the restoration strategy for the coming years.

Implementation of adaptive management has been ineffective

The scientific policy of adaptive management has been a central tenet of the Program since the late 1980s. Adaptive management calls for a deliberate effort to conduct management experiments that can provide useful information for *future* decision making; information that would not otherwise be available. Adaptive management is also a system policy, combining monitoring, evaluation, and research so that the aggregated effects of the Program can be detected, assessed, and improved over time. The monitoring and evaluation process provides feedback on the outcome of projects within the adaptive management cycle. Unfortunately, adaptive management is not being practiced as originally intended (e.g., Shurts 2005, Lichatowich and Williams 2009, Westgate et al. 2012) and its implementation has not been successful overall (Cosens and Williams 2012).

Almost without exception, project sponsors state that they use adaptive management to modify the tasks and work elements in proposals. At the same time, project proposals rarely provide (1) an experimental design to identify whether biological objectives have been met by employing specific strategies, or (2) a decision tree that would be used to modify management based on updated scientific information. Often project sponsors propose to continue to employ tasks and work elements even when monitoring data indicates that biological objectives are unattainable because of environmental and biotic conditions. Sponsors of these projects are understandably reluctant to abandon efforts in which they have invested much time and energy. The reasons why adaptive management has not been implemented effectively are varied and complex, but can be summarized as follows (from Shurts 2005, Cosens and Williams 2012):

Overconfidence – Scientific and management personnel involved in restoration actions, are for the most part, overly certain about their understanding of the ecosystem and the relationships between restoration actions and effects. Therefore, the adaptive management process is perceived as delaying effective actions.

Lack of real experimentation – People tend to be skeptical about the possibility of learning for future decisions when deciding on management actions; the lag time seems too great and the political, social, and environmental issues are immediate and always changing. Further, the Basin and organisms of interest are so variable over time and space that the ability to control or understand the confounding variables or designate reference conditions makes true experimentation difficult.

Lack of effective monitoring – Actions are monitored, but systematic evaluation falls short of what is needed, for at least two reasons. Few, if any, analyses are conducted at appropriate scales (e.g., province level) and the components being monitored are limited in scope (e.g., an almost exclusive emphasis on a limited number of fish species with relatively little attention to ecosystem characteristics).

Lack of will to terminate unproductive activities – Rarely are restoration actions to benefit salmon determined to be clear failures or clear successes, or if successful in some way, that the benefits are substantially greater than costs. Further, investments in restoration create vested interests, jobs, and constituents such that the human costs of terminating particular approaches can be socially and politically crippling.

Lack of scientific consensus – Scientific information is susceptible to different interpretations, and scientists are often overconfident of their own interpretations of information. Some decisions become a matter of choosing among competing models (Section II.2.A).

Lack of adaptive governance – adaptive management is only one of four criteria of *adaptive governance* needed to foster social-ecological resilience by focusing on diversity, redundancy, and multiple levels of management that include local knowledge and local action (Cosens and Williams 2012). The other three criteria for effective adaptive governance include polycentricity (also referred to as legal pluralism in legal scholarship), public participation, and management at the bioregional (or provincial) scale.

Structured Decision Making could help resolve conflicts

Fortunately, new approaches have emerged for resolving these conflicts and improving understanding, management, and decision-making associated with complex systems. Structured Decision Making (SDM) is a transdisciplinary approach that incorporates key elements of adaptive management, quantitative modeling, social dimensions, statistical rigor, and ecological understanding. SDM explores alternative decisions by first clearly defining the problem, agreeing upon objectives, developing alternatives over several iterations, and then evaluating consequences. It requires stakeholder and expert input, aided by simulation modeling, and appears to be well suited to addressing Program issues.

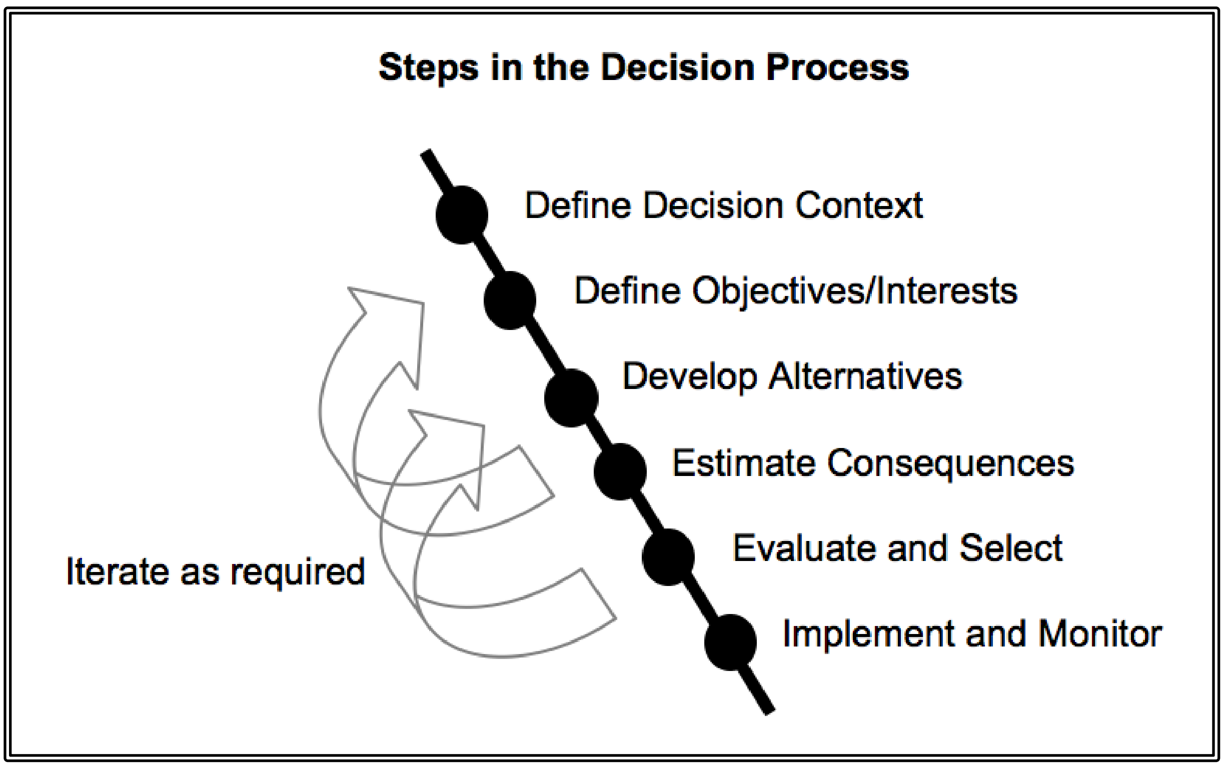
The ISRP introduced and described the SDM process in previous retrospective reports (ISRP 2008-4, 2011-14; Figure III.2.1). While there have been few, if any, direct applications of the SDM approach within the Columbia Basin supported by the Program, numerous successful examples of SDM have emerged in the formal fisheries literature, e.g., for recreational fisheries (Peterson et al. 2008, Irwin et al. 2011), water resources (Liua et al. 2007), hydroelectric developments and water use (Failing et al. 2004), coastal marine ecosystems (Espinosa-Romero et al. 2011), lamprey control in the Great Lakes (Haeseker et al. 2007), and for other natural resource applications (e.g., Tenhumberg et al. 2004, Wenger et al. 2011). In addition, several recent management plans within the Columbia River Basin have benefited from a similar, although indirect SDM approach (e.g., Chief Joe Hatchery Master Plan and the All-H Analyzer [AHA] model application to hatchery reviews). Also within the Basin, Peterman (2004) included a decision analysis example from the Snake River in his review of recent work on fisheries challenges, illustrating that decision analysis is a useful framework for focusing members of a diverse multi-stakeholder team, and accounting for sometimes differing views about hypotheses and uncertainties, even for issues related to Chinook salmon and dams in the Columbia River.

As well as improving the overall effectiveness of decision making, SDM would expand the professional base for analyses and communication. In reality, the current scope of Program projects is based largely on a relationship network of previous projects rather than on the scientific foundation needed to achieve current Program goals. The Program would benefit from broader analyses and better communication, and these endeavours will require support to capture the region's best professional skills.

Expanding the project solicitation process to provide for full and open competition would improve the scientific quality and scope of analyses, opportunities for understanding, and chances for Program success. Examples of analyses may include province-scale analyses of restoration actions; a basinwide understanding of how biological diversity contributes to recovery and resilience, better decisions and increased local responsibility through SDM; and provision of leadership in addressing complex issues like chemical contaminants, biological diversity, and carrying capacity.

The ISAB recognizes that a commitment for the Program to operate within a science-based decision framework is a policy decision; however, science can play an educational role in discussions leading to a change as well as a role in proper crafting (optimization) of decision rules that are also policy decisions (Goodman 2009).

Figure III.2.1. The backbone of the Structured Decision Making process.



<u>ISAB recommendations for moving forward:</u>

1. **Acknowledge that artificial production alone cannot achieve the Program's biological objectives for salmon and other species, and revise artificial production strategies appropriately.** Adopt a landscape approach and implement strategies that unambiguously establish the necessity and primacy of an environment sufficient to maintain self-sustaining natural fish and wildlife populations.

2. **Acknowledge that adaptive management is not being practiced as originally intended and seek opportunities for "intentional learning" as part of the adaptive management cycle.** As well, it would be timely to explore institutional changes (adaptive governance) to focus on diversity, redundancy, and multiple levels of management to include local knowledge and actions.

3. **Encourage Structured Decision Making (SDM) as a tool within the Program.** SDM can augment the adaptive management cycle with a decision process that addresses uncertainty and engages stakeholders, scientists, and decision-makers in an iterative manner.

4. **Revise the scope of projects and project selection process to capture the best professional skills in the region.** Key aspects of the Program would benefit from broader analyses and better communication, and these require appropriate projects. Outcomes may include province-scale analyses of restoration actions; a basinwide understanding of how fish biodiversity contributes to recovery and resilience; better decisions and increased local responsibility through SDM; and improved leadership in addressing complex issues like chemical contaminants.

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