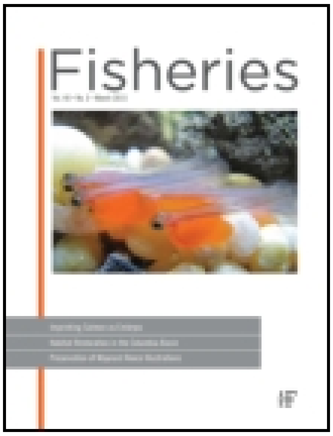

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A Comprehensive Approach for Habitat Restoration in the Columbia Basin

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FEATURE

A Comprehensive Approach for Habitat Restoration in the Columbia Basin

The Columbia Basin once supported a diversity of native fishes and large runs of anadromous salmonids that sustained substantial fisheries and cultural values. Extensive land conversion, watershed disruptions, and subsequent fishery declines have led to one of the most ambitious restoration programs in the world. Progress has been made, but restoration is expensive (exceeding US$300M/year), and it remains unclear whether habitat actions, in particular, can be successful. A comprehensive approach is needed to guide cost-effective habitat restoration. Four elements that must be addressed simultaneously are (1) a scientific foundation from landscape ecology and the concept of resilience, (2) broad public support, (3) governance for collaboration and integration, and (4) a capacity for learning and adaptation. Realizing these in the Columbia Basin will require actions to rebalance restoration goals to include diversity, strengthen linkages between science and management, increase public engagement, work across traditional ecological and social boundaries, and learn from experience.

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Un enfoque integral para restauración de hábitats en la cuenca de Columbia

La cuenca Columbia alguna vez albergó una gran diversidad de peces nativos y grandes corridas de salmones anádromos que sostuvieron importantes pesquerías y valores culturales. La conversión extensiva de la tierra, la interrupción de cuencas hidrológicas y la subsecuente disminución de las pesquerías han puesto en marcha uno de los programas más ambiciosos de restauración a nivel mundial. Se ha progresado, sin embargo la restauración ecológica es costosa (más de 300 millones de dólares al año) y aún no queda claro si, en lo particular, las acciones en pro del cuidado de los hábitats han sido exitosas. Se requiere un enfoque integral que sirva de guía para llevar a cabo una restauración de hábitats eficiente en términos de costos. Para ello es indispensable abordar de manera simultánea cuatro aspectos: 1) los fundamentos científicos de la ecología paisajística y el concepto de resiliencia; 2) apoyo público amplio; 3) gobernanza para la colaboración e integración; y 4) adaptabilidad y capacidad de aprendizaje. Lograr esto en la cuenca de Columbia demanda de acciones que tiendan a un balance en los objetivos de la restauración incluyendo la diversidad, el fortalecimiento de los lazos entre la ciencia y el manejo, un mayor compromiso social, trabajo a través de las fronteras de la ecología y la sociedad y el aprendizaje derivado de la experiencia.

INTRODUCTION

The native fish community in the Columbia Basin evolved in a landscape as diverse as any major river system in the world. That landscape supported more than 80 native species, including six anadromous salmonids *Oncorhynchus* spp. and a variety of other migratory and resident fishes. Although total species diversity was not remarkable for a large river basin, intraspecific diversity was, particularly for salmonids (Thurow et al. 1997). Moreover, annual adult returns of all anadromous salmon and steelhead *O. mykiss* were estimated to have exceeded 7.5 million before Euro-American development (Figure 1). Those fish populations have been dramatically altered through land conversion, hydropower development, water extraction, grazing, mining, logging, and road construction (Independent Science Advisory Board [ISAB] 2011b; Figure 2); proliferation of nonnative species and toxic chemicals; and a shift from natural to extensive artificial production of native (and nonnative) fishes (ISAB 2011a; Naiman et al. 2012). Remnant populations are fewer, smaller, less connected, and more restricted in spatial extent, and there is less diversity within and among populations than in the past (Thurow et al. 1997; Shepard et al. 2005; ISAB 2011b). McClure et al. (2003) concluded that 84% of remaining salmon and steelhead populations in the basin were not viable. Many populations will become increasingly vulnerable as environmental disruptions continue (Naiman et al. 2012; Naiman 2013).

The Pacific Northwest Electric Power Planning and Conservation Act of 1980 (Northwest Power Act of 1980) created the Northwest Power and Conservation Council (NPCC) to protect, mitigate, and enhance fish and wildlife and their habitats affected by hydroelectric development. The program now guides a basin-wide fish restoration effort. In recent years, more than US$300M has been spent annually for research, monitoring, and evaluation; hatchery support of fisheries and failing populations; control of predators; and acquisition and restoration of habitat (Naiman et al. 2012). Although actions are diverse, the focus is on freshwater and estuarine habitat to support naturally productive populations (NPCC 2009). Habitat restoration throughout the basin is also seen as compensation for effects of the hydropower system and a key to formal recovery of federally listed wild salmon and steelhead. More than 13,000 habitat projects have been implemented since 1980 (NOAA 2015), representing about 40% of recent annual expenditures for restoration.

Despite the investment, many if not most native salmonid populations remain depressed (U.S. Fish and Wildlife Service 2008; Ford 2011). There is still little empirical evidence to show that tributary habitat actions have led to measurable improvements in abundance or survival of fish populations (Marmorek et al. 2004; Paulsen and Fisher 2005; ISAB 2013a; Figure 2). Some actions can certainly improve the quality and capacity of individual habitats (e.g., Bonneville Power Administration, Bureau of Reclamation 2013) and even the reexpression of life history diversity (Jones et al. 2014). But in the Columbia Basin, net habitat losses have been substantial, existing efforts are often piecemeal and limited in extent (Independent Scientific Review Panel [ISRP] 2013; Wiley et al. 2013), and environmental disruptions continue (ISAB 2011a, 2011b; Naiman et al. 2012). It simply is not clear that habitat restoration as currently practiced can be effective enough to be successful.

In this article, we outline a more comprehensive approach to habitat restoration drawing directly from a previous review of relevant science and management experience both in and outside the Columbia Basin (ISAB 2011b). In ISAB (2011b), we argued for a "landscape approach" not because we saw some critical scale for future work but because we saw landscape ecology and integration with the allied biophysical and social sciences as critical to success. We describe four elements that, taken together, comprise our view of comprehensive habitat restoration: (1) a scientific foundation in landscape ecology and the concept of resilience; (2) broad public support; (3) governance supporting collaboration and integration; and (4) a capacity for learning and adaptation. Although many habitat programs in the Columbia Basin have embraced several of the general concepts, we found no effort successful in all elements of a comprehensive approach. We identify five actions that are needed for progress in the Columbia Basin and conclude with suggestions for moving beyond the status quo. More detailed recommendations, a summary of case histories, examples, and other resources can be found in ISAB (2011b).

ELEMENTS OF A COMPREHENSIVE APPROACH

Landscape Ecology and Resilience

Landscape ecology and the conditions underpinning resilience provide the perspective required for comprehensive restoration. Landscape ecology emphasizes the importance of patterns in ecological elements and the physical, biological, and ecological processes that create and maintain those patterns (Turner et al. 2001; Hobbs et al. 2014). Few populations, for example, can persist in isolation and generally must be buffered from environmental variation and disturbances and supported by flows of energy, food, and genes, or other organisms from other places (Bisson et al. 2009; Wipfli and Baxter 2010; Anderson et al. 2014). Although landscapes have no fixed size or scale, they generally encompass areas larger than the local habitat units commonly considered in traditional restoration. Most fishes have adapted to a diverse set of habitats dispersed across encompassing landscapes or "riverscapes" (Fausch et al. 2002; Jones et al. 2014). For instance, salmon use interconnected habitats as they migrate from mountain tributaries to mainstem rivers, estuaries, into oceans, and back. Ultimately, they depend on the suitability of individual habitats as well as the size, juxtaposition, and connections among habitats required for complete life cycles, diverse life histories, and functioning metapopulations.

Resilience is the capacity to absorb and adapt to disturbance or change while maintaining essential functions (Walker and Salt 2006). It is enhanced by retaining diversity and redundancy of species, populations, and life histories (i.e., maintaining options) and by avoiding land use and management actions that reduce natural variability. Modularity (multiple distinct elements such as populations) and heterogeneity among elements (such as the genetic and life history diversity among populations) confer resilience in the larger ecosystem (Walker and Salt 2006; Bisson et al. 2009; Jones et al. 2014). For example, in the Columbia River estuary, at least 27 identifiable habitat types occur in repeatable patterns (Figure 3), all of which influence abundance, distribution, and life histories of aquatic and riparian organisms. The resulting mosaic of habitats imparts important resilience to the ecosystem in the face of environmental change. Human communities draw on resilience as well, through diversity in their landscapes, fisheries, and other natural resources, but also through experimentation and sharing of diverse ideas and information (Gunderson and Pritchard 2002; Berkes et al. 2003; Healey 2009).

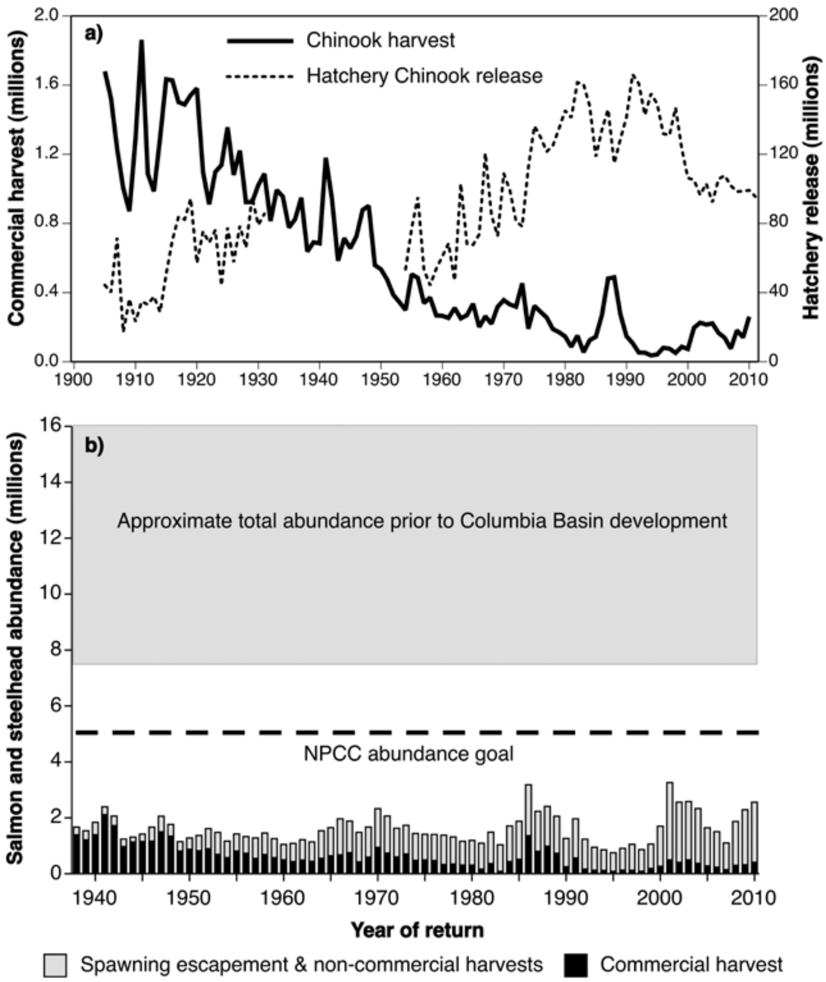

Figure 1. Abundance of Columbia Basin anadromous salmonids. (a) Estimated Columbia River commercial harvests and hatchery releases of Chinook Salmon since 1905. Hatchery numbers are shown 3 years postrelease to approximate the year of return. (b) Annual adult returns to the river and commercial harvest of all salmon and steelhead since 1938 after the first dams were built. Noncommercial harvests were not consistently estimated in the early years and are included in escapements. The range of estimated predevelopment returns is shown in the shaded bar. The current NPCC goal is total returns averaging 5 million fish by 2025 as a means to support tribal and nontribal harvests (NPCC 2009). Declining commercial harvests in recent years reflect, in part, the need to protect ESA-listed populations. Higher total numbers in recent years also have been linked to improved ocean conditions, hatchery releases, and some improvements in dam passage. Hatchery fish have contributed to larger returns of naturally spawning fish in some populations even though return per spawner is often less than replacement and wild populations may not be viable. (Primary data sources: Cobb 1931; Chapman 1986; Mahnken et al. 1998; Oregon Department of Fish and Wildlife and Washington Department of Fish and Wildlife 2002).

A landscape perspective is required to conceive and guide effective restoration. That perspective will require analyses and planning across spatial scales matching the patterns and processes influencing the populations of interest. Actions should not focus just on the physical structure of habitats but on sources of degradation and the processes creating and maintaining habitats (e.g., Beechie et al. 2010, 2013). Goals and objectives should recognize biological diversity and the spatial structure of populations, as well as abundance and productivity (e.g., McElhany et al. 2000), as critical elements of long-term resilience.

Broad Public Support

A comprehensive approach must integrate social and economic patterns and processes as well as the ecological ones (McKinney et al. 2010; Shultz 2011; Kareiva and Marvier 2012). That requires an understanding of the constraints and potentials that are imposed by both the landscapes and the people inhabiting them (e.g., Scarnecchia 1988; Lackey 2013; Lichatowich 2013). Too often social, economic, and cultural considerations remain outside, or occur too late in, planning and action (Nassauer 1997; Kareiva and Marvier 2012; Fremier et al. 2013; Menz et al. 2013). A comprehensive approach will engage the full spectrum of people who are interested in, and affected by, restoration (Hampton et al. 2013; Naiman 2013). Early and continuing public engagement is critical to define goals, consider alternatives, provide active education, and, especially, grow the support required to take action. Trust in those leading restoration is critical to engaging people in the discussion and the actions needed to conserve and restore habitats (ISAB 2011b). Action is easier to obtain when people understand the science and support the intended outcomes that are derived from it. Otherwise,

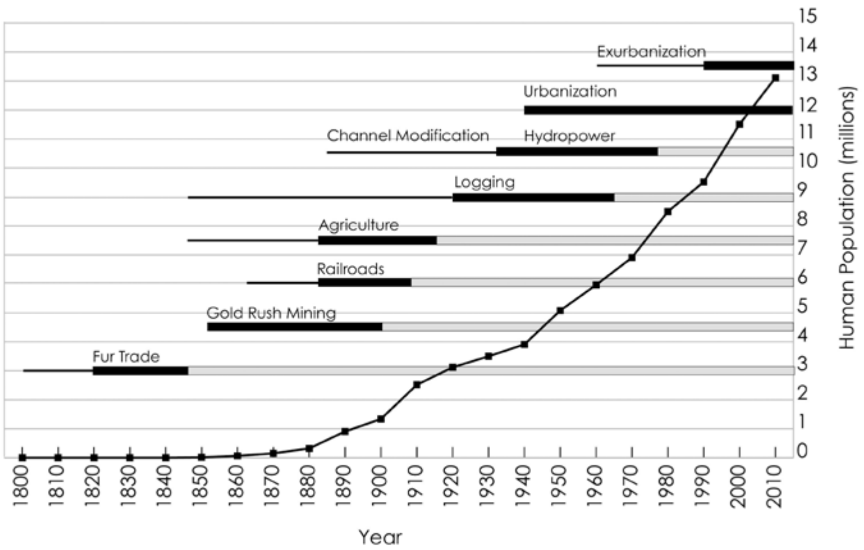

Figure 2. Sequential development driving landscape change in the U.S. portion of the Columbia Basin and concurrent changes in human population size. Wide dark bars indicate the period of peak development and rapid habitat conversion. Wide light bars indicate continued effects following the initial period of rapid change (from ISAB 2011b).

actions often end up delayed by policy and legal battles.

Broad engagement is achieved through a breadth of outreach activities. Efforts may include public meetings, print, radio, TV, social media, and web-based tools. Advisory groups, university extension, volunteer programs, citizen science, and experiential learning activities for youth and adults engage people and help them develop a deeper understanding of ecological conditions. Effective public engagement must begin early, encourage debate and discussion of alternatives, and include individuals and groups that will be positively and negatively affected.

Governance for Collaboration and Integration

Comprehensive restoration requires working across disciplines, landownerships, management responsibilities, and public and private interests (Gunderson and Holling 2002; McKinney et al. 2010; Tabor et al. 2014). That requires a supporting structure (Cosens and Williams 2012; Fremier et al. 2013), specifically, an intentional process or framework for governance that supports collaboration and integration of the work of multiple participants (Sabatier et al. 2005; Flitcroft et al. 2009; McKinney et al. 2010). The process needs to include mechanisms to share information, resolve differences, make decisions, and identify critical uncertainties.

Collaboration and integration emphasize working relationships and common goals among individuals and organizations, science and management disciplines, and the institutions or agencies needed to do the work (Rogers 2006; Kania and Kramer 2011). Success requires common or complementary visions, shared knowledge and conceptual models, and funding to support integrated planning as well as on-the-ground actions (Sabatier et al. 2005; Reeve et al. 2006; McKinney et al. 2010). Effective collaborations form only after considerable time and effort to understand one another, establish trust, and foster cooperation (Kenney 1999; Smith and Gilden 2002; Flitcroft et al. 2009).

Learning and Adaptation

Comprehensive restoration will require new and untried actions that must evolve with experience. Learning and using what is learned to modify future restoration actions are key. Adaptive management is a full-cycle process starting with the identification of quantitative objectives to fulfill agreements, policies, or laws. This is followed by an assessment of physical, biological, social, and economic conditions that need to be addressed to meet the objectives. Based on the assessment, actions are designed and implemented. Periodic monitoring and evaluation provide critical feedback (Reeve 2007; Runge 2011). The results are then used to gauge progress toward objectives and ultimately to support or modify actions.

Adaptive management ideally uses deliberate experiments to inform future decisions (Holling 1978; Lee 1993; McDonald et al. 2005; Armitage et al. 2008). It can still provide a useful path, however, where traditional scientific experimentation, replication, and intensive monitoring become difficult or impossible at very large scales (Runge 2011). For example, models can be used to explore restoration scenarios and help managers and the public visualize the response of complex systems (Holl et al. 2003). The models can be integrated in a structured approach to making decisions, and the results can be updated periodically to focus new work and limited financial resources (Runge 2011).

Ultimately, learning and adaptation require sharing experiences across watersheds, regions, and cultures so that each project becomes an observation for a larger collective evaluation of successes and failures. Active networking across groups with common interests must be part of the process.

A COURSE OF ACTION FOR THE COLUMBIA BASIN

Many of the ideas highlighted above have been recognized in guidance for Columbia Basin restoration for some time (e.g., McElhany et al. 2000; Williams 2006; NPCC 2009; Bottom et al. 2011). Despite that, success remains uncertain and implementation has been inconsistent (Lichatowich and Williams 2009; ISAB 2013a; ISRP 2013; Naiman 2013). Wild salmon stocks remain depressed; most are vulnerable to changing conditions, and hatchery programs continue to produce most of the fish (Paquet et al. 2011; Naiman et al. 2012). Societal constraints to progress in the basin have been linked to lifestyle choices and priorities, including the drive for economic efficiency, competition for natural resources and resulting scarcities (especially water), and accommodations for increasing numbers of people (Lackey et al. 2006; Lackey 2013). McKinney et al. (2010) argued that most restoration efforts lack landscape ecological information and analytical capacity, policy tools, and a realistic funding structure. Groups working in the same landscapes often have different conceptual models (Reeves and Duncan 2009; Rieman et al. 2010; Columbia River Inter-Tribal Fish Commission 2013). Institutional structures needed to support integration are often lacking (e.g., Samson and Knopf 2001), and political interference can impede the incorporation of science into management (Lichatowich and Williams 2009; Lichatowich 2013).

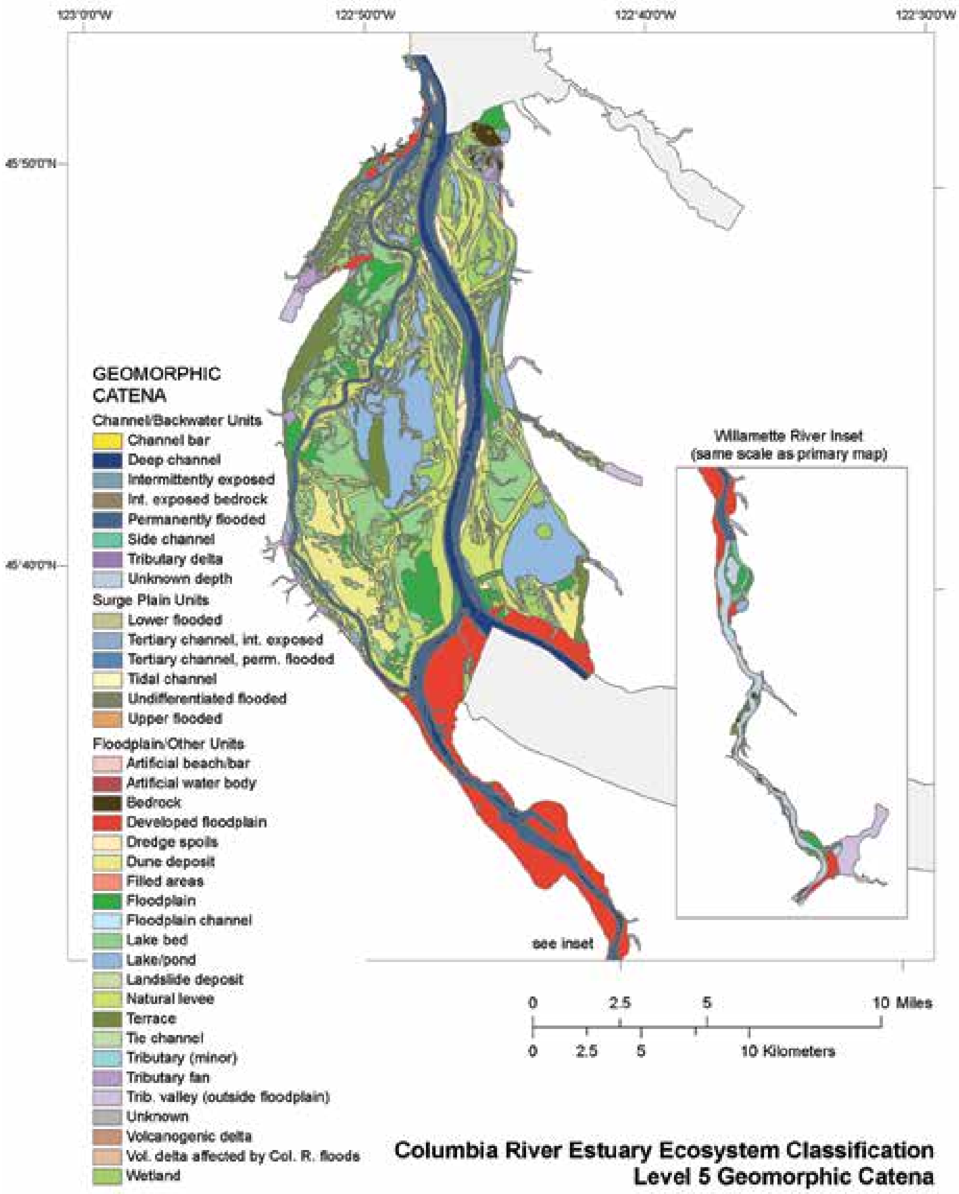

Figure 3. Geomorphic catenae described for a reach in the Columbia River estuary. There are at least 27 distinct habitat types present that affect the distribution and abundance of aquatic and riparian organisms (modified from Simenstad et al. 2011; ISAB 2011b).

Five actions are needed for more comprehensive habitat restoration in the Columbia Basin. To provide a strong science foundation, we must *rebalance the goals* for the program to include resilience and biological diversity, not just fish abundance. We must also *strengthen the linkages between science and management*. To gain broad public support for the program, we must *increase public engagement*. To provide governance for collaboration and integration, we must *work across traditional ecological and social boundaries*. And, to learn and adapt, we must fully commit to *learn from experience* at all levels of the program. We briefly consider these five actions below.

Rebalance the Goals

The Columbia River Basin Fish and Wildlife Program (NPCC 2009) speaks to a more comprehensive restoration effort, but vision, goals, and action remain at odds (Lichatowich and Williams 2009; ISAB 2013a). The program notes that biological diversity is important, but the specific objectives focus on abundance and in-river survival of salmon and steelhead and do not include species, genetic, life history, or habitat diversity or the number and spatial structure of populations. Abundance remains the focus of public discussion, and biological diversity and the ecological patterns and processes that underpin resilience are mostly limited to the technical literature (ISRP 2005; ISAB 2013a).

Reliance on hatcheries to produce large numbers of fish is an example of the narrow focus on abundance. Hatcheries now number about 200 (with new facilities being planned and built) and are influential enough to impede recovery of wild fish (ISRP 2005; Naiman et al. 2012; ISAB 2013a). Extensive artificial production also fosters a public expectation that hatchery technology can provide abundant salmon for harvest, irrespective of habitat conditions (Lichatowich 1999, 2013). Abundance is the commonly publicized measure of fish status. Clearly, increased abundance is an important and popular goal, but increasing hatchery production while ignoring the overall capacity of the ecosystem to support extensive diversity in wild populations is ill-advised (Naiman et al. 2012; and see Lindley et al. [2009] for a case in point).

Steps toward a more balanced vision can be taken with an intentional effort to engage the broader public on the importance of biological diversity and resilience. This requires communicating more than simple numbers of fish. Schindler et al. (2010), for example, found that the frequency of fishery closures could increase 10 times as multiple independent stocks were homogenized to a single population. Discussions like this can help the public (and managers) understand the benefits of diversity to fish populations and fishing opportunities. Recent research has focused on the influence of hatchery releases on fitness of both wild and hatchery stocks (Paquet et al. 2011); a similar focus is needed on the effects of hatcheries on concentrations of predators, disruption of food webs, and habitat capacity influencing wild populations (Naiman et al. 2012). Moreover, we do not know whether biological and habitat diversity is increasing or declining across the basin (ISAB 2013a). Rapidly changing science and technology (e.g., Miller et al. 2010; Campbell et al. 2012; Hess et al. 2014), synthesis of existing regional viability assessments (Ford 2011; ISAB 2011b), and refined analyses of new or existing information (e.g., Moore et al. 2010; Jones et al. 2014) could dramatically extend our collective understanding of the trends in biological diversity and the ability to communicate those to the stakeholders in the basin.

To provide a more comprehensive vision for habitat restoration basin, state and local policy makers, and project managers must:

- develop and communicate goals and measurable objectives for biological diversity that are held as equal priority to the goals and objectives for abundance;
- directly engage all stakeholders and the general public to broaden understanding of the critical value of biological diversity;
- develop indicators for monitoring that measure and communicate progress on abundance and biological diversity at multiple scales across the basin; and
- consider the implications of hatchery production for carrying capacity and diversity of wild fish as a basis for integrating hatchery production with habitat restoration.

Strengthen Linkages between Science and Management

Science provides information to help guide management. A comprehensive approach to habitat restoration requires the broad perspective that only landscape ecology and supporting disciplines can provide. Analytic and technological advances have dramatically extended our ability to describe broad habitat patterns (e.g., McKean et al. 2008; Isaak et al. 2010) and watershed and biological processes (e.g., Beechie et al. 2010; E. A. Steel et al. 2010; Campbell et al. 2012). But widespread application of new tools and analyses and the design of scientific experiments in the adaptive management process remain a challenge (e.g., McDonald et al. 2005). We still need the capacity to monitor not only the effectiveness of habitat restoration actions (e.g., Roni et al. 2008) but the cost-effectiveness of those actions measured as benefits in the status of entire populations. We need the help of sociologists, cultural anthropologists, and others to understand and communicate with the full range of stakeholders.

Too often, scientists have little incentive to collaborate with managers (e.g., Arlettaz et al. 2010), and managers often lack time, funding, or analytical expertise to effectively engage with scientists, use their tools, or guide the development of new ones. In many cases, managers do not use information that already exists because traditional funding mechanisms favor piecemeal, localized actions over extensive analysis and more comprehensive planning (McKinney et al. 2010).

Attempts to bridge these barriers in the Columbia Basin include the creation of technical recovery teams, application of life history and habitat models in decision analysis (e.g., E. A. Steel et al. 2008; Beechie et al. 2013; Peterson et al. 2013; Anderson et al. 2014), integrated population and habitat monitoring (Bennett et al. In Press), and work to visualize management alternatives and scenarios (Baker et al. 2004; Guzy et al. 2008; Hulse et al. 2008; Bolte 2013). A restoration extension service built on the model of agricultural extension and Sea Grant programs or "communities of practice" (Collay 2010) could further efforts like these to bridge the science–practice gap (Cabin et al. 2010). Although there has been consideration of dedicated technical support in the past, the commitment has not materialized. Scientific bodies such as the Columbia River Hatchery Scientific Review Group (Paquet et al. 2011), formed to deal with a growing concern over hatchery programs, could be formalized to provide continuing support for project and hatchery managers. Emerging habitat–life history modeling could help managers understand what, where, and how much habitat restoration is actually needed and whether it will be cost effective; however, dedicated support will be required to realize the potential (ISAB 2013b).

These examples show that science and management can engage effectively (Naiman 2013). Learning from these and other experiences (ISAB 2011b), and making sure that the scientific capacity to conduct effective large-scale assessments is available and used, is key.

To strengthen the science and application of science in restoration, program and project managers must:

- use landscape sciences and technology in assessment and restoration planning and support and expand common application of relevant research, monitoring, modeling, and analytical tools.

Program managers, funders, and policy makers must:

- create and support communities of practice and peer-learning networks that demonstrate science–management integration; highlight new tools and analyses that are innovative and promote those with real potential for success; and
- recommit to options for broadly based technical assistance to provide analytical support, constructive criticism, and feedback to proposed and ongoing projects.

Increase Public Engagement

Articulating a widely supported vision remains a problem. The Columbia Basin is socially and ecologically complex. Cultural and political histories lead to different values and intentions, constraining solutions that people will support (Malle et al. 2001). Conflict among stakeholders is time consuming and stressful, resulting in habitat actions attempted where conflict is least rather than where it is needed most.

Restoration strategies are commonly developed within the confines of individual resource uses (e.g., terrestrial or aquatic but rarely together). Managers for different resources or agencies frequently fail to communicate or work effectively with each other as well as the full spectrum of potentially competing stakeholders (e.g., Rogers 2006; Rieman et al. 2010; Cosens and Williams 2012). Public and planning meetings are held; plans are revealed but not necessarily debated or revised, and parties talk past one another. The public is often brought in after internal discussion, after planning options are chosen (Smith et al. 1998; Johnson et al. 1999), or after their input would be useful.

One approach to more effective public engagement is to foster discussion of ecological services such as clean water, mitigation of natural disturbances (such as wildfire and flooding), production of fish for harvested food and recreation, and resilience in the supply of fish with environmental change. Modeling and other assessment and communication tools can also help put restoration actions into a landscape and social context and help stakeholders visualize alternatives, contemplate different roles, and understand potential results or tradeoffs of any actions. Experience in the Willamette River Basin, outlined as a case history in ISAB (2011b), is a good example where these concepts have been explored in some detail. Helping the public recognize the problem as complex and related to other values has a real advantage because it looks at reality (Rogers 2006), making it, in the end, a broad-based consensus easier to achieve. In the case of the Columbia River, and for most other rivers ongoing large-scale restoration, efforts fall short of goals because the social aspects are neither well developed nor well integrated with the physical restoration efforts and therefore do little to create a public or scientific consensus (Naiman 2013).

To increase public engagement to achieve more comprehensive restoration, policy makers and program and project managers must:

- include education and outreach specialists as key players at the earliest stages of project development;
- engage people and organizations early through forums that encourage dialogue between managers, researchers, and stakeholders associated with a range of resource values;
- align ecological needs with social and economic incentives and consider benefits and costs to people and their communities;
- use a wide diversity of media and forums for public and community engagement; and
- make public involvement and active learning through citizen science in monitoring and research a central element in project implementation.

To support actions like these, basin, state, and local program managers and policy makers across must:

- recognize the social sciences as a critical element of scientific review and guidance and include social scientists as primary contributors to the advisory, review, and planning processes.

Work across Traditional Ecological and Social Boundaries

The Columbia Basin encompasses two countries and, within the U.S. portion, seven states, 15 Native American tribes, 11 ecological provinces, 62 subbasins, more than 100 counties, many more towns, and other entities representing diverse patterns of ownership, management, and regulatory jurisdiction (e.g., Forest Service and Bureau of Land Management districts, irrigation and water districts) as well as a wide range of ecosystems (Figure 4). Responsibilities for managing natural resources are scattered across agencies and jurisdictions with different missions, authorities, and scientific capacities (Samson and Knopf 2001; Reeves and Duncan 2009; Rieman et al. 2010). One result can be a bewildering array of plans, rules, and regulations. Regulatory complexity can be so daunting that landowners become suspicious of government and reluctant to participate in conservation and restoration programs. Still, private lands are critical to landscape structure, diversity, and connectivity (Dale et al. 2000; ISRP 2005).

A comprehensive approach should seek integration with cities and counties that control many mid-level land use actions (Smith 2002) as well as private landowners and other jurisdictions not well represented by traditional approaches (Cosens and Williams 2012). Private landowners will favor improved coordination among regulators and managers that simplifies and streamlines land and water use rules where appropriate and possible without compromising intent. This can also lead to increased public support for proposed restoration actions.

Although coordination across very large areas (such as the entire basin or large subbasins) is extremely challenging, important steps can certainly be made within smaller subbasins and watersheds that are important ecological components of the larger system. Familiarity can bring trust in the process (Smith and Gilden 2002; Sabatier et al. 2005; B. S. Steel et al. 2003). Extension and other outreach and programs, such as the watershed organizations, soil and water conservation districts, and the U.S. Department of Agriculture Farm Service Agency's Conservation Reserve Enhancement Program that exist in many Columbia Basin counties have already engaged farmers, ranchers, and other private property owners in a conservation discussion and could serve as a useful foundation (Flitcroft et al. 2009; Collay 2010). Nongovernmental organizations are playing an increasingly important role bringing nontraditional partners together as well (McKinney et al. 2010). One example is the Upper Salmon River Basin, Idaho, where multiple agencies, nongovernmental organizations, and some ranchers are working together to restore habitat and stream flows while also encouraging more landowners to conserve habitat as a means to improve quality of life (Upper Salmon Basin Watershed Program 2010). Other examples can be found in current experiments with "collective impact" (Kania and Kramer 2011), "networking governance," and "nested adaptation" (Tabor et al. 2014), where nontraditional partners in and across watersheds are supported through network organizations that share common goals (e.g., Wiley et al. 2013; RCC 2012; Russell Family Foundation 2013). Learning from nonconventional efforts like these, providing new incentives, and supporting alternative structures that work across traditional boundaries will be important.

More effective collaboration and integration across traditional boundaries will require efforts where program and project managers embrace governing structures that engage and support a broad diversity of stakeholders, communities, and interests in the planning and decision process.

To support that, program managers and those funding projects should:

- highlight and support experiments in governance for collaborations that bridge agency and intellectual groups, local and regional organizations, governments, landowners, and science–management disciplines and
- bring innovative and successful examples (including those from other resource and restoration disciplines) to others in the basin.

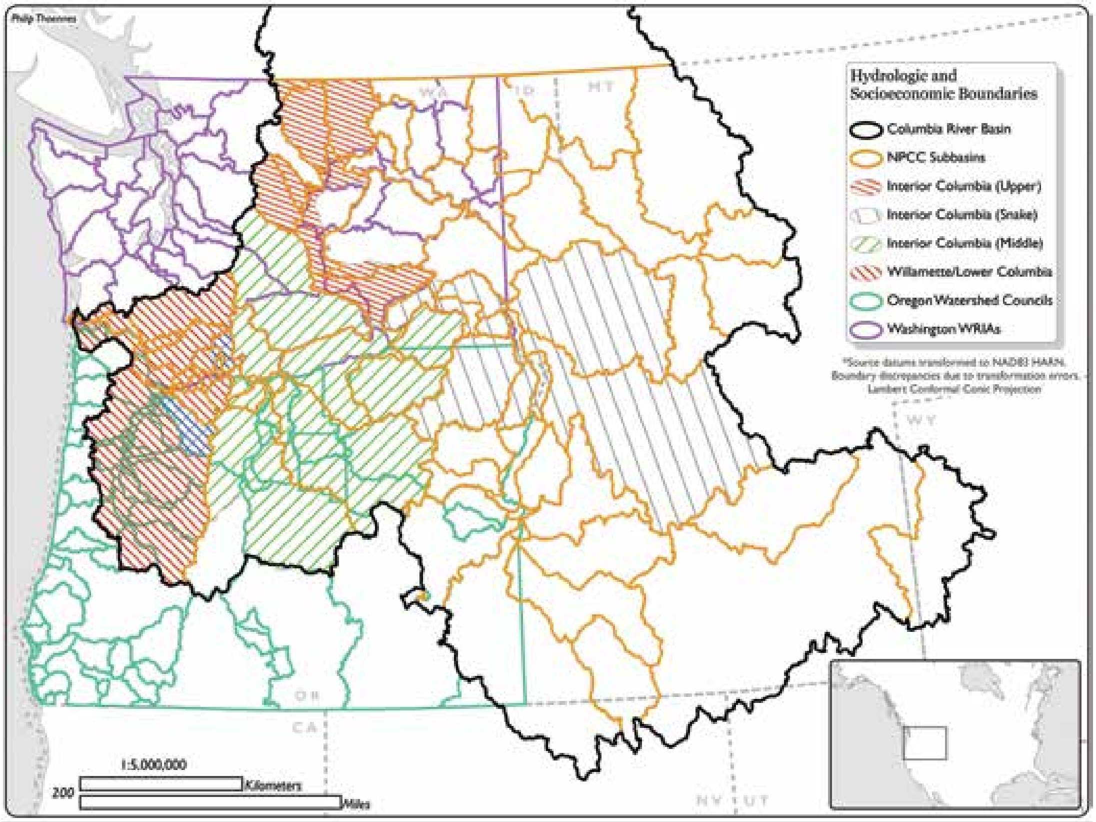

Figure 4. An example of organizational complexity and overlap in the Columbia Basin. The Northwest Power and Conservation Council subbasins are intermediate regions for planning used across the basin. Subbasins encompass multiple fourth field watersheds often used to consider hydrologic or large-scale ecological issues. Four Columbia Basin National Oceanic and Atmospheric Administration salmon and steelhead recovery domains (crosshatched areas), Oregon's Watershed Council planning areas and Washington's Water Resource Inventory Areas are shown as well. Not shown are the counties, national forests, tribal lands, state fish and game agency regions, or other districts used to organize activities that can influence watershed conditions as well as fisheries.

Learn from Experience

A commitment to learn from the experiences gained through the extensive restoration efforts already in progress across the Columbia Basin is critical. Adaptive management has been a central tenet of the Columbia Basin Fish and Wildlife Program since the 1980s (Lee 1993). Unfortunately, adaptive management has not always been practiced as originally intended (e.g., Smith et al. 1998; Stankey et al. 2005; Lichatowich and Williams 2009; Westgate et al. 2012), and application has often failed (Reeve 2007). Though project leaders routinely assert that adaptive management is used, many efforts have no measurable objectives, and very few have either an experimental design or conceptual model that could be used to revise management based on updated information. Often, projects continue even when monitoring indicates that biological objectives are unattainable. The reasons why adaptive management has failed are varied and complex (Walters 1997), but they can be summarized in the Columbia Basin as overconfidence in projected restoration outcomes, unwillingness to terminate unproductive activities, limited funding for monitoring, unwillingness to experiment, and lack of formal analysis, scientific guidance, or effective governance (Cosens and Williams 2012; ISAB 2013a; J. Shurts, NPCC, personal communication).

One suggestion for improved learning is to expand approaches such as structured decision making (SDM) and be guided by the precautionary principle to better implement and communicate an adaptive management cycle (ISAB 2013a). Structured decision making is a transdisciplinary approach that incorporates elements of adaptive management, quantitative modeling, social engagement, statistical rigor, and ecological understanding (Runge 2011; ISAB 2013a, 2013b). Broad implementation of SDM, which is being explored in the basin, will require additional commitment and facilitated guidance, but it may help both managers, and the public, visualize and formalize the process.

There are also opportunities to learn from other experiences with large-scale restoration. Worldwide, there are numerous ongoing attempts at restoring large rivers (e.g., ISAB 2011b; Naiman 2013; Murray-Darling Basin 2010). Admittedly, these are highly difficult undertakings and fraught with problems, but there is much to be learned from their successes as well as their failures. In general, two important attributes central to the successful aspects are setting clear ecological goals and encouraging public participation, both of which are important attributes proposed here.

Beyond renewed efforts to practice adaptive management, implement SDM, and learn from others around the world, restoration efforts with similar objectives and project actions within the Columbia Basin need to share information, innovations, successes, and failures continually. Learning from experience will require more rigorous application of adaptive management in addition to broad communication among restoration projects to learn from each other.

Demonstrated commitment to learn through experience must include efforts from project managers that:

- identify clear, quantitative objectives, including diversity objectives that form the baseline for the adaptive management cycle;
- implement intentional, science-based management experiments that promote learning about landscapes, cost-effective restoration actions, and understanding of their social–ecological implications;
- incorporate options for citizen science in monitoring and experiential programs that help reduce monitoring costs and promote broader understanding of the results; and
- use formal models to guide more structured decision making and to communicate a broader vision of the system and its critical uncertainties to all involved.

Program and project managers and funding authorities must include structures and forums to broadly share experiences, innovations, successes, and failures as a foundation for shared learning across projects.

MOVING FORWARD

We advocate an approach to restoration where all four elements outlined above are fully embraced in every project and the policy, planning, and management direction that make them possible. There are important examples of progress in the Columbia Basin, but few efforts have effectively incorporated all four elements. These are not new ideas or radically divergent hypotheses about how restoration can and should work; rather, they emerge directly from nearly two decades of guidance for salmon conservation (e.g., Stouder et al. 1997; McElhany et al. 2000), river and ecosystem management (e.g., Naiman and Bilby 1998; Bernhardt et al. 2005; Williams 2006), and landscape or riverscape ecology (e.g., Wiens 2002; Fausch et al. 2002). It is time to weave that guidance into a more comprehensive approach to habitat restoration.

Some will argue that costs will be prohibitive or that social and ecological complexity will become overwhelming with a broader context. There are formidable challenges, but a broader context will make the opportunity for efficiencies and tradeoffs more apparent and allow managers to focus limited resources more effectively (Noss et al. 2006; Hobbs et al. 2014). Cost-effective restoration can only be defined by the response of entire populations that depend on encompassing landscapes. Even so, a comprehensive approach does not mean working only at the largest scales. Instead, it means working at the scales relevant to the social and ecological patterns and processes driving the habitat networks and populations of concern. The approach we advocate can be adapted to many scales, with clear understanding that the needed perspective will change as we move across scales and that some process for nesting work across scales must also exist. Indeed, the modularity emphasized in resilience thinking implies building in a hierarchical fashion, securing fundamental pieces (e.g., local populations), and understanding the linkages among them that ultimately structure a larger system.

We have offered a series of elements, recommendations, and examples (with more detail in ISAB 2011a, 2011b, 2013a), but important steps are needed at the highest levels of the program as well to provide the incentive and direction for change. The ISAB (2013a) strongly recommended a revised series of scientific principles underpinning the Columbia Basin Fish and Wildlife Program based on the concepts outlined here (see text box). We urge policy makers to embrace those principles by establishing clear goals and quantifiable objectives for biological diversity and communicating the importance of resilience in the face of an uncertain future for the Basin. The ISAB (2011b) argued that the four elements outlined here should become criteria for review and funding of long-term projects. Continued funding for projects implemented within this context should demand commitment to the program's underlying principles and demonstrated progress toward those criteria.

Stronger leadership is needed. Those funding or providing the policy direction can provide leadership directly (e.g., setting the course and prescribing the process). Alternatively, they can foster and support leadership in other partners across the basin. These two options are not mutually exclusive, but the first requires an understanding of issues, actors, and environments and a level of control that may be virtually impossible. The second requires a capacity to recognize and champion local and regional efforts that are innovative and effective even though they may not follow a common or prescribed structure. That will require support for nontraditional models of governance and networking with new partners. It will require investment and technical support in social sciences, environmental education, and outreach, not just salmon ecology and watershed processes.

Some have argued that the challenges to progress in the basin are largely social and perhaps insurmountable (Lackey 2013). But, salmon and other species continue to be central components of the basin's cultures, and people can decide to conserve and restore what matters to them. People are tied to their landscapes—a living synthesis of ecology, people, and place that is vital to local and regional identity and social and economic well-being. Landscapes help define the self-image of a region, a sense of place, and structure social interactions (Kemmis 1990). Because human decisions and actions interact within landscapes to shape abundance, diversity, and resilience of Columbia Basin fishes and cultures, a more comprehensive approach to habitat restoration, a landscape approach, provides the best opportunity for success.

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The Evolution of Scientific Principles for the Columbia Basin Fish and Wildlife Program

In 2013, the ISAB reviewed the NPCC Fish and Wildlife Program's existing scientific principles (NPCC 2009) based on the elements of a landscape approach and subsequent work (ISAB 2011b; Naiman 2013). The ISAB (2013b) proposed that the eight principles be reduced to six that better reflect recent advances in scientific knowledge about complex adaptive systems and their patterns, processes, diversity, and resilience. The proposed principles focus guidance for management and restoration activities placing greater recognition on the importance of human influence and involvement. The original principles included one describing humans as an integral part of the ecosystem. The revised principles expand on this concept and emphasize that broad public engagement and cultural diversity are required for effective ecosystem management and restoration (see especially 3, 5, and 6 below). We expect the principles will continue to evolve with new insights into social–ecological dynamics and as restoration and management approaches are improved in the basin.

The proposed, revised principles were as follows:

1. The abundance, productivity, and diversity of organisms are sustained by complex and adaptive ecosystems.
2. Biological diversity allows ecosystems to persist in the face of environmental variability.
3. Human health and well-being are tied to ecosystem conditions.
4. Ecological management is adaptive and experimental.
5. Socioeconomic understanding and engagement is required to make management actions more sustainable.
6. Biological and cultural diversity provide the raw material for reorganization and adaptability during unexpected transitions to new ecosystem regimes.

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