Using a Comprehensive Landscape Approach for More Effective Conservation and Restoration

Independent Scientific Advisory Board

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Executive Summary

Landscapes are the features of an area of land, including the physical, biological, and socioeconomic characteristics. Collectively, they reflect the biophysical origins and the overlay of culture and human presence, often created over millennia. However, and more importantly, landscapes reflect a living synthesis of ecology, people, and place vital to local and regional identity, and social and economic wellbeing. Landscapes, their character and quality, help define the self image of a region - a sense of place. They are the dynamic backdrop to people's lives. Most importantly, for this report, human actions interact within the Columbia River Basin landscapes to ultimately shape abundance, productivity, diversity, *and* resilience of fish and wildlife populations.

Columbia River Basin landscapes are as varied as those of any river in the world, but they also carry the signature of large-scale change through human activities. A history of land use and conversion, alteration of habitat and habitat connectivity, socioeconomic growth and development, expansion of non-native species, and a shift from natural to artificial production of native and non-native fishes translate to declines in abundance and diversity of native species. Remnant native populations are often fewer, smaller, and more restricted in spatial extent; have more limited connectivity; and have less within and among population diversity. The net result is populations and species that are increasingly vulnerable in a changing and unpredictable world. These trends can be reversed if critical habitats and connections among them and their landscapes are conserved and restored, but the perspective guiding these efforts must be larger and more comprehensive than in the past.

The objectives of this report are to distill current concepts and understanding of the critical processes shaping landscapes and their associated fish and wildlife populations, and to synthesize the best approaches for conserving and restoring self-sustaining fish and wildlife populations within the landscapes of the Columbia River Basin. This report builds on and extends previous ISAB and ISRP reports that consider restoration in the Basin. Expanding on general guidance, a major focus of this report is on current understanding of the workings of *landscapes as integrated ecological and socioeconomic systems*. We emphasize past guidance to extend beyond the stream, consider the full life history needs, and build from a larger context, but to do so with a more effective engagement of social and economic issues in the Basin.

This report focuses strongly on the socioeconomic dimension that has not been explicit in earlier ISAB reports. We emphasize the need for effective socioeconomic and ecological integration and interdisciplinary collaboration. Our review supports an effort to move beyond spatially isolated or independent projects to broader integration of actions. A landscape perspective is critical for effective habitat conservation and restoration. Species and populations depend on the highly heterogeneous characteristics of land, water, and people and on the interdisciplinary knowledge needed to manage and restore resilient habitats. A comprehensive landscape approach demands a strong and continued coupling between biophysical and socioeconomic knowledge. It brings understanding and engagement on social and economic issues, making effective management and restoration possible.

The concepts of *landscape ecology*, *resilience,* and *adaptive capacity* provide a critical foundation in conjunction with the focus in the Columbia River Basin on abundance, productivity, diversity, and spatial structure (defined in Appendix IX). Landscape ecology argues that spatial and temporal patterns of organisms, their habitats, and the processes that create and maintain them, matter. Virtually all organisms depend on linkages among a variety of habitats embedded in larger landscapes. These habitats collectively supply the conditions that support abundant and productive populations, but only if they are suitable, large enough or connected enough, and maintained in enough places through time.

Resilience is a key concept in landscape ecology and socioeconomics. Resilience is a capacity to absorb and adapt to disturbance and change – while maintaining essential functions. Resilience for fish and wildlife results, in part, from diversity within and among species; modularity or compartmentalization that defines individual habitats, habitat patches, and populations; and the connections and feedbacks among them. Resilience in human systems follows from parallel conditions. Promoting an enduring resilience requires a landscape context.

Adaptive capacity is the foundation for management of resilience in natural and human systems that are increasingly variable and unpredictable. Adaptive capacity depends on the integration of diverse interdisciplinary knowledge as well as the capacity to learn and adapt through better experimentation, innovation, and diffusion of new and better information and approaches. New goals, plans, and actions that build adaptive capacity enable managed systems to provide valuable ecological services, even when they may be very different from natural systems of the past.

Throughout the report we follow four general themes to summarize important processes, underlying principles, and criteria to evaluate a comprehensive landscape approach to conservation and restoration. These criteria form the basis of our general recommendations for any group pursuing a more comprehensive approach and the use of these criteria is the main recommendation of this report:

- Engage the public and diverse social groups associated with the landscape and build socioeconomic understanding.
- Incorporate a strategic approach with a foundation in the concepts of comprehensive landscape ecology.
- Develop organizations that support collaboration, integration, and effective governance and leadership.
- Promote adaptive capacity based on active learning through assessment, monitoring, innovation, experimentation, and modeling, combined with a clear process to share new information and revise objectives, strategies, and actions in response to that information.

Many of the concepts and recommendations in this report are not new. The basic principles of ecosystem management and the need to consider larger scale pattern and process in conservation and restoration are already part of the vision and direction offered in planning and policy documents from the Council, NOAA Fisheries, the Tribes, and others. But, successful implementation still faces technical and socioeconomic challenges. These include inconsistent and conflicting conceptual models and incomplete information; limited agency or public commitment and engagement; competing preferences, values, and understanding of the larger vision; a lack of science-management-public engagement and integration; and missions that conflict among or within agencies. As a result, planning and implementation of restoration can be piecemeal. Even with broader planning, restoration activities tend to be opportunistic, inadequately monitored, and without coordination between adjacent landowners or responsibilities, rather than integrated and strategic.

Our understanding and implementation of a more comprehensive approach must be strengthened and will continue to evolve. The basic concepts must become part of the culture of conservation and restoration. Much of the distillation to *rules of thumb* and *best management practices* occurs as scientists, managers, administrators, and the public review, compare, apply and modify approaches and as new knowledge and experience develop. We provide a series of points for each general recommendation that summarize current knowledge and guidance (Table VII.1) to facilitate that process. We also provide seven recommendations in addition to our recommendation that the four criteria (Section IV) listed above be used in all evaluations. These are to:

1. **Build Broader Public Support**
   Enlist the public and diverse social groups associated with the landscape to build socioeconomic understanding and support for comprehensive restoration.

2. **Rebalance the Vision for Restoration**
   Organize a strategic approach with a foundation in comprehensive landscape ecology that balances the goal of abundance, with the vision of diversity and resilience.

3. **Establish Leadership in Linking Science and Management**
   Support and facilitate a strong engagement of landscape science in assessment, restoration planning, and actions

4. **Work Across Boundaries**
   Support or extend existing and non-traditional efforts and develop more, cost effective partnerships.

5. **Reinvigorate and Extend Adaptive Management**.
   Fully develop adaptive management to support adaptive capacity.

6. **Develop Best Practices**
   Support the development and diffusion of best practices to guide more consistent actions.

7. **Strengthen the Social and Economic Capacities of ISAB and ISRP**
   Increase formal cooperation and collaboration between the two bodies to improve the integration of ecological and socioeconomic perspectives.

I. Introduction and Background

"Landscape shapes culture" - Terry Tempest Williams

Objective of the Report

In recent decades, understanding of the ecology of large and complex landscapes and how societies shape their resilience has advanced substantially. Landscapes are now understood to be heterogeneous and integrated natural and socioeconomic systems that are continually changing. Despite their complexity, biophysical and socioeconomic scientific knowledge can be applied to manage landscapes for the mutual benefit of human societies and nature. River corridors and their adjacent lands are complex landscapes that have served throughout history as critical focal areas for human activity and development. Resilient landscapes, and their resilient human societies, have well-developed capacity to adapt and persist in changing conditions, and have internal self-sustaining capabilities.

The Columbia River Basin landscape, 673,396 square kilometers (260,000 square miles) in area and consisting of 11 ecological provinces and 62 Council-defined subbasins, includes *"climatic conditions and topography as varied as any river in the world - from alpine to desert to rainforest*" (Northwest Power and Conservation Council, Fish and Wildlife Program, 2009, p 1). Within the Columbia River Basin landscape, diverse human industries, including agriculture, forestry, mining, manufacturing, and hydropower, are typically associated with water demands and other impacts on the Columbia River, its tributaries, and riparian zones. Human actions in upland zones far removed from large tributaries and the mainstem river also can have major impacts throughout the Columbia River Basin and into the estuary.

A *comprehensive landscape approach* is needed for understanding the interdependence of habitats, fish and wildlife, and people and their enterprises in the Columbia River Basin. There is a long history of high quality research in the Basin in a wide range of disciplines, including fisheries, aquatic and wildlife ecology, geology and geomorphology, stream and river processes, sociology, anthropology, economics, and political science. However, inadequate attention has been given to developing a sufficiently broad conceptual framework for interpretation and application of results, which no doubt involve factors that interact and which must play out over the landscape and over long time periods.

Recent advances in science and technology enable broader-scale and more comprehensive study, visualization, and management of the Columbia River Basin landscape, including its habitats and fish and wildlife populations. It is the view of the ISAB that such advances can significantly improve the efficiency and effectiveness of conservation and restoration of the landscape, including habitats, biota, and the human societies and economies that depend on them. The need for a comprehensive landscape perspective to guide regional and subbasin approaches to restoration (ISAB/ISRP Subbasin plans review, 2004-13) is especially strong as the Basin faces rapid increases in population (ISAB 2007-3) and changes in land use, climate (ISAB 2007-2), biotic community structure (ISAB 2008-4), and aquatic food supplies (ISAB 2011-1). In particular, a comprehensive landscape perspective will be useful as full life cycle perspectives are incorporated into recovery and conservation of salmonid and other populations. A comprehensive landscape approach will require interacting with very large numbers of people who depend on the Basin's resources.

The objective of this report is to review the recent scientific literature and distill current understanding of the best approaches for restoring self-sustaining fish and wildlife populations within the landscapes of the Columbia River Basin. For anadromous fish, such as the salmonids of the Basin, the landscape includes diverse and connected habitats, from freshwater tributaries where they spawn and rear, to mainstem rivers, reservoirs, dams, and the estuary and ocean. In addition, watersheds, hillslopes, and riparian and forest communities influence those habitats. So too do the many and various activities of the people, and a comprehensive landscape perspective includes consideration and engagement of people. Effective conservation and restoration require monitoring of ecosystem status and trends, assessment of the results of actions, and application of knowledge gained to future actions. This report therefore includes discussions of adaptive management, forecasting/scenario planning, and monitoring and assessment of habitats and species at broad spatial scales.

Effective conservation and restoration of the Columbia River Basin *requires* a broader, more comprehensive, and more coordinated approach. This view is not new. For instance, an earlier group of independent science advisors noted that *"…implementation of tributary restoration efforts …. requires agencies to achieve a level of communication and coordination that is unprecedented for such a large area, particularly because their institutional mandates may occasionally promote actions that are contradictory*" **-** Return to the River (ISG 2000, p. 610). However, the needs remain and have grown more pressing in the face of current trends in climate, human population, economy, and globalization (e.g., ISAB 2007-2, 2007-3, 2008-4, 2011-1).

One need is for *coordination of conservation and restoration actions over large areas*, and landscape ecology provides a foundation for this. Another need is for *coordination of social and institutional governance*, involving leadership, improved communication, collaboration among all interests, and development of shared goals and values. This aspect of coordination is widely acknowledged but has proven difficult to achieve. A third aspect of needed coordination is *between social and ecological sciences and of social and economic actions with environmental/natural resource actions*. This coordination can be particularly difficult, as it involves integration among parties that may have conflicting goals, values, or agency missions. Coordination of socioeconomic and environmental/natural resource actions remains a pressing need, and paths to this coordination feature prominently in this report.

This report supports progress on these three aspects of coordination by examining recent science and concludes that restoration of the Columbia River Basin requires implementing a *comprehensive landscape approach*. It is the opinion of the ISAB that a comprehensive landscape approach will improve the efficiency and effectiveness of efforts to conserve and restore the Basin. A comprehensive landscape approach moves beyond spatially isolated or independent projects to broader integration of actions in order to restore a healthy and resilient regional ecosystem that sustains both diverse habitats and fish and wildlife populations and also vibrant human societies. The recommendations of this report are intended to enhance progress on management of ecosystems as natural-cultural systems that support shared social and ecological values and are *resilient*; that have the potential to adapt to changing environmental and social conditions, sustain diverse habitat, fish and wildlife populations, and cultures, and retain the basic functions and services on which those populations and cultures depend. Thus, the report provides guidance for progress toward the visions and goals of the Fish and Wildlife Program, Tribal recovery plans, and NOAA recovery plans.

Scope of the report

This report extends efforts to develop best practices to foster restoration of salmonids, and other fish and wildlife, in the Columbia River Basin. Expanding on the general guidance in *Return to the River* (ISG 2000) to think big, think comprehensively, take note of connections and diversity, and improve mitigation effectiveness, a major focus of this report is on current understanding of the workings of landscapes, from heterogeneous watersheds to even larger areas such as the Subbasins and Ecological Provinces of the Columbia River Basin. In presenting this landscape perspective, we also update recommendations from a previous ISAB report, *Review of Strategies for Recovering Tributary Habitat* (ISAB 2003-2).

The current report adds a focus on the socioeconomic dimension that was not explicit in *Return to the River* (ISG 2000). We emphasize the need to approach restoration and management with interdisciplinary studies and projects. Ecosystems are natural-cultural systems; people and their activities are integral parts of ecosystems and have been for millennia. Landscapes are integrated and coupled ecosystems that include many biological and physical players: people and many other organisms, including fish and wildlife, as well as the lands, waters, and diverse physical, chemical, and hydrologic processes that support them.

Structure of the report

The report consists of this introduction (Section I), seven other sections, and two Appendices.

Section II (*Landscape Legacy of the Columbia River Basin*) describes changes in the Columbia River Basin landscapes over historic time. Emphasis is on the extensive landscape changes that followed European colonization and continue to form the Basin and its cultures.

Section III (*Foundations for a Comprehensive Landscape Approach*) presents current understanding of how the patterns and processes structuring landscapes underpin the abundance, diversity, productivity, and resilience of both fish and wildlife populations and socioeconomic systems. The section distills principles for restoration of large landscapes.

Section IV (*Criteria to Evaluate Landscape Conservation and Restoration*) identifies four Criteria that are necessary for effective landscape conservation and restoration. These Criteria are the organizing framework for the report. Examples are provided to illustrate the effectiveness of approaches to landscape restoration and how these relate to the Criteria.

Section V (*Implementing a Comprehensive Landscape Approach*) notes several long-standing challenges to successful implementation of landscape-level restoration of the Basin's landscapes and discusses paths to resolving them.

Section VI (*Building Adaptive Capacity through Adaptive Management*) discusses building adaptive capacity, through adaptive management, monitoring, and assessment. It provides brief guidance as to ways to overcome the considerable challenges to these enterprises that are posed by the size and physical, biological, and social complexity of the Basin. This review emphasizes feasibility and adequacy to assess status, trends, and effectiveness at large spatial scales, as well as approaches that better integrate the social, economic, and cultural aspects with the natural resources that are the typical focus of monitoring.

Section VII synthesizes the central recommendations from the report

Section VIII provides concluding remarks.

Appendix A provides more detail on viable salmonid populations; adaptation, diversity, and restoration; classification systems; spatial structure; and linked habitat and life history models considered in Section III.

Examples of how guidelines drawn from a comprehensive landscape approach have influenced efforts to restore large areas are given throughout the report and in Appendix B, which provides case studies for seven large-scale restoration programs considered in Section IV.

II. Landscape Legacy of the Columbia River Basin

Landscapes are a product of their history, carrying the overt and subtle imprints of past natural events and human activities:

> *"... the legacies of land use activities continue to influence ecosystem structure and function for decades or centuries – or even longer – after those activities have ceased. Consequently, recognition of these historical legacies adds explanatory power to our understanding of modern conditions... and reduces missteps in anticipating or managing for future conditions." (Foster et al. 2003, p 77).*

People have greatly changed landscape patterns and processes of the Columbia River Basin through activities that have included depletion of fur-bearing animals and large predators, development of agriculture, mining, timber harvest, fisheries, and hydropower, industrialization, and urbanization. These activities came into prominence sequentially over a period of only 200 years (Figure II.1). Each activity developed rapidly over a span of four to five decades, and each continues to have significant social, political, economic, and ecological impacts. The fundamental drivers of landscape change have been growth of the human population, expansion of the economy, advances in technology, and globalization.

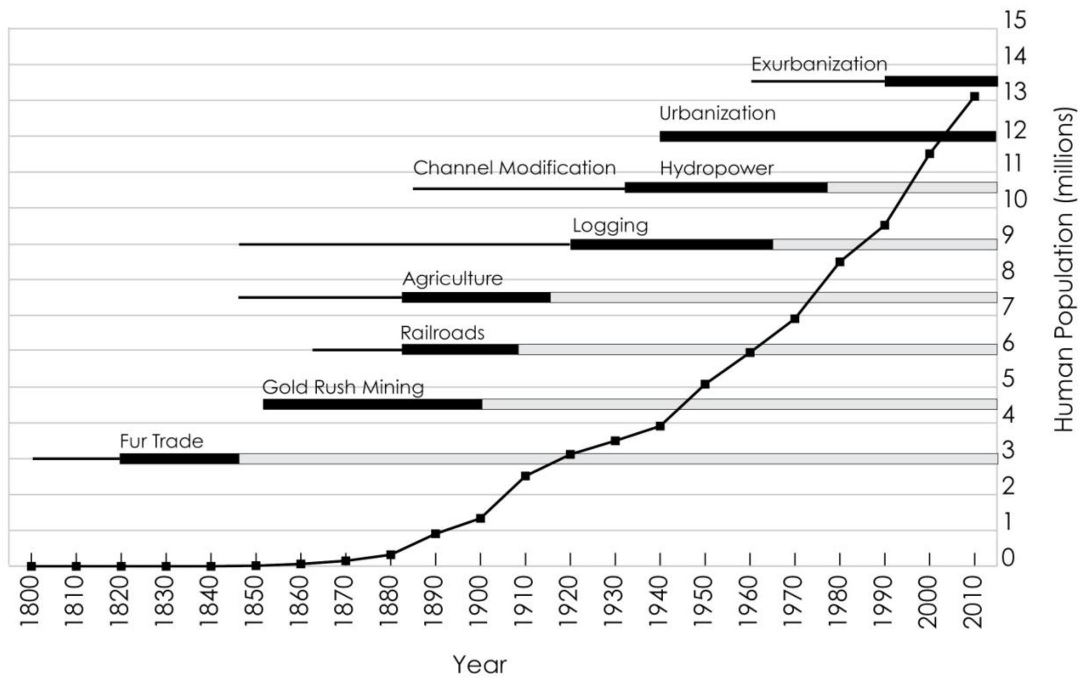

Figure II.1. Sequential development of activities driving landscape change in the Northwest and concurrent changes in human population size. (U.S. Census data for Oregon, Idaho, Montana and Washington). Wide dark bars indicate the period of peak development and rapid habitat conversion, and wide light bars indicate continued effects following the development period (prepared by NPCC staff).

Landscape Effects of Pre-settlement Resource Use by Native Americans

Human interactions with the landscape did not begin with the arrival of Euro-Americans. Native Americans had occupied the region for at least 10,000 years (Campbell and Butler 2010) and had established their own accommodation with the landscape; they managed the resources on which they depended. The "footprint" of native cultures on Northwest landscapes was small, relative to the pervasive impacts of modern industrial society.

Use of fire to manage habitat

Native American tribes occupying the Northwest prior to Euro-American settlement used fire as a tool for manipulation of local habitat (reviewed by Robbins and Wolf 1994, Hessburg and Agee 2003). Fires were set at times and locations favorable for new growth of plants used as food by both humans and the animals they hunted (Boyd 1986, Boag 1992). Cessation of burning by Native Americans likely contributed to successional changes in grassland, shrub, and lower-elevation woodland and forest biomes throughout the Northwest over the past century, but other influences, such as fire suppression and livestock grazing, also have contributed to these changes.

Use of aquatic resources

Salmon and other aquatic foods were an integral part of the culture of Native American tribes in the Columbia Basin and figured prominently in mythology and ceremony (Gunther 1926, Williams 1980, Landeen and Pinkham 1999, NPCC 2004, ISAB 2011-1). Salmon were a food of major importance as early as 8200-9300 BP (Butler and O'Connor 2004) and remained so (Butler and Campbell 2004). Anthropological data and the observations of early explorers and fur traders indicate that native people regulated harvest of salmon at important fishing areas on the Columbia River and tributaries through social custom and negotiation (Campbell and Butler 2010). The weight of evidence suggests that Native Americans in the Columbia River Basin avoided the overuse of aquatic resources that has characterized many modern fisheries. Fisheries were concentrated at favorable mainstem locations and harvested mixed stocks, so overharvest of specific populations or subpopulations may have occurred at times, but impacts would have been reduced by the great diversity of life history types within and among populations and species at that time.

The Fur Trade: Agent of Landscape-Scale Change

The original impetus for exploration of the Northwest was the lure of profits from the fur trade. The resulting near extirpation of beaver[1] was the first major impact of Euro-American exploration and settlement on Northwest ecosystems, and the effects on landscape patterns and processes, although often unrecognized, remain evident today. Attitudes toward beaver today vary; reintroduction efforts are underway in some areas, while elsewhere beaver removal is still official policy.

Beaver dams strongly influence stream flows and sediment transport. The highest density of beaver dams is on the smaller first- through fourth-order streams (Naiman 1988) that account for >80% of the total length of river systems (Naiman 1983, Benda et al. 2005).

[1]Beaver were a casualty of competition between Britain and the United States. The two countries had competing claims to the territory then known as the Oregon Country, but an agreement in 1818 allowed joint use and settlement of the region. Both parties realized that long-term joint occupancy of the region would be untenable and that control would eventually be established by settlement. The strategy of the Hudson's Bay Company was to extirpate fur-bearing animals, particularly beaver, to discourage American trappers and traders (Langston 1995, Thorson 2009). This campaign of extermination severely reduced beaver populations throughout the Northwest.

Individual beaver dams have a life span of a year or two to a few decades. When they are breached or abandoned, newly exposed sediments are colonized by terrestrial plants and become valley bottom meadows, which may persist for centuries (Rudemann and Schoonmaker 1938). Chemical elements accumulated from decay of the originally inundated upland vegetation support growth of plants in the new meadows (Naiman et al. 1994). The result over time is a longitudinal mosaic of ponds, meadows in different successional stages, and steeper, free-flowing steam reaches. In large river systems, beaver build dams on floodplain channels and backwaters, adding to the patchiness of the mosaic of habitats. Beaver impoundments and beaver-formed meadows modify the hydrology, geomorphology, and ecology of streams and the exchange of nutrients with adjacent terrestrial ecosystems: consequently, aquatic and riparian habitats in watersheds with healthy beaver populations differ considerably from those of watersheds without beaver (Sidebar II.1).

Continued over millennia, the process of beaver dam building and rebuilding flattens valley profiles and elevates valley floors (Naiman et al. 1988, Pollock et al. 2003). The rapid stream incision and loss of sediment that has been noted in many areas of the west in recent years in many cases probably reflects erosion of meadow sediments deposited behind now absent beaver dams, accelerated by removal of large woody debris and trampling of stream banks by livestock. Stream incision lowers groundwater levels and may change perennial into intermittent streams, with severe consequences for aquatic and terrestrial biota.

Beaver populations can reestablish rapidly, given habitat and protection from harvest or removal (Figure II.2), and can contribute to watershed restoration. A study (Pollock et al. 2007) of the ability of beaver dams to reverse incision in an eastern Oregon stream found aggradation rates as high as 0.5 m/yr behind new dams and rapid expansion of the riparian zone.

Sidebar II.1. Did Decimation of Beaver Contribute to the Decline of Coho Salmon?

Concern that beaver dams might block the upstream movement of adult salmon sometimes prompts their removal from spawning streams. This concern is probably valid only for annual low flow periods; several studies have shown that salmon can easily pass beaver dams at higher flows (Swanston 1991). Beaver ponds eliminate some potential salmonid spawning areas because of reduced flow, increased depth, and siltation, but scouring below the dams may also create clean gravel depositions suitable for spawning. Aquifer recharge from beaver impoundments can help maintain dry season flows in small streams (Pollock et al. 2003). Little research has been done In the Columbia River Basin on the use of beaver pond habitat by juvenile salmonids, in part because populations of naturally spawning coho salmon, the species that may derive the most benefit from use of beaver-created habitat, have been almost eliminated.

Coho were widespread in the Columbia Basin in the early 20th century. These runs were reduced to less than 5% of historical levels by the late 1950s (NOAA 1991). As with declines in the abundance of other salmonid species in the Basin, the causes were multiple and included over harvest, loss of access to spawning areas, and habitat modification. Because beaver ponds and backwater areas are preferred rearing habitat for juvenile coho (Murphy et al. 1989, Leidholt-Bruner et al. 1992, Pollock et al. 2004), it is highly likely that loss of beaver pond habitat in the Basin during the late 19th and early 20th centuries contributed to the decline of this species and continues to be detrimental to recovery efforts.

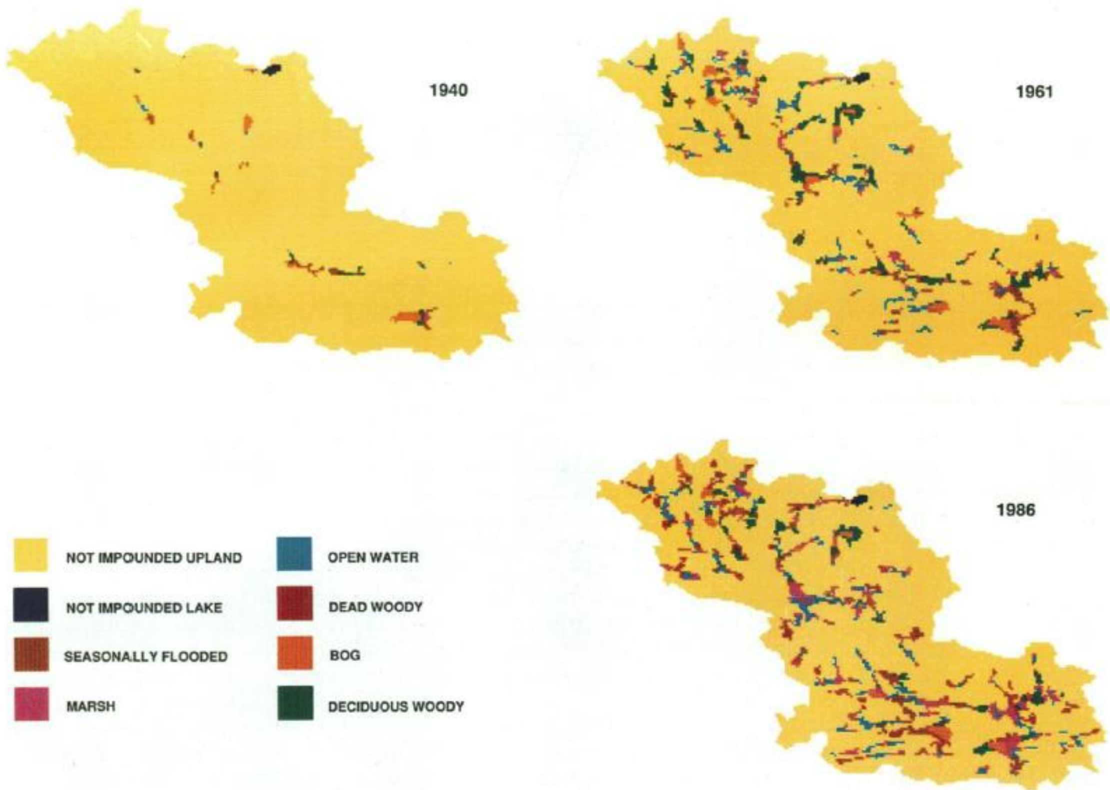

Figure II.2. Changes in aquatic and riparian habitats during expansion of beaver populations on the ~300 km^2 Kabetogama Peninsula, Minnesota, over a 46-year period (1940-1986; from Naiman et al. 1988).

Habitat Conversion and Fragmentation: Railroads, Agriculture, Timber Harvest, and Roads

Improved transportation, passage of Federal legislation[2] intended to encourage immigration, and discovery of abundant deposits of gold and silver spurred population growth and development in the Northwest during the second half of the 19th century. Only a few hundred settlers made the arduous wagon journey to the Oregon Country in the 1830s, but extension of the Oregon Trail to The Dalles in 1843 and discovery of gold in California in 1848, followed by subsequent gold and silver strikes in Idaho, Montana, Oregon, eastern Washington, and Canada, opened the door to mass immigration (Schwantes 2000, HistoryLink, accessed 2011). The population of the Northwest surged to 60,000 by 1860 and to over 900,000 by 1890 (Figure II.1). Soaring demands for food and lumber, along with development of the rail system, spurred rapid

[2] Four years after resolution of the Oregon Country dispute with Britain in 1846, Congress passed the Donation Land Claim Act, which led to the development of the Willamette Valley. By the time the law expired in 1855, more than 7,000 settlers had filed on more than 2.8 million acres in Oregon. An even greater stimulus to immigration was passage of the Homestead Act in 1862, which offered settlers free title to 160 acres (65 hectares) of undeveloped Federal land.

expansion of agriculture and the timber industry.

Railroads

Railroads brought the industrial revolution to the Northwest. An immediate effect was to connect croplands (already in use or with potential for production) and beef-producing rangelands with eastern and California markets (Robbins and Wolf 1994). Resulting changes in land use for grazing and farming activities are discussed below. Another change with enduring consequences was the transfer of vast amounts of public land to the railroad companies. To subsidize railroad construction, the companies were given every odd-numbered section (one square mile, or 259 hectares) of public land within 10 miles of the right-of-way. For a time the land owned by the railroads continued to be publically available for grazing and other uses, but eventually most sections were leased or sold. The resulting checkerboard pattern of public and private land ownership cross-cuts landscapes in many areas; different land-use objectives and attitudes toward land stewardship have fragmented once extensive tracts of habitat and altered suitability for some species of wildlife (Figure II.3). The railroads were also important in opening up large tracks of timber for harvest, often with devastating effects on old-growth forests (also see Figure II.7 below).

Grazing

The cattle industry grew rapidly during the Gold Rush years, first on the west side of the Cascades and then eastward into the valleys of Columbia Basin tributaries. As ranching pushed further into the Columbia Plateau, drier and more fragile lands were grazed. By the time that additional stimulus was provided by arrival of the railroads in the 1880s, damaging effects of grazing on riparian, grassland, and dry shrubland-forest habitats were already evident in many parts of the Basin. Riparian zones, with abundant vegetation and water, are preferred by cattle and thus are particularly vulnerable to grazing damage. Although riparian zones make up only 1-4% of the land area of eastern Oregon and Washington national forests, they supply over 80% of the vegetation eaten by livestock (Hessburg and Agee 2003 and citations therein). Removal of native vegetation and trampling of stream banks often leads to bank collapse, sedimentation, stream shoaling, and increased solar warming (Figure II.4). The degradation of the riparian zones profoundly influences connections between terrestrial and aquatic ecosystems and the movements of materials, energy, and organisms.

Dry shrublands and grasslands are also easily damaged by overgrazing. Following the introduction of large numbers of cattle and sheep, native grasses were largely replaced by grazing-resistant, non-native plants such as thistles, cheatgrass, toadflax, knapweeds, and spurge (Robbins and Wolf 1994). Ecological effects are far-reaching: reduced quantities of fine, highly combustible materials no longer support the frequent fires that were part of the natural disturbance regimes of grasslands and prairies, periodically killing the young stages of woody plants. Consequently, in many areas sagebrush-juniper woodlands and ponderosa pine-Douglas fir forests have replaced shrublands and grasslands that had not been converted to agriculture (Figure II.5).

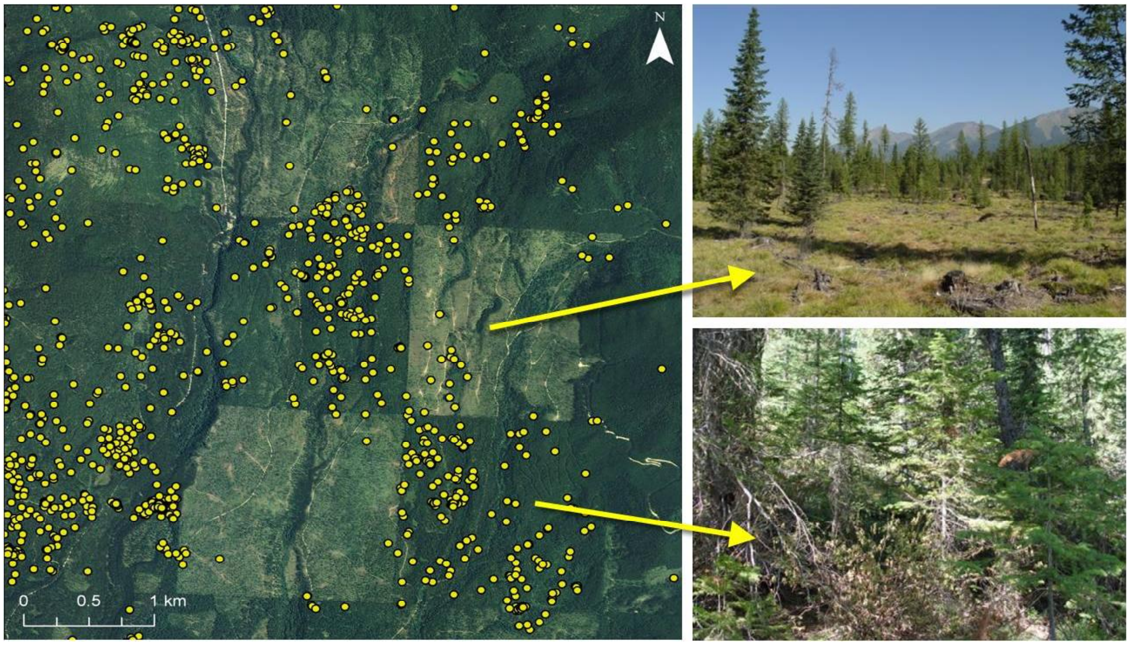

Figure II.3. Avoidance of clear-cut areas by radio-collared lynx, Morrell Creek drainage, Montana (2006). The checkerboard pattern is a legacy of land grants to the Northern Pacific Railway in the 1860s (courtesy of John Squires, Northern Rockies Lynx Study, Rocky Mountain Research Station, Missoula, Montana).

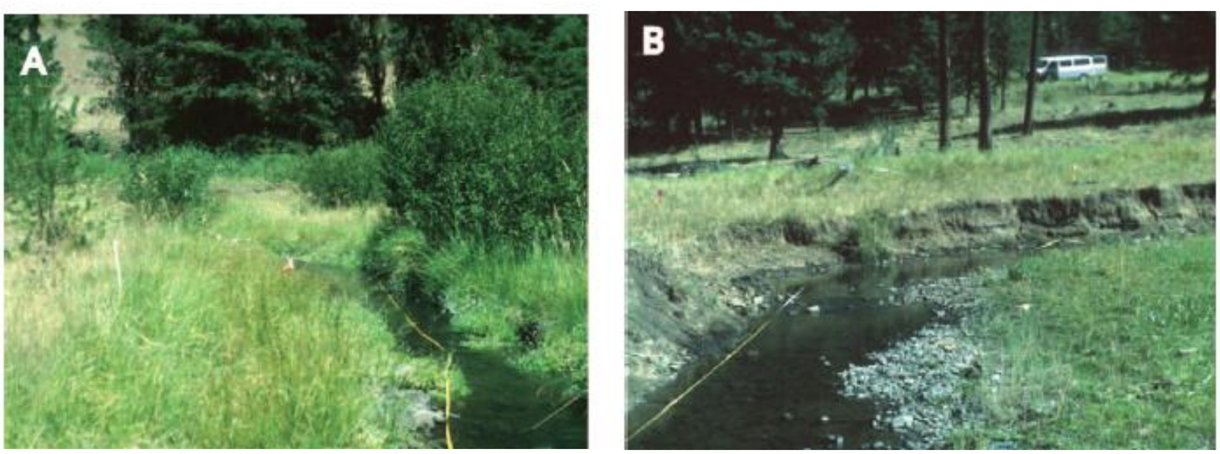

Figure II.4. Riparian vegetation at (A) ungrazed (fenced) and (B) grazed sites on Devil's Run Creek, eastern Oregon (from Bayley and Li 2008).

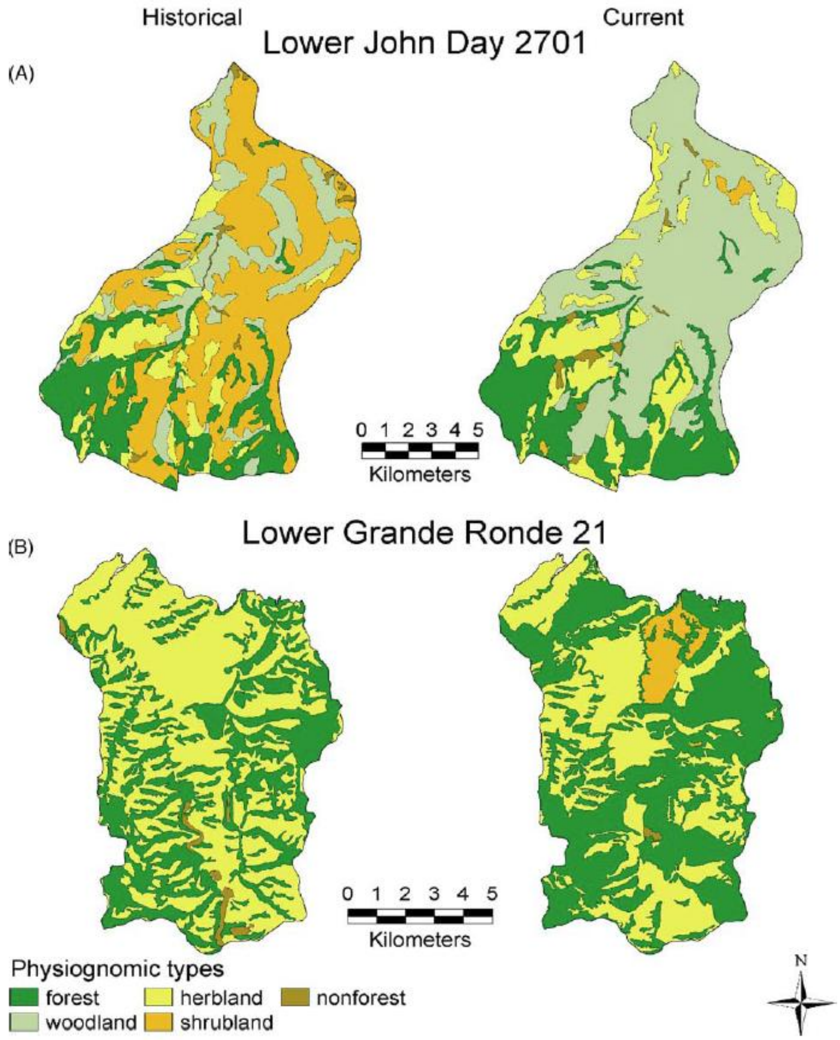

Figure II.5. Historical (1930s) and current (1990s) habitat-type patterns in two subwatersheds of the Columbia Plateau Province. (A) Lower John Day 2701, note replacement of shrubland by woodland and (B) Lower Grande Ronde 21, note replacement of herbland-grassland by forest cover (from Hessburg and Agee 2003).

Government agencies began limited regulation of grazing practices during the early decades of the 20th century, and protection subsequently improved. Shrublands and grasslands have recovered some from past abuse, but land-use legacies are persistent and sometimes irreversible (Foster et al. 2003 and citations therein). Exotic rangeland plants are difficult to eradicate and reestablishment of historical burning regimes may fail to reestablish original soil characteristics and plant communities (Foster et al. 2003).

Farming

Early settlers found ideal farming conditions in the Willamette Valley and other fertile valleys of the Columbia River Basin. Although the amount of land put into crop production was relatively small through the mid-1800s, the areas selected for conversion to farmland were the most productive, biologically diverse, and closely linked with stream networks. After railroad lines reached the interior Columbia Basin in the late 1800s, the acreage of cultivated land increased rapidly. By the 1930s, most of the native grasslands in the Basin were converted to cropland or grazing land (Robbins and Wolf 1994, Hann et al. 1997).

Today, agriculture (cropland, pastureland and rangeland) is the dominant anthropogenic landscape feature in the Northwest (40% of total land area, Wuerthner 1994, citing data in Jackson and Kimerling 1993), in the United States (46%, Vesterby and Krupa 2001), and worldwide (38%, The World Bank Open Data 2011). Conversion to agriculture, which generally replaces native habitats and destroys or disrupts habitat connections, fundamentally alters the geomorphic and ecological processes (Foley et al. 2005, Donald and Evans 2006). Agriculture has had a disproportionately large impact on low-elevation areas with productive soils and easy access (Huston 2005, Leu et al. 2008), and these areas are typically tightly linked to aquatic systems (Figure II.6). Some birds and mammals make use of cultivated land and adjacent "edge" habitats but fare less well as the intensity of agricultural practices increases (Donald et al. 2001). Additionally, the ecological functions of non-agricultural lands in a landscape matrix can be reduced if agricultural lands act as barriers to the transfer of energy and materials and the movements of organisms (Donald and Evans 2006). The barrier effect becomes increasingly evident as smaller farms become consolidated into large, spatially homogenous, industrial farms (Benton et al. 2003). For these reasons, conservation and restoration of landscape pattern and process and of function in landscapes with a major agricultural component is challenging (Benton 2007) but can be improved (e.g. Colvin et al. 2009).

Changes in the physical and chemical properties and microbial communities of cultivated soil can persist long after cultivation ceases (Foster et al. 2003 and references therein). Similarly, changes in plant and animal communities may persist for many decades or centuries after former habitats types are reestablished on

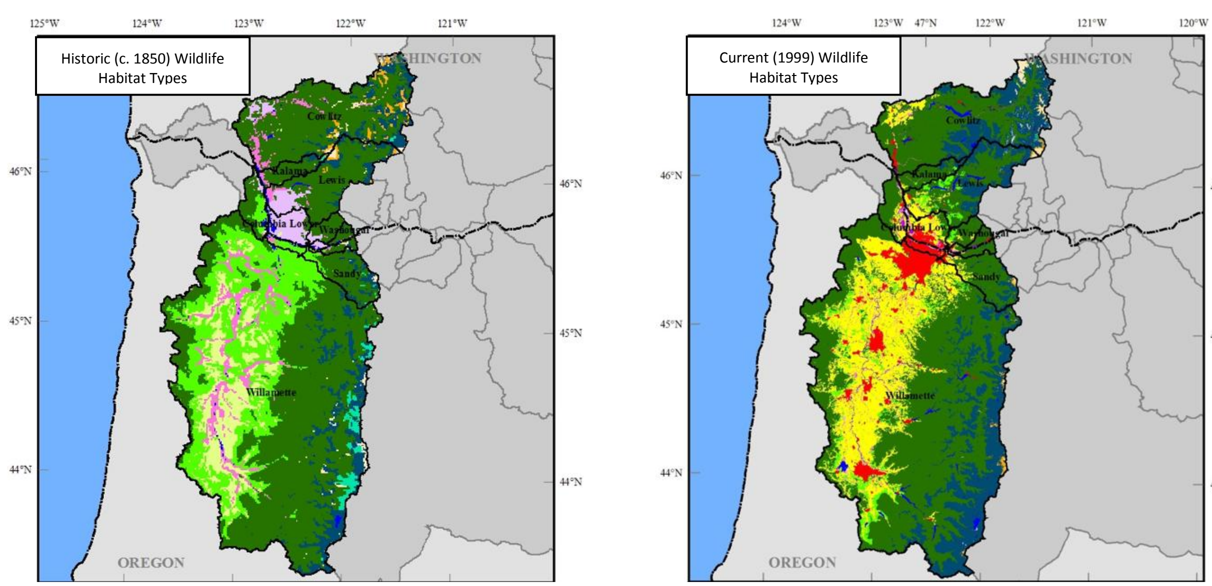

Figure II.6. Changes in habitat types in the Lower Columbia Province from 1850 (left) to 1999 (right). The most salient changes are conversions of mesic oak-dry Douglas fir forest and woodlands (light green) and of herbaceous wetlands (lavender) and mesic riparian-wetlands (pink) to agricultural (yellow) and urban-suburban (red) uses (from Northwest Habitat Institute; www.nwhi.org/index/ibis).

previously cultivated lands (Foster et al. 2003). Many factors contribute to this refractory response to restoration: soil conditions may no longer be favorable for native plant species, limited mobility or barriers to movement may prevent access by native species, or non-native competitors may have become established and monopolize key resources.

Logging and forest management

The development of mining, agriculture, railroads, and urban centers in the late 19th century created strong local demand for lumber, accelerating growth of the timber industry. Large-scale lumber production began after World War I, when adoption of the gasoline engine to power tractors, logging trucks and yarding machines, along with increased access to eastern U.S. and international markets, pushed timber harvests upward to levels that were maintained for over four decades (Robbins and Wolf 1994, Figure II.1). In earlier years, ponderosa pine was the preferred species. After selective removal reduced the abundance of this species, broader market interest developed in species such as Douglas fir, larch, cedar and spruce, and clear-cutting became the preferred method of harvest (Robbins and Wolf 1994). The industry declined after the mid-1980s, as it became uneconomic as a consequence of decreased availability of old-growth timber, competition with foreign competitors, and new environmental protection laws. Clear-cutting substantially alters forest habitat (Figure II.7), and the time required for reestablishment of mature forest depends upon both natural factors (soil, slope, exposure, precipitation and others) and management practices. Early successional stages create favorable conditions for some wildlife; for example, forb and shrub regrowth in clear-cuts provides forage for elk and deer. On the other hand, birds such as the spotted owl and marbled murrelet and mammals such as fisher, marten, and lynx (see Figure II.3) require old-growth forest.

Prior to settlement and the advent of logging and fire suppression, old-growth forest was abundant in the Basin, and fires ignited by lightning or by Native Americans created a

Figure II.7. Clearcut timber harvest, likely Washington, circa 1934. University of Washington Special Collections (http://content.lib.washington.edu/u?/indocc,541) matrix of forest types in various stages of succession. Stands of old-growth timber are now uncommon and isolated. Creation of a mosaic of forest in different seral stages, limitations on the maximum size of clearcuts and alternative harvest prescriptions, and provision for migration corridors between patches of mature forest can help maintain connectivity, gene flow, and persistence of animal populations (Swetnam et al. 1999, Keane et al. 2002).

Fire suppression and grazing have decreased the frequency of wildfires in the Columbia Basin, allowing accumulation of fuel loads. In the absence of low-intensity ground fires, clear-cutting, selective logging, and plantation forestry have simplified forests. In concert with a changing climate, the result has been larger and more severe fires, affecting millions of hectares of Federal, state, and private land (Figure II.8, Hessburg and Agee 2003). Although stand-replacing fires can have both immediate and long-term deleterious effects on ecosystems, fire also maintains the structure, function, diversity and complexity aquatic and terrestrial ecosystems (e.g., Reeves et al. 1995, Bisson et al. 2003), and aggressive management of fire and fuels can be detrimental (Rhodes and Baker 2008). The threats and benefits of fire and fuels management are debated (Bisson et al. 2003, Rieman et al. 2003, 2010), underscoring the need to engage and integrate all perspectives in deciding on strategies for conservation, restoration, and management of landscapes (Rieman et al. 2010).

Roads

Roads are a dominant landscape feature in the American West (Leu et al. 2008). The largest contributor to the road network is tertiary roads that were built to access timber and other natural resources; road densities on lands managed for timber production are often much higher than in rural agricultural areas (Figure II.9). Valley bottoms along streams are favored locations for “arterial” roads, while others are constructed on steeper hill slopes for logging access. Roads have caused erosion, altered hydrology, and commonly act as barriers to movement of terrestrial and aquatic species. They can also facilitate the establishment and spread of exotic species (Trombuka and Frissell 2000). Under-road culverts often act as barriers to fish during periods of low flow or, in some cases, throughout the year (Figure II.10). The conservation status of native fishes in the interior Columbia Basin is consistently and negatively correlated with forest road density (e.g., Lee et al. 1997, Rieman et al. 2001).

Habitat Conversion and Fragmentation: River Channel Modification and Hydropower

Until partially supplanted by railroads in the late 1800s, rivers were the primary corridors for travel and commerce in the Columbia Basin. To facilitate passage of boats and barges, the U.S. Army Corps of Engineers modified larger rivers by deepening primary channels, removing large woody debris, and eliminating side channels, sloughs, alcoves and islands (ISAB 2011-1, Chapter B.2). Dikes were constructed to convert bottomlands to farmland.

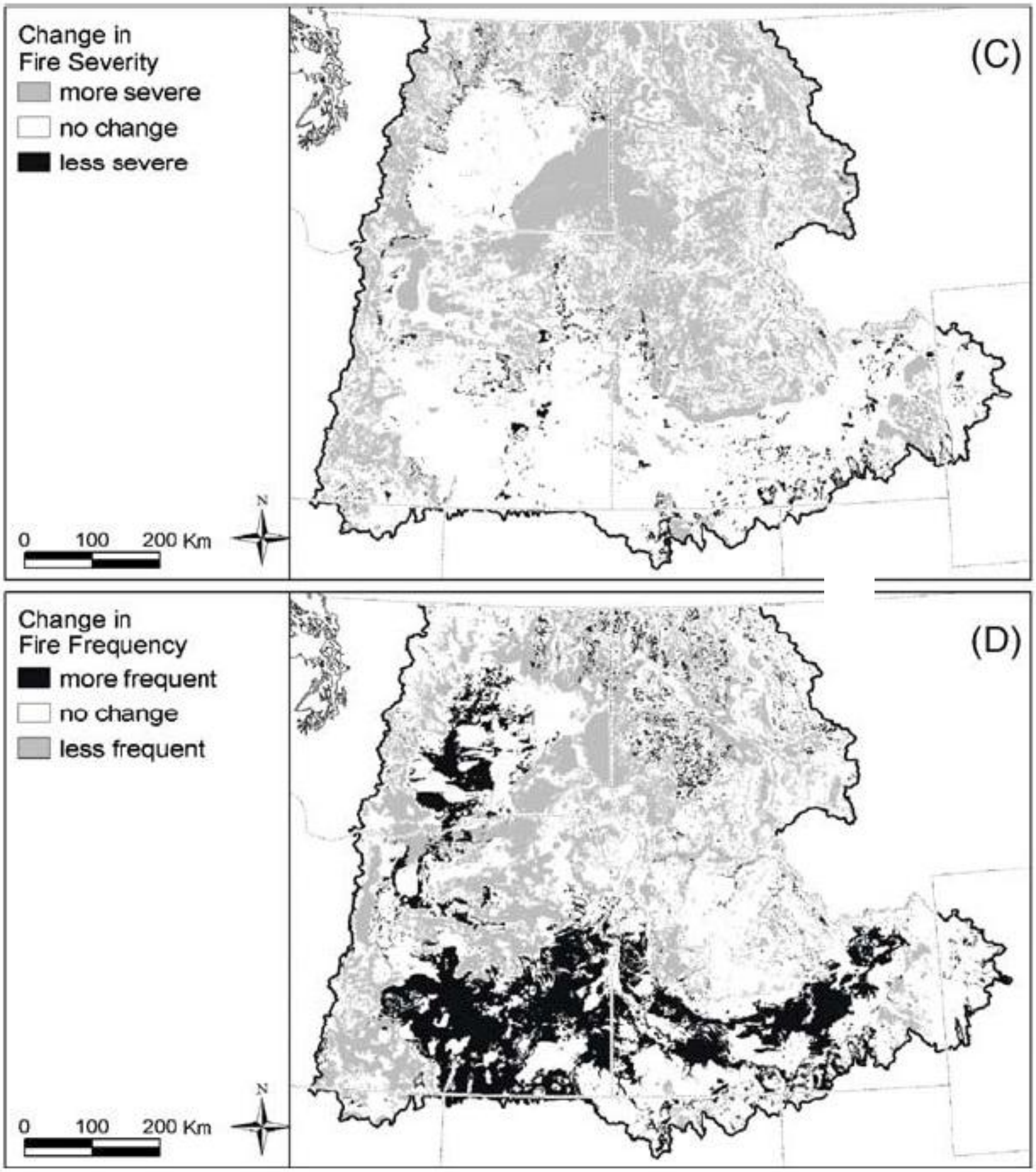

Figure II.8. Changes in fire severity (upper) and frequency (lower) in the Columbia River Basin, 1800-2000 (from Hessburg and Agee 2003).

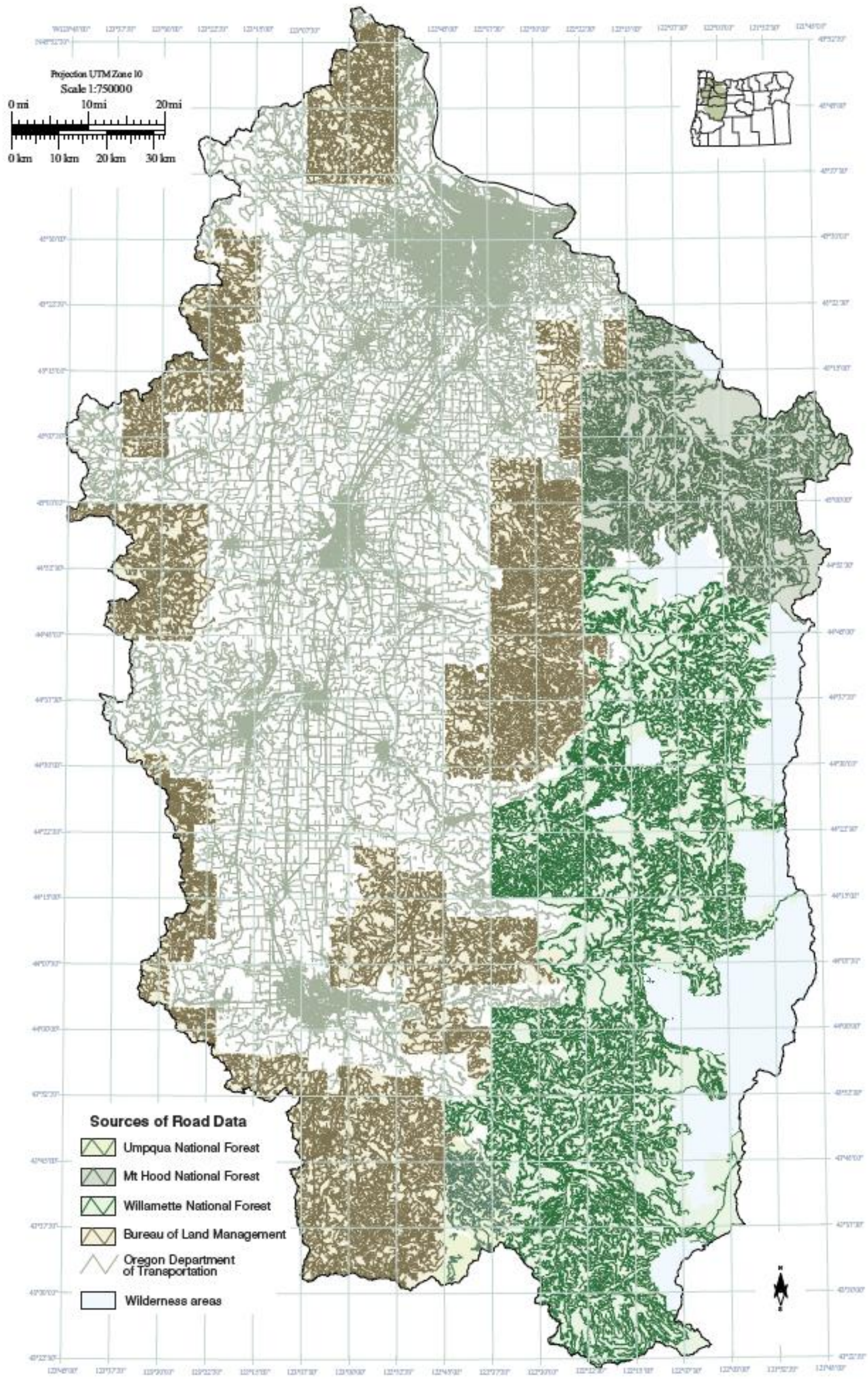

Figure II.9. Roads of the Willamette River Basin. Roads shown in light gray are maintained by the Oregon Department of Transportation, in dark gray (or brown) by the Bureau of Land Management, and in all other colors by the U.S. Forest Service. The densest road networks (other than in urban areas) are on Forest Service and Bureau of Land Management lands managed for timber production. From Hulse et al. 2002:71 with permission.

Figure II.10. Poorly designed culverts block upstream fish passage. Photo: Cecil Rich.

Channel modification

Channel modification began early in the Willamette and other larger river valleys, due to the importance of the valley centers for settlement and agriculture. On the upper Willamette River, the network of braided channels was progressively simplified until flow was largely confined to a single channel. The complex of biologically diverse riparian, bottomland, and backwater habitats bordering the river was reduced by over 80% (Figure II.11; Hulse et al. 2002). Similarly, modifications to channels and tidelands in the Columbia River estuary reduced the area historically occupied by wetlands by about one-half (ISAB 2011-1, Chapter D.7). River and stream channels throughout the Basin were also altered by dams, water diversions, and channelization. Large wood was removed from stream channels to reduce the danger of flooding and because (for a period in the mid-20th century) it was believed that log jams were obstacles to upstream movement of adult salmon (Merrell 1951). Another change was the construction of large upstream water storage dams, which reduced the spring freshets that in earlier years periodically reshaped and renewed the mosaic of floodplain habitats. In aggregate, these changes affect thousands of kilometers of rivers and streams and have greatly reduced riparian and floodplain habitats, as well as connectivity between terrestrial and aquatic habitats (ISG 2000, ISAB 2011-1). Loss or simplification of the mosaic of habitats previously available in these mainstem areas has altered food webs and reduced the availability of feeding and refuge areas used by salmonids and other fishes (ISAB 2011-1).

Dams

Small dams are located on public and private lands throughout the Basin (Figure II.12). Almost 1/2 of the identified dams in the Columbia River Basin are used to store water for irrigation use (Lee et al 1997, Figure II.13). Small dams eliminate flowing-water habitat and increase sedimentation, but may increase aquifer recharge. Low dams are often barriers to fish movement, blocking migrations to and from spawning or rearing areas and increasing the risk of extirpation for isolated subpopulations.

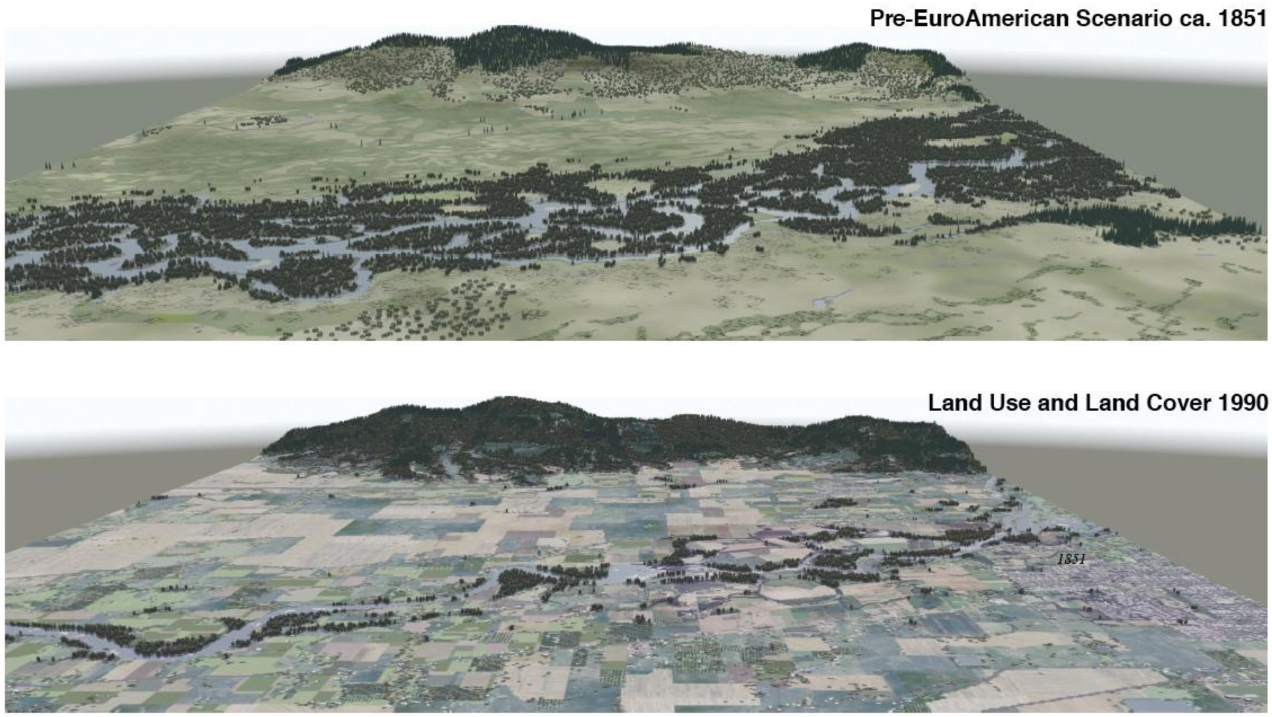

Figure II.11. Simulated aerial views of the upper Willamette River between Harrisburg and Eugene, Oregon, in 1851 and 1990 (from U.S. Environmental Protection Agency's Willamette Valley Alternative Scenarios website, based on data from Hulse et al. 2002:82 with permission).

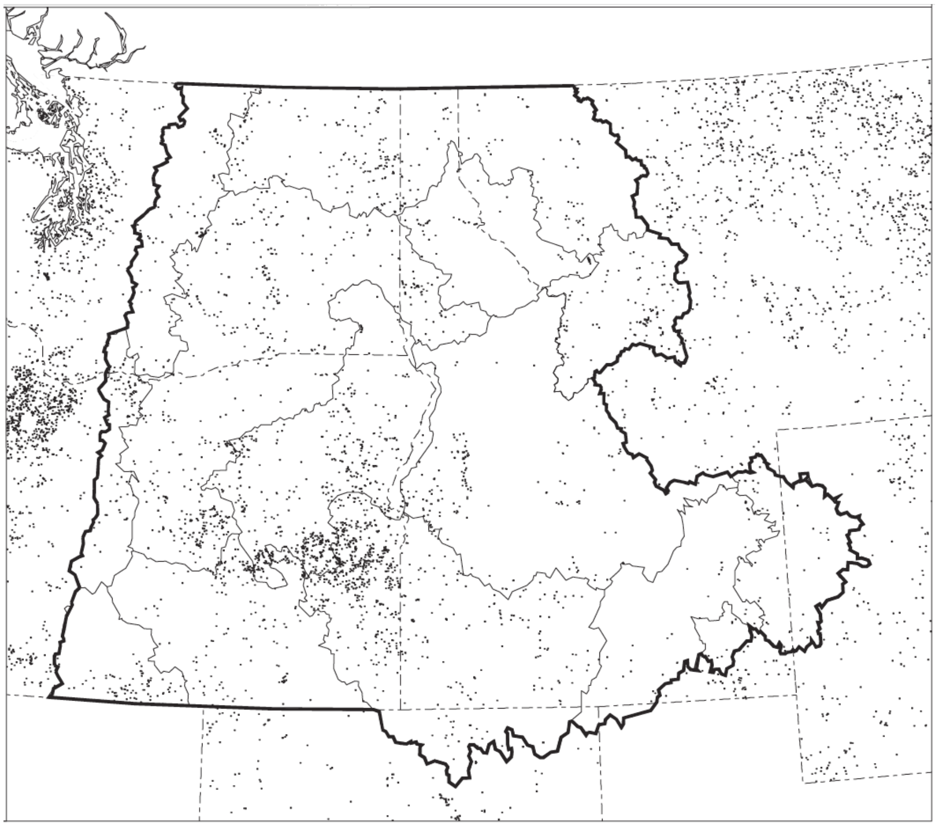

Figure II.12. Each dot represents a recorded dam in the Interior Columbia River Basin (east of the Cascade crest delineated by the heavy line). From Lee et al. 1997. Based on state inventories of dams generally meeting federal regulatory requirements (e.g. > 2m height).

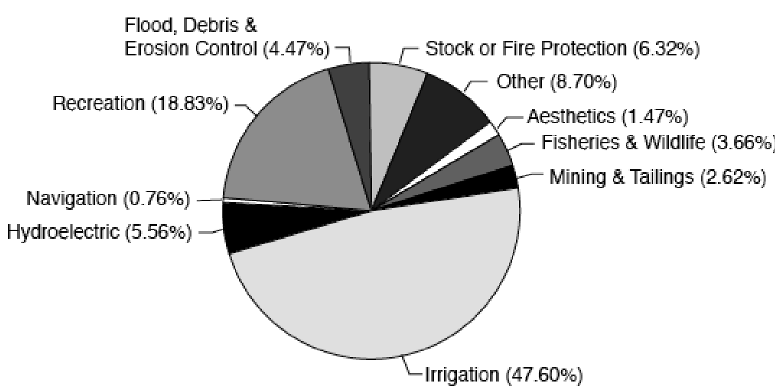

Figure II.13. Summary of primary uses of dams in the Interior Columbia River Basin. Summarized by Lee et al. 1997, see figure 11.12

The hydropower potential of the Columbia River was recognized early in the 20th century, but no major projects were undertaken until the Great Depression began and dam construction was identified as an instrument of economic stimulus. Rock Island Dam was completed in 1933, followed by Bonneville Dam (1938) and Grand Coulee (1941). These major dams and others constructed during the following decades provided abundant cheap electrical power for the Northwest and supported quickening economic activity, human population growth and urbanization throughout the second half of the 20th century (Figure II.1).

Large hydroelectric dams on the mainstem Columbia River and its major tributaries have substantially altered riverine and riparian habitats, aquatic food webs, and fish migrations (NRC 1996, ISG 2000, ISAB 2011-1). Impoundments behind the dams provide habitat for many non-native organisms, ranging from aquatic plants and zooplankton to predaceous fishes; some of these organisms compete with, feed on, or are fed on by native species, while the effects of others are not yet known (ISAB 2008-4, ISAB 2011-1). Since the 1980s, survival of juvenile and adult salmon migrating through the series of hydroelectric dams on the Snake and Columbia Rivers increased as fish-passage facilities at the dams have improved (Williams et al. 2001) and as hydrosystem operations have been modified (e.g., release of stored water from upstream storage reservoirs and increased spill) to assist fish migrations. Nevertheless, substantial mortality is still associated with hydrosystem passage, and white sturgeon and Pacific lamprey have not benefited from fish-passage facilities, which were specifically designed to assist passage of salmon. The combination of the hydrosystem, loss and fragmentation of

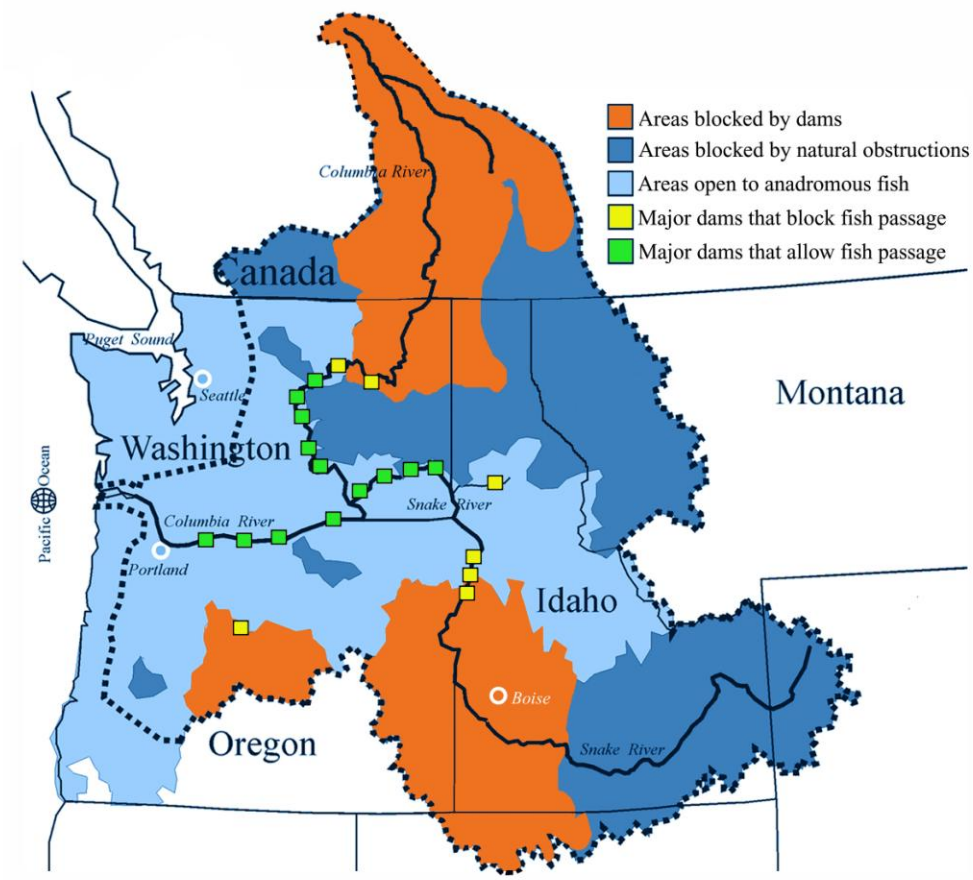

Figure II.14. Map of major dams that allow or block fish passage and the areas open to or blocked to anadromous fish (modified from the Northwest Power and Conservation Council's first fish and wildlife program, November 1982, Page 7-2 as Figure 9, titled "Anadromous Salmon and Steelhead Habitat, Columbia River Basin").

spawning and rearing habitat, harvest mortality, water pollution, and other factors make recovery of depleted salmon stocks a challenging objective.

Some dams in the upper portions of the Basin do not allow passage of anadromous fish. Chief Joseph Dam on the mainstem Columbia River, Hells Canyon Dam on the lower Snake River, Dworshak Dam on the Clearwater, the Pelton-Round Butte Dam complex on the Deschutes River,[3] and most tributary dams in the upper Willamette River Basin are impassable barriers for migrating adult salmon, steelhead, and lamprey. These dams and other impassable dams on smaller tributaries have eliminated access to about 31-35% of historically available spawning and juvenile rearing habitat in the Basin (Figure II.14).

Habitat Conversion and Fragmentation: Urbanization and Exurbanization

Economic and population growth slowed in the Pacific Northwest during the 1920s and the depression decade that followed. This period ended suddenly with the Japanese attack on Pearl Harbor in December 1941. Within months, Portland and Seattle became active centers for the production of armaments. Jobs in shipyards and airplane factories attracted workers from throughout the country, increasing the population of the Northwest by 25% between 1940 and 1947. Most new residents stayed after the war, buying homes in the suburbs that developed around urban centers. The resulting housing boom fueled demand for lumber and other manufactured products. A growing economy and increased birthrate, along with continued immigration, set population growth on a new, higher trajectory that continued through the second half of the century (Figure II.1). Over time, land availability near urban centers decreased or was restricted by land-use regulations. Subdivision developers pushed further into rural areas, where land was cheaper, development less regulated and taxes lower. In recent years, the population growth rates of some smaller metropolitan areas have exceeded those of larger metro areas. Nevertheless, absolute population growth is much greater in the larger metropolitan centers (www.census.gov/popest/metro/metro.html; ISAB 2007-3). Despite continued growth, densely populated urban and suburban areas occupy less than 3% of the land area of the Northwest, but these areas have

Table II.1. Percentages of populations and numbers of residents (millions, in parentheses) classified as “rural” in the four Northwestern states, 1920-2000.[1,2]

State	1920	1940	1950	1990	2000[2]
Idaho	72.4 (0.31)	66.3 (0.35)	57.1 (0.34)	42.6 (0.43)	33.6 (0.43)
Montana	68.7 (0. 38)	62.2 (0.35)	56.3 (0.33)	47.5 (0.38)	45.9 (0.41)
Oregon	50.2 (0.39)	51.2 (0.56)	46.1 (0.70)	29.5 (0.84)	21.3 (0.73)
Washington	45.2 (0.61)	46.9 (0.81)	36.8 (0.88)	23.6 (1.15)	18.0 (1.06)

1) Definition of rural by U.S. Census Bureau: “...not in urbanized areas and not in centers of more than 2,500 persons outside of urbanized areas”.
2) Source: www.allcountries.org/uscensus/37_urban_and_rural_population_and_by.html, except for 2000 data, obtained from www.census.gov/compendia/statab/cats/population.html. “Urban” and “Rural” definitions were changed between 1990 and 2000, decreasing the percentage of residents classified as rural by 3 to 5 percent.

[3] Round Butte Dam now has a functioning surface collection system for juveniles, with transport around Pelton Dam downstream.

disproportionate impact through their demand for resources, which drives the growth of agriculture, forestry, mining, road, and energy development, and the fragmentation and conversion of land used for producing these goods.

The distribution of population changed during and after the war. From 1920 to 1940, approximately one-half to two-thirds of the population of the Northwest lived in rural areas (Table II.1); by 1990, only about one-quarter of the populations of Oregon and Washington lived in rural areas. Decreases in the relative proportions of rural to urban residents also occurred in Idaho and to a lesser extent in Montana, although these states remain more rural than Oregon and Washington. In recent years many small towns with economies based on logging, mining, or agricultural activities have struggled to remain viable, and some have been abandoned.

Although urban and suburban populations grew more rapidly than rural populations through the 20th century, absolute numbers of people living in rural areas continued to increase (Table II.1). In recent decades, the fastest-growing use of land in the West has been development for low-density second and retirement homes (Hansen et al. 2005, Leu et al. 2008). Some states have become concerned about the resulting loss of productive agricultural land (e.g., Oregon Department of Land Conservation and Development[4]), but many of these small land holdings are not located in lower-elevation areas favored for agriculture. Instead they tend to be in areas that offer attractive scenery and recreational opportunities, often near large tracts of higher-elevation land that is managed for timber production, wilderness, and other values that may not be compatible with residential development. This trend accelerated with the information technology economic boom of the 1990s (Huston 2005); internet access became widely available and allowed many to work at home rather than commute to an urban office. Development of previously less-disturbed rural areas eliminates and fragments habitat, encourages colonization by non-native species (e.g., weedy plants, domestic cats) and human-associated native species, and overall results in loss of habitat and connectivity and changes to disturbance regimes (e.g., frequency and magnitude of fires and floods; Hansen et al. 2005, Radeloff et al. 2010).

Consequences of Landscape Change for Fish and Wildlife Populations

For fish and wildlife, the consequences of human-caused landscape change in the Columbia Basin have been profound. Habitat loss and fragmentation have translated to substantial declines in abundance and distribution of native species. One of the most comprehensive assessments of the status of native fishes across the Basin (Lee et al. 1997) estimated that over one-half of the native species were listed or considered for listing under the Endangered Species Act or were of special concern to managers. None of seven "key" native salmonids persisted as "strong" populations in more than 22% of their potential range (Thurow et al. 1997) and strong bull trout populations were limited to less than 6% of their potential range (Rieman et al. 1997, Figures II.15, II.16). Steelhead and Chinook salmon have been lost entirely from approximately 50% and 70%, respectively, of their potential ranges (Thurow et al. 1997), and McClure et al. (2003) concluded that 84% of the remaining populations in the Basin were not currently viable.

Most native fishes still persist in the Basin, and some remain widely distributed, but local populations are often fewer, smaller, and more restricted in spatial extent and connectivity than in the past (USFWS 2008; Figure II.17). High dams and other impassable barriers have eliminated anadromous and freshwater migratory forms from substantial areas of river

[4] www.oregon.gov/LCD/farmprotprog.shtml

and stream habitat. Where resident forms still persist, the loss of large-bodied migratory forms has restricted gene flow and demographic links among populations, as well as growth and fecundity within them (Rieman and McIntyre 1993, Fausch et al. 2006). Many remnant populations persist, but habitat fragmentation has increased the vulnerability of these isolated populations (Dunham et al. 2003), and that will be aggravated with changing climate (ISAB 2007-2, Rieman et al. 2007, Figure II.18).

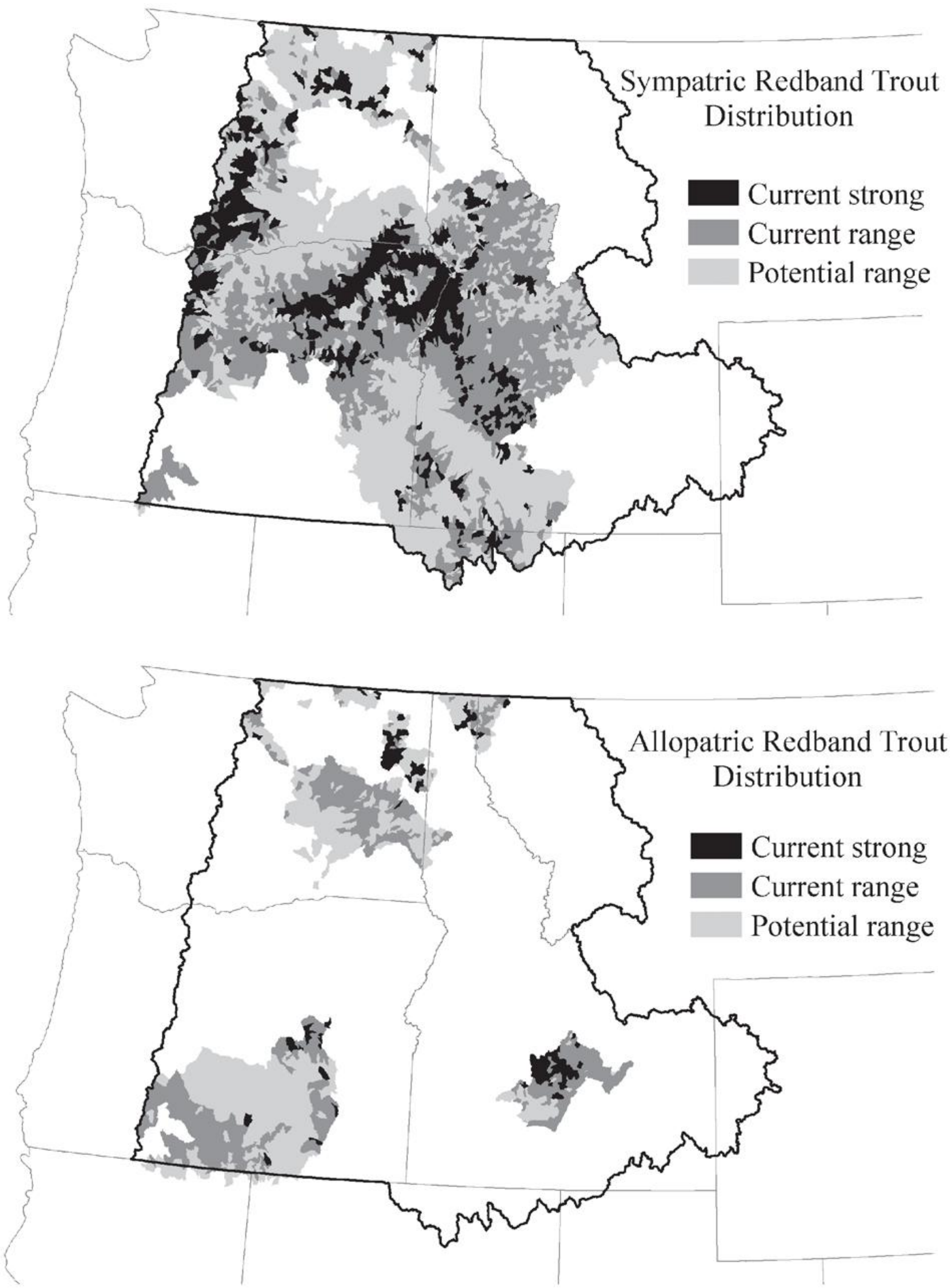

Figure II.15. Changes in the distribution of native, non-anadromous rainbow trout (“redband” trout) in the interior Columbia River Basin (from Thurow et al. 2007). “Allopatric redband” exist outside the range of anadromous forms; “sympatric redband” include both resident and anadromous forms.

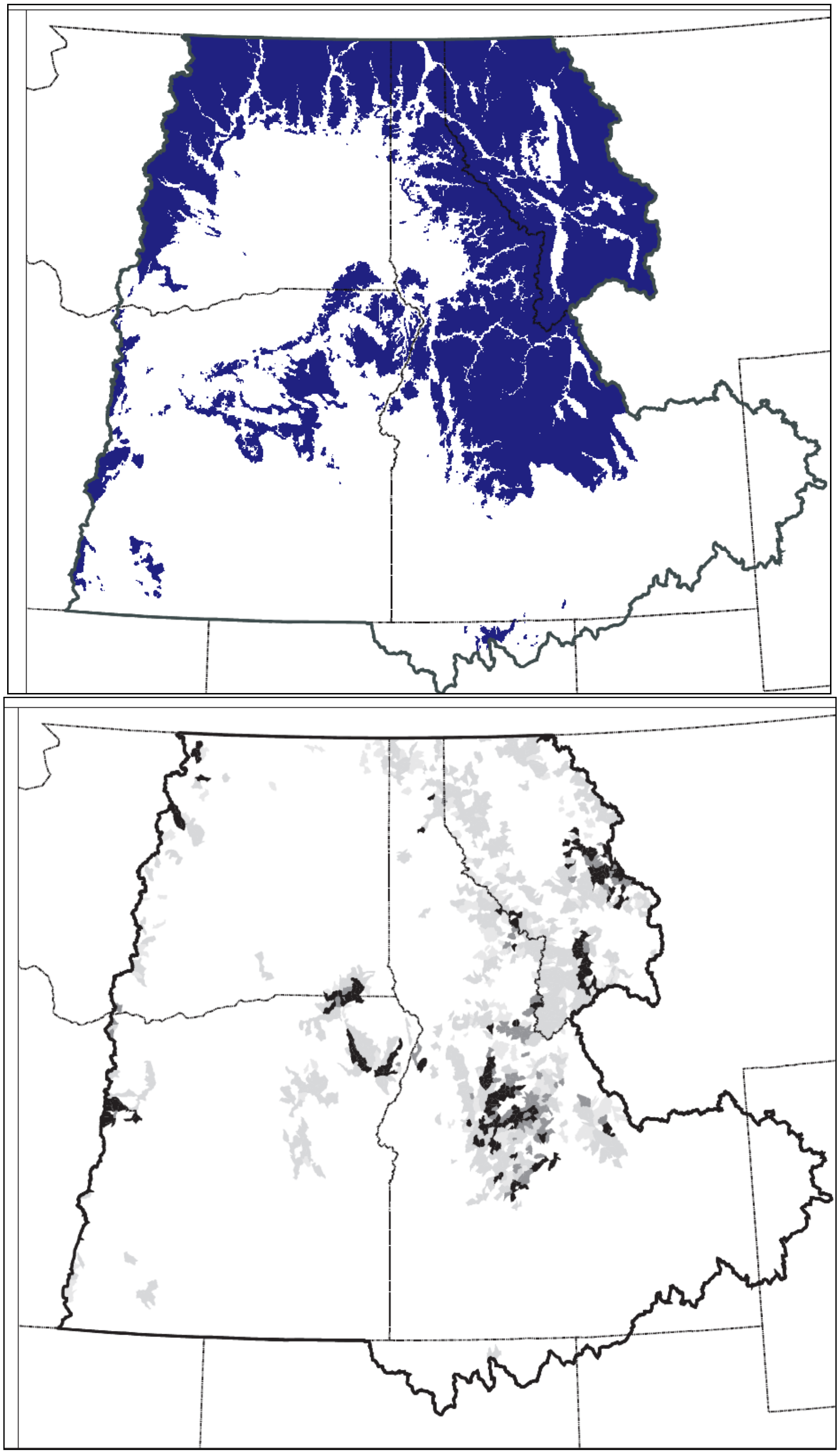

Figure II.16. Changes in the distribution of bull trout within the interior Columbia River Basin. The top image represents the potential historical range; the bottom image represents the predicted distribution of existing strong (black and dark gray), and depressed (light gray) populations (from Rieman et al. 1997).

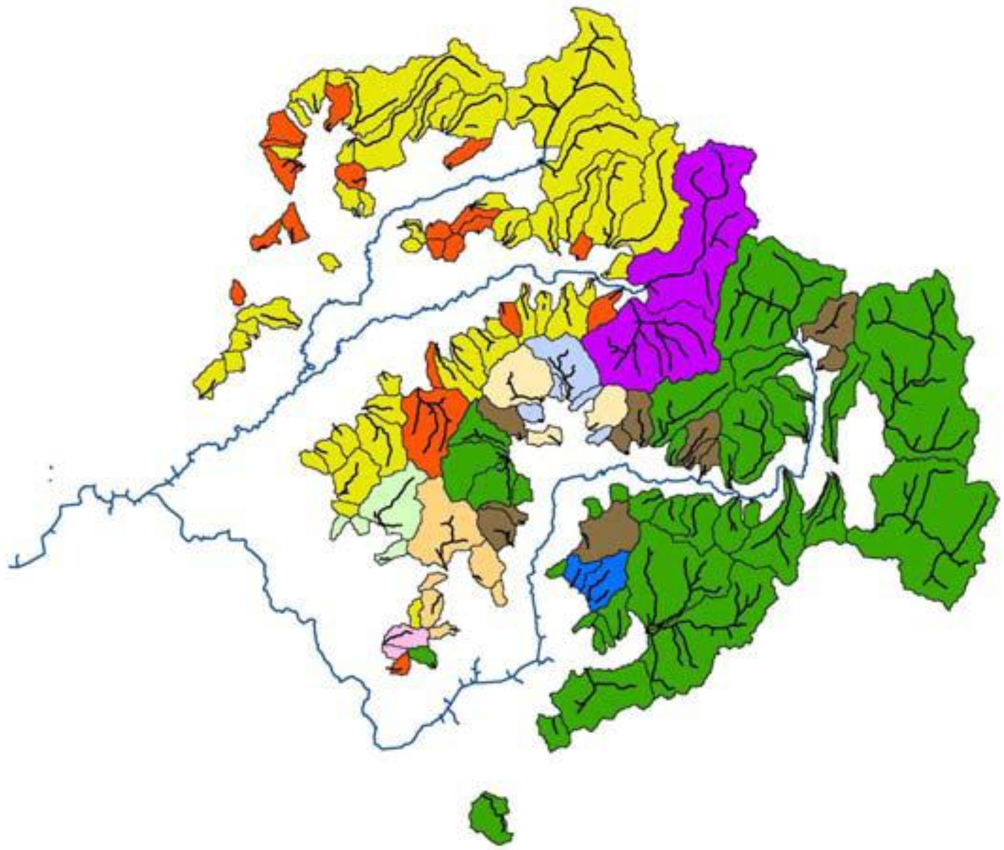

Figure II.17. Fragmentation of bull trout habitat in the Boise River Basin, Idaho. All colored watersheds represent potential spawning and rearing habitat for bull trout. All patches of a common color are connected and accessible to individuals moving from any other patch, with the exception of those that are dark brown or orange. Brown and orange patches are completely isolated from all others. Bull trout persist primarily in the larger and more connected patches. Under pre-development conditions, bull trout could move freely throughout the entire Basin, and are believed to have been more widely distributed and abundant (from USFWS 2008).

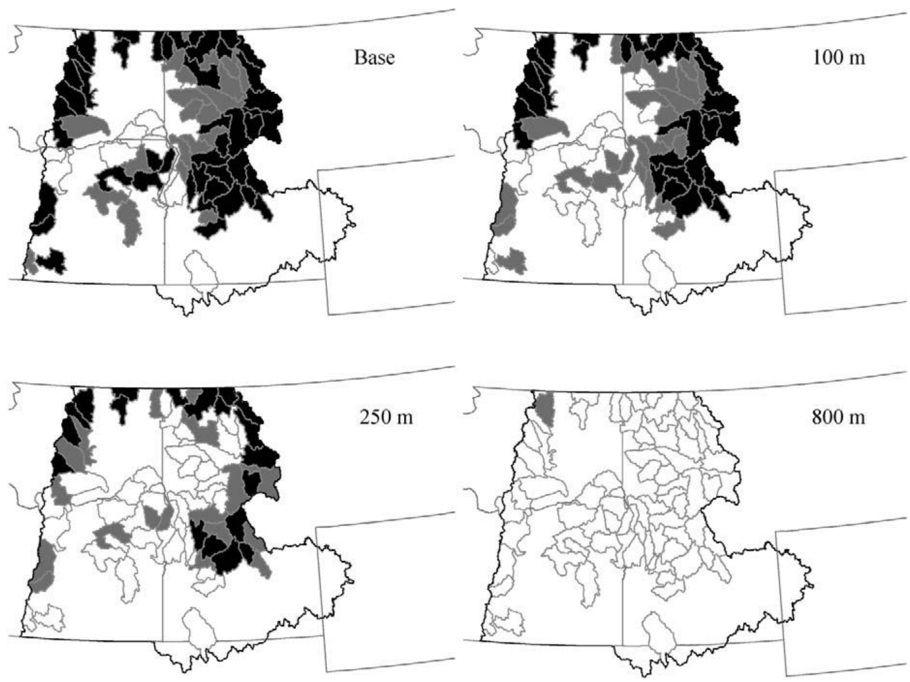

Figure II.18. Spatial patterns in “risk” of bull trout extirpation based on the structure of large habitat patches in individual subbasins of the interior Columbia River Basin. The scenarios represent 100-, 250-, and 800-m rises in the lower elevation limits for this species as a result of climate warming anticipated in the next century (from Rieman et al. 2007). Risk was considered high (no shading) if no medium or large patches remained, moderate (gray shading) if one to four medium patches or one large patch remained, and low (black shading) if five or more medium–large patches or two or more large patches remained.

As stock abundances and numbers of populations have declined, diversity, both within and among populations, has been lost. Interior populations have generally fared worse than those closer to the ocean (Gustafson et al. 2007); the result is a loss of genetic diversity among the populations that evolved in those distinctly different environments. Even within many subbasins, habitat loss has not been random. Generally, development or encroachment has been pronounced on lower-elevation private lands that are flatter, more accessible, and more productive than on higher-elevation, steeper, and more isolated public lands (Rieman et al. 2000, 2003, Burnett et al. 2007, Whittier 2011). Dams and migration barriers that eliminate migratory forms and isolate remnant populations have been more common at higher elevations (Fausch et al. 2006, McClure et al. 2008). Because genotypic and phenotypic diversity are strongly associated with environmental gradients at these scales, the bias in habitat loss has further restricted diversity (McClure et al. 2008, Bottom et al. 2005).

The losses of diversity have not been well quantified but are likely substantial (Gustafson et al. 2007, Lindley et al. 2009). For instance, within the Columbia Basin, where fish once entered the river in virtually every month of the year, diversity in the timing of adult Chinook migrations has been reduced to several temporally discrete runs (Waknitz et al. 1995). For many populations of both anadromous and interior salmonids, some distinct life-history types no longer exist (McClure et al. 2008, Fausch et al. 2006). As variation in life histories among streams and local populations has declined, so has asynchrony in spawning abundance (Isaak et al. 2003, Moore et al. 2010), reducing the overall stability of populations and metapopulations.

Attempts to manage fish and wildlife have sometimes aggravated losses of abundance and diversity. Fisheries can impose artificial selection by disproportionately exploiting some components of mixed stocks. Hatchery programs developed to restore higher numbers of fish may inadvertently contribute to the loss of genetic and life-history diversity through artificial selection or homogenization of stocks and life-history patterns (Lindley et al. 2009). In some areas, the introduction of non-native species, often to create new sport fisheries, threatens native species (Sanderson et al. 2009). Conservation efforts are commonly focused on populations that are currently the most abundant or productive, but marginal or currently unproductive populations may represent a disproportionately important part of total diversity or evolutionary potential (e.g. Hilborn et al. 2003).

Consequences of Landscape Change for Fisheries-dependent Communities

Abundant fish and aquatic resources sustained a Northwest tribal population of over 180,000 prior to Euro-American settlement (Boyd 1999). A series of epidemics in the 18th century (originating from Spanish settlements in the Southwest) and first half of the 19th century reduced Native American populations by 80 to 90%, decreasing fishing pressure on salmon stocks until the advent of commercial fishing in the 1860s. As tribal populations declined, fish harvest by settlers increased, with much of the catch canned for export. Development of the gasoline engine early in the 20th century enabled fishing for salmon in the ocean, and commercial and recreational salmon fishing became important for communities up and down the Pacific Coast. The economic base for these coastal communities and for communities on the lower Columbia River was a mix of fishing, logging, and farming.

Beginning in the 1930s, Columbia River salmon runs declined significantly, reflecting a combination of excessive harvest rates and landscape change throughout the Basin. Fishing-based communities lost significant parts of the fishing sector of their economy, and Native American tribes experienced increasing difficulty in harvesting the fish they depended upon for sustenance and ceremonial purposes. Lower Columbia River communities were hard-hit as fish canneries on the river closed in the 1970s (Smith 1979, Martin 1994, 1997). Gillnetting and trolling vessels that occupied the West Basin harbor in Astoria in 1970 were almost completely replaced by recreational watercraft by 2010 (C. Smith, personal communication). Decline of the fishing industry eliminated jobs both for fishermen and for those employed in fish-processing, as well as other service and production jobs generated by the fishing industry. Although fisheries in groundfish, shrimp, crab, and albacore grew as the salmon fishery declined, the net result was a decline in the economic base for many coastal and lower river communities that persists today.

Future Trends

Human population growth and technological advancement are the fundamental drivers of anthropogenic landscape change. The human population of the Northwestern states (Idaho, Montana, Oregon and Washington) increased by almost 900% during the 20th century, and rapid growth is expected to continue well into the present century.[5] The impacts of a growing population on natural resources will be felt throughout the Northwest (ISAB 2007-3, ISAB 2011-1) and beyond. A growing global

[5]The population of the Northwest is expected to increase by 26% over the next 20 years (U.S. Census Bureau nd; www.census.gov/population/www/projections/stproj.html).

population[6] will further add to pressures on the land and water resources of the Northwest. International demand for wheat and other grains and for beef will increase, and rising costs for air transport of perishable foods such as fruits and vegetables may increase the economic feasibility of local production. As demand for food increases, undeveloped land will be converted to agricultural use and new water sources will be required. Growing urban and rural populations will also require land for housing and economic development and water for domestic and manufacturing uses.

Projected climate trends are expected to further complicate management of water resources: flows will become increasingly variable, peak flows will occur earlier in the spring, and the lowest summer flows will be lower than at present (Mote et al. 2005, ISAB 2007-2, Hidalgo et al. 2009). Warmer temperatures will increase the use of air conditioning and the need for electric power during the summer months (NPCC 2010). Water needs for agriculture, domestic, and commercial needs, and power generation will increasingly conflict with water needs for fish and wildlife resources (Mote et al. 2003, Payne et al. 2004, Battin et al. 2007, Lettenmaier et al. 2008, Alexander et al. 2011).

Preparation for future change typically includes efforts to improve understanding of land-use legacies and of the cumulative effects of land-use change (Dale et al. 2005, Hobbs and Cramer 2008). However, 21st-century changes in the environment, landscapes, and ecosystems will raise new and unexpected challenges (Hobbs and Cramer 2008). Climate change is expected to increase the frequency of wildfire, extreme flow events, and other natural disturbances, and to increase threats presented by disease and invasive species. Land-use change, climate change, disturbances (e.g., fire, flood), stressors (contaminants, disease) and invasive species (Strayer 2010) can be expected to interact in unanticipated ways ("compounded perturbations," Paine et al. 1998), adding to the uncertainty. Planning for conservation of biological diversity in an unpredictable future will require innovative and flexible strategies to adapt to changing conditions.

Conclusions

Historical review

Historical review reveals landscape legacies that constrain future options. Actions in the Basin in the past 200 years have changed every ecosystem characteristic, giving each a significant human footprint. The loss of both habitat and connectivity between habitats has been particularly consequential for fish and wildlife. Efforts to conserve and restore landscapes face a future for which there is no clear analog. Efforts to prepare for future change must include improved understanding of land-use legacies and of the interactive and cumulative effects of land-use change over time (Dale et al. 2005, Hobbs and Cramer 2008).

Agents of change

Each of the human activities responsible for landscape change – the fur trade, mining, railroads, agriculture, logging, hydropower development, and urbanization – developed over periods of only three to five decades. Other changes associated with urbanization and human population growth, notably the introduction and spread of non-native species (ISAB 2008-4, 2011-1) and the release of environmental contaminants (ISAB 2011-1), have contributed to such change. Population and economic growth and changing technologies have been and continue to be major causes of change.

[6]World population is expected to increase from the present 7 billion to 9 billion by mid-century (United Nations Population Division 2008; www.un.org/esa/population/publications/popnews/ Newsltr_87.pdf).

Non-random and cumulative change

The loss of habitat for native biota is enormous and non-random, and remaining habitat is fragmented to various degrees. Losses of critical habitat and connectivity and changes in spatial structure are most extensive at lower elevations and in riparian and floodplain areas. Changes in landscape structure and function are persistent and not easily reversed. Most restoration efforts to date have been small, unconnected projects, completed by willing landowners and managers, and are unlikely to be sufficiently integrated, complementary, and strategically located to be effective at the landscape scale. As described in the next section of this report, populations are basic units for restoration of fish and wildlife, and populations require landscape-level restoration.

Loss of Habitat and Connectivity

Loss of habitat and habitat connectivity isolates subpopulations and increases the probability of extirpation. Fish and wildlife are adversely affected by blocking of migration corridors by urban development at river mouths, highway development, agricultural practices in lowland river basin areas, filling of estuaries and sloughs to create area for urban and agricultural development, forest harvest practices, and damming of rivers to generate electric energy for urban and agricultural needs. Because landscapes are dynamic and are formed of habitat matrices that change continually over time, restoration to a preexisting historical condition may not be possible or desirable. An alternative management approach is to reestablish natural processes and plan human activities so that the landscape matrix contains a wide range of habitat types and connectivity is maintained between patches of similar habitat. The most powerful tools for accommodation to changing conditions are maintenance of landscape diversity and of genetic diversity within species.

Changing values

Early Euro-American settlers brought the values of “manifest destiny,” which led to the view that landscapes would produce unending quantities of fish, forest, and agricultural products to support human communities. The value systems of modern Columbia Basin residents increasingly incorporate the importance of landscapes for sustenance of fish, wildlife, and humans. Recognition has increased that humans are integral parts of ecosystems, derive considerable benefits from them, and must pay more attention to the impacts they have on them, but, as discussed in this report, full engagement of this recognition in conservation and restoration planning and action needs to be much more fully developed.

A challenging future

Human population growth in the Basin will continue at least through mid-century, so that pressures for use of land, water, and natural resources will intensify. A changing climate is expected to bring higher temperatures, changes in precipitation patterns, earlier and more variable spring flows, and decreased and more variable late-summer water availability. These climatic changes will interact with land-use changes and disturbances in unpredictable ways, pointing to a future for which the past is informative, but for which there are not precise analogs. Nonetheless, it is clear that biodiversity and resilience will continue to decline unless landscapes are protected and restored.

III. Foundations for a Comprehensive Landscape Approach

"Say you agree that humans have an obligation to care for the earth. What does that mean in particular, in this place and time? What are you going to do? The point I want to make is that it isn't easy to know. You can't assume you know what to do. Everything changes around you and you can't do nothing, but something is often the wrong thing. And what you do in one place has unexpected effects a hundred miles away or a hundred years in the future." - Kathleen Dean Moore, The Pine Island Paradox

As this quote suggests, habitat conservation and restoration are challenging tasks that must consider vast, heterogeneous, and changing ecosystems. The Fish and Wildlife Program outlines a Vision of the Columbia River ecosystem as one of "abundant, productive, and diverse" fish and wildlife populations that also provide "abundant opportunities" for harvest (NPCC 2009-09:6). In its Scientific Principles, the Program recognizes that populations are integrally linked to the biophysical components of their environments, that ecosystems are dynamic, and that their *resilience* depends on the capacity to adapt to change and disturbance. A primary focus of the Program is conserving or restoring habitats that support populations.

The Program's vision is consistent with past guidance and a growing body of ecological work, with guidance for recovery of viable salmonid populations (Appendix IX.A) and with Tribal recovery plans (Jones et al. 2008, CRITFC 2011). This vision implies landscape-level restoration, and it cannot be realized without successful implementation of a landscape-level approach (e.g., Dale et al. 2000, Turner et al. 2001, Fausch et al. 2002, Steel et al. 2010, Hansen et al. 2011). Additionally, the vision requires, and would be enabled with, more comprehensive consideration of the socioeconomic constraints and processes. Thus, this report develops the background for a comprehensive landscape approach.

The objective of this section is to review the scientific basis for a larger perspective in conservation and restoration of fish and wildlife populations and habitats. We provide an overview of landscape ecology and of the comprehensive approach needed to explicitly integrate consideration of, and participation by, the human inhabitants of the landscape. The material is summarized as a series of Principles that emerge from the review and form guidance for more effective large-scale conservation and restoration.

A Landscape Context

Landscape ecology (Sidebar III.1) and the concept of *resilience* provide the foundation for a larger perspective. Landscape ecology argues that spatial and temporal patterns of habitats and the processes (or flows of energy, water, and materials) that create and maintain them, matter. Few populations can persist indefinitely in small or isolated habitats. Populations flourish only when they are buffered from the vagaries of climate and disturbance and supplied with flows of energy, nutrients, other materials, and organisms from other places. Virtually all organisms use or depend on a variety of habitats and linkages among them, within a larger landscape. Thus, it is ultimately the landscape that provides the conditions that support abundant and productive populations.

Resilience (Sidebar III.2) refers to the capacity to absorb and adapt to disturbance or change while maintaining essential functions (Harrison 1979, Holling and Meffe 1996, West and Salm 2003, Walker and Salt 2006). Thus, resilience is even more fundamental to the success of restoration than are abundance and productivity. Resilience results from *diversity* within and among species; *modularity* of habitats and populations; and the *connections and feedbacks* among them. These conditions in turn depend on landscape patterns and processes that occur over large areas, so promoting resilience requires a foundation in landscape ecology. Resilience is as much a socioeconomic as an ecological concept (Gunderson and Pritchard 2002, Berkes et al. 2003, Healey 2009, Davidson 2010). Like fish and wildlife populations, societies and economies can be resilient, drawing on their diversity and capacity to adapt to changing conditions.

Landscapes generally encompass areas larger than the more traditional focus of habitat units or reaches of stream, but have no single fixed size. Landscapes range in spatial scale from the smallest watershed to the entire Columbia River Basin and beyond. For populations of some aquatic invertebrates or fish like sculpins or dace, the relevant landscape may include interconnected habitats within a single reach of stream and its encompassing hillslopes. Salmon provide an example of organisms that use linked habitats across far larger and more complex landscapes. Ultimately, the quality or value of individual habitats depends on their suitability, but also their size, distribution, and accessibility within those broader landscapes. These depend in turn on the characteristics and history of larger watersheds, landforms, and climates, as well as past land use and future development.

Thus, conserving and restoring habitats to support resilient populations depends on constraints that are imposed by landscapes and by people. Bisson et al. (2009) argue, "Management of the freshwater habitat of Pacific salmon should focus on natural processes and variability rather than attempt to maintain or engineer a desired set of conditions through time (Dale et al. 2000)." However, conservation and restoration are done within the context of people's capacities, interests, and values. Ecologists often have neglected the social, economic, and cultural considerations (Dale et al. 2000, McKinney et al. 2010, Reid et al. 2010). For example, Nassauer (1997:4) concludes that ecologists have offered "… many landscape ecological solutions … only to be impeded or disregarded because they did not fit their cultural context." For a landscape approach to be effective, people must be engaged in the process and must understand the relevant science. Success depends on past values given to landscapes, fish, wildlife and their habitats, and on future values and benefits desired from them.

A comprehensive landscape approach to conservation and restoration implies an understanding of physical, biological, and socioeconomic processes, their integration, and a capacity to adapt. We consider these in turn.

Sidebar III.1. Landscape Ecology: Pattern, Process, and Scale

Despite the desire to restore the broader landscape of the Columbia River Basin, habitat restoration has been focused mostly at small spatial scales. Landscape ecology is an integrative discipline that forms the basis for restoration of landscapes. The foundations of landscape ecology are in the basic concepts of *pattern* and *process, scale* and *hierarchy* (Turner et al. 2001).

Pattern and process refer to the composition, arrangement, dynamics of, and movements among basic elements or "patches" in a landscape. For example, distinct patterns in stream and forest habitats can be linked to movement and survival of organisms. Underlying processes (e.g., hydrology and geomorphology) create and maintain patterns in habitats. Those patterns in turn, influence physical, biological, and socioeconomic processes, including the sources and movements of organisms, material and energy between organisms and the parts of ecosystems, and the related of social systems. Spatial pattern and temporal dynamics of habitat influence abundance, productivity, diversity, and the persistence and even evolution of populations. Landscape ecology is concerned with the interactions between pattern and process.

Scale refers to the spatial and temporal dimensions of patterns and processes. Scale matters because different patterns become visible at different scales and different processes dominate at different scales. For example, occurrence of non-native brook trout and native bull trout are negatively correlated at the scale of reaches along a stream. This is presumed to reflect interactions such as competition and predation between the species that depend on the gradient of habitat conditions along the stream (e.g., Rieman et al. 2006). In contrast, the two species are positively correlated at the scale of sub-watersheds across the Columbia River Basin, presumably because both require cold streams, even though they are locally separated by mechanisms that operate at the finer scales (e.g., Dunham and Rieman 1999).

The concept of Scale is linked with the concept of ***hierarchy*** (or nested levels of organization). Each level can be recognized by a limited set of patterns, behaviors, or processes constrained or controlled by levels above and below the one of interest. Frissell et al. (1986) proposed a framework of stream habitats organized within a hierarchy of land form, valley form, and habitat respectively; Soranno et al. (2010) outlined a similar framework for lakes.

There is no single relevant landscape scale. The point is to consider pattern and process at scales large enough to understand the basic controls for the habitat, population, or phenomenon of interest (O'Neill et al. 1986, Ruggiero et al. 1994, Schultz 2010) but also with a resolution fine enough to understand the critical underlying mechanisms. That will often require a larger spatial and temporal context than has been typical of past habitat restoration efforts.

Sidebar III.2. Resilience Thinking

Walker and Salt (2006a) define resilience as "*the capacity … to absorb disturbance and still retain … basic function and structure*." Resilience refers to the capacity of natural-cultural systems to adapt to, absorb, or recover from environmental change, allowing continued support of important functions; thus, resilience is a fundamental mechanism leading to sustainability. Resilient societies or ecosystems are better able to meet challenges and are better able to do so without compromising their potential to meet future challenges. The notion of resilience is essential to meeting the vision of the Columbia River Basin Fish and Wildlife Program.

Attempts to maximize production of some single natural good or service generally entail trade-offs in which other goods or services are limited (Lichatowich 1999). Examples of such trade-offs include timber harvest vs. water quality, maximum yield fisheries vs. conservation of spawning stocks, hatchery production to support harvest vs. native species recovery, and spill vs. transport of migrating salmon. "Resilience thinking" recognizes that diversity is a fundamental attribute of resilient systems. Resilience is promoted by maintaining diversity, which may require foregoing some other opportunities. Efforts to make ecological benefits more predictable and less variable tend to reduce diversity and resilience, making them more susceptible to collapse. Management that focuses narrowly in increasing one (or a few) thing(s) while degrading diversity makes ecosystems and society more vulnerable to change that might otherwise have been absorbed (Holling and Meffe 1996).

Resilience results from three factors--*diversity, modularity*, and *feedback* (Walker and Salt 2006. Diversity is variety in basic elements such as habitats, species, life histories, genes, populations, social-cultural institutions, and knowledge (e.g., Healey 2009; Bisson et al. 2009), and it provides options and the legacy of materials for reorganization. Intentionally maximizing productivity of one element generally leads to a reduction in diversity. Modularity reflects independence among elements such that they have the capacity to contain local damage and reorganize afterward. Resilient systems have elements or modules that are neither too tightly nor too loosely connected, which allows both local containment of damage and reorganization afterward. Feedback refers to how well a change in one part of a system, such as abundance of one species in a biotic community, is recognized and responded to adaptively by other parts. Density-dependent population growth is an example of ecological feedback. Feedback can be developed in social-cultural systems by monitoring programs and experiments.

The following are rules of thumb for building resilience:
for ***diversity*** - maintain many populations, species, and habitats and tolerate the perspectives of diverse socioeconomic groups and individuals; recognize and embrace variability (which is a form of and a support for diversity) rather than trying to control it;
for ***modularity*** - maintain redundant habitats or other entities (e.g., subpopulations, social groups, or economic units) that are connected enough to allow interactions, but not so connected as to experience the same conditions;
for ***feedback*** - maintain connectivity of social and ecological networks, foster learning and experimentation, and support redundancy in capacity and jurisdiction.

The Resilience Alliance www.resalliance.org provides extensive resources to explore these concepts and applications in the real world. See also www.ecologyandsociety.org.

Biophysical processes

Physical processes continually shape landscapes and the habitats within them. These are commonly viewed in a hierarchical (nested levels of organization) scheme (Montgomery and Buffington 1998, Buffington et al. 2003, Montgomery and Bolton 2003, Beechie et al. 2006, 2010; Figure III.1). At the broadest level, geology, climate, and the history of landform evolution through tectonics, glaciation, and erosion over geologic time scales (10^4-10^6 years) have shaped a general “litho-topographic template” (Montgomery and Buffington 1998). This broad pattern has in turn constrained the size, geometry, topography, and local climates of the Columbia River Basin (e.g., its watersheds, stream networks, hill slopes and valley bottoms; Benda et al. 2004, Beechie et al. 2010). The physical characteristics of stream reaches and habitats within this setting are defined largely through processes of hydrology (amount, timing of flow and transport of energy and materials), geomorphology (erosion, deposition and storage of sediments and coarse materials), vegetative growth and succession (wood recruitment, bank stabilization, shading, nutrient cycling), and their interactions, feedbacks, and alterations through land use (e.g., agriculture, road construction) and natural disturbances (e.g., wildfire, storms, droughts) (Naiman et al. 2000).

Frissell et al. (1986) outlined a hierarchical classification of aquatic landscapes, including geomorphic provinces, watersheds, valley segments, channel reaches, and channel units as a framework to understand broad and finer level controls. These concepts have been extended to classify and understand variability in habitat and ecological conditions across watersheds, rivers, and streams (e.g., Schlosser 1995, Montgomery et al. 1999, Ugedal and Finstad 2011). The conclusions are that watersheds within a province should be more similar to one another in their characteristics than they are to those in different provinces; streams within similar valley segments may have similar reach and habitat characteristics. Within time frames relevant to land management and restoration (i.e., 10-100 yr), geologic and topographic conditions at scales larger than valley segments are relatively static. In contrast, conditions at the scale of stream reaches and habitats are more dynamic, responding to the flux and storage of water, sediment, and wood, and interactions of channel and floodplain. Formalizing these concepts, Montgomery (1999) and others (Montgomery and Buffington 1998, Beechie et al. 2010, Naiman et al. 2000, 2010) proposed a classification at the valley segment scale defined principally by confinement and gradient as the constraints on source, transport, and storage of materials and the feedbacks from biotic components and their actions. Such classifications can assist in understanding and assessment of landscape patterns and controls and can be used to guide habitat restoration and monitoring (Sidebar III.3).

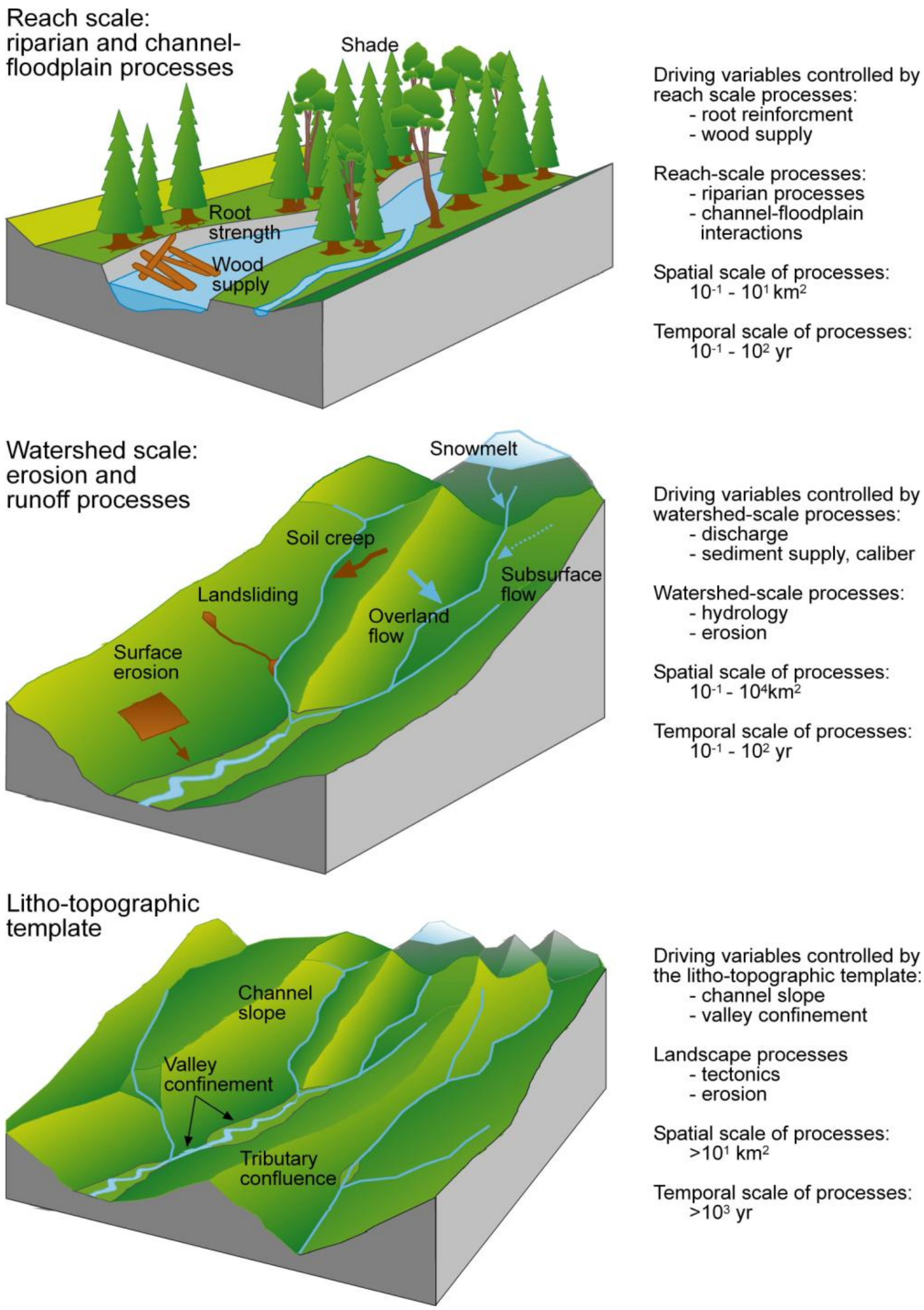

Figure III.1. Illustration of the hierarchy of process that controls the dynamics and distribution of stream habitats and ultimately the distribution, abundance and diversity of aquatic organisms (from Beechie et al. 2010).

Sidebar III.3. Developments in the Classification of Land and Water

The practice of classifying landscape features is advancing rapidly. The speed of data acquisition and analysis and the quantity, accuracy, and precision of data are transforming understanding of landscapes and socioeconomic systems and are making it possible to manage them at scales heretofore unimaginable. Four technological arenas – *remote sensing, geographic information systems (GIS), data management, and spatial analyses* – have enhanced our ability to examine the geographic context of both natural landscapes and their socioeconomic components in detail. These technologies allow significant advances in effective place-based restoration and conservation.

Landscape and stream classifications help to identify conservation potential and restoration needs (e.g., Frissell et al. 1986, Naiman et al. 1992, Brierley et al. 2008). Moreover, classification facilitates communication among disciplines (Kondolf et al. 2003).

Four integrative approaches promise to change management fundamentally. They are NetMap (www.netmaptools.org); River Styles (www.riverstyles.com/publications.php); remote sensing, models and statistical analyses (Beechie and Imaki 2011, Whittier et al. 2011); and the use of catenae in the estuary (Si Simenstad, University of Washington, pers comm). Equally important, the emergence of regional databases, such as the PNW Habitat Classification Systems (PHaCS) Database, provides common links among classification systems. Each of these is more fully described in Appendix IX.B.

Effective classification systems have several attributes (Table III.1; Beechie et al. 2011 in press). They recognize the influence of higher level (larger scale) and lower level (smaller scale) factors on the subject of interest. In other words, they use landscape or valley features to define the boundaries of possible conditions, as well as current conditions within those boundaries (Naiman et al. 1992; and see Sidebar III.1). They recognize that agents of change (e.g., wind, water, fire) continuously influence conditions within a specific location. They recognize local restoration goals and are suited to the geomorphic, ecologic, and historic context of the region (Cullum et al. 2008). In this context, effective classification helps guide restoration of habitat conditions (e.g., pools, riffles, channels) that are constrained by the biophysical context (e.g., supply large wood and sediment) as opposed to influenced by management and human history (Naiman et al. 1992, Buffington et al. 2004). Further, effective classification systems are ecologically relevant; their use depends on the goal of the activity (e.g., habitat for fishes vs. sites vulnerable to disturbance). Finally, they explicitly recognize uncertainties associated with both the classification and predictions of ecosystem responses to changes in driving processes (Whittier et al. 2011).

Importantly, "buy in" by actors concerned with a landscape is an essential attribute of an effective classification system. Researchers need to find compromises between complex classification systems that are scientifically acceptable and rigorous methods that users and the general public can understand. This may require considerable investment in consultation, outreach, and training.

Table III.1. Guiding criteria for developing an effective classification system (from Beechie et al. 2011 in press and adapted from Kondolf et al. 2003).

Criterion	Description
Hierarchical	Recognizes that lower level conditions are controlled by higher level processes
Process-based	Based on, and predictive of, responses to changes in watershed or reach level processes
Locally tailored	Suited to the local geomorphic, ecological, and human historical context
Ecologically relevant	Relevant to local ecological or environment restoration goals and objectives
Recognizes uncertainty	Explicitly recognizes uncertainties in both classification of sites and predicted responses to process changes

The geometry of channel networks (i.e., branching patterns and interspersion of stream size, gradient, and confinement) also influences habitats and ecological conditions (Benda et al. 2003, 2004, Poole 2002). Channel networks can be viewed as a template organizing transport, deposition, and storage of sediment, water, wood, and other materials (Miller et al. 2003). An important result is a "waxing and waning" of reach and habitat patches whose characteristics are determined by disturbances such as wildfire, debris flows, floods, and subsequent ecological succession (Reeves et al. 1995, Benda et al. 2004). The longer-term patterns of disturbance (or "disturbance regimes" including their magnitudes, durations, frequencies, and spatial patterns) are formed by climate, landform, and geology, as well as the history of past disturbance (Moritz et al. 2011). Similar concepts have been used to consider stream flow and temperature regimes (Olden and Naiman 2010, Poff et al. 2010).

Biological processes reflect the physical template. Physical and ecological processes continually mold and remold habitats, creating the environments for fish and wildlife. The nature of populations and communities depends on interactions between species, interaction of species with habitats, on broader controls and biological processes such as invasion and evolution (Sidebar III.4), and on landscape history.

At the broadest scale of the Columbia Basin, much of the potential diversity among and within species was constrained long ago through influences of evolution, speciation, and ocean and freshwater invasions (Matthews 1998, Reeves et al. 1998, Montgomery 2003). The native fish assemblages derive from a zoogeographic history influenced by glaciation, vicariance events (splitting and isolation of populations by natural processes), and dispersal along routes defined by landform, river networks and hydrologic and geomorphologic processes such as headwater capture and glacial flooding (e.g., Haas and McPhail 2001). Subsequent radiation and adaptation have created the diversity now recognized within distinct ecological or zoogeographic regions, evolutionarily significant units, and distinct population segments (e.g. Waples 1995, Allendorf et al. 1997, Lee et al. 1997, Matthews 1998, Waples et al. 2008).

At the finest scales of stream reaches, habitat patches, or even microhabitats, distributions and diversity of species reflect local habitat characteristics (e.g., Fausch et al. 1988, 2002, Fausch 2010). At these scales, the physical and chemical suitability of landscapes have been seen as "filters" (Tonn et al. 1990, Poff 1997) for traits of species or life stages that can occur within them. The characteristics of populations and communities are shaped by the physical and biotic processes that act on species that pass through these filters (Matthews 1998). Thus, the abundances and life history characteristics of species tend to vary predictably along environmental gradients that are defined by factors such as temperature, flow, depth, velocity, substrate, and availability of food and refuge (Reeves et al. 1998, Jager et al. 1999, Reeves et al. 2011). Occurrence of individuals of any species or life stage depends on habitats that support growth, survival, and reproduction. Growth, survival, and reproduction are influenced by interactions with other species through a diversity of processes such as primary production, foraging, predation, competition, hybridization (Matthews 1998, Falke and Fausch 2010, Reeves et al. 1998, 2011) and through continuing adaptation and evolution (Sidebar III.4).

Sidebar III.4. Adaptation and Diversity

An organism's ability to survive, grow, and reproduce in a set of environmental conditions depends on its physical traits and behavioral repertoire (its "phenotype"). An organism's phenotype is constrained by genetic adaptations that evolve over many generations, through natural selection. A population that is adapted to a particular habitat will be more productive there than would other populations of the species that are not adapted to those conditions.

Diversity among local populations of a species (such as evolutionary significant units [ESUs] of listed salmonids) provides at least two benefits in terms of ecological goods and services. First, the variety of specialized adaptations (such as migratory timing) in a diversified "portfolio" of populations can provide benefits such as extended seasonal availability of salmon to food webs and fisheries. Second, a diversified portfolio can stabilize aggregate benefits and provide insurance against fluctuating conditions. Populations with different local adaptations are likely to have distinct responses to changing environmental conditions, such that productivity increases for some and decreases for others. This "response diversity" can reduce variation in the overall abundance and productivity of a species in the landscape. For instance, Schindler et al. (2010) summarized the diversity of run timing among sockeye salmon populations of the Wood River Lakes system in Alaska and demonstrated how that diversity contributed to the long-term stability of the composite salmon run. See Appendix IX.C for more detail.

As landscape concepts have developed in fish and wildlife sciences, considerable interest has been focused at scales intermediate to those outlined above (i.e., networks of streams to river basins; Fausch et al. 2002, Fausch 2010). One result is growing recognition of processes dependent on movement of individuals (Ward 1998, Fausch et al. 2002, Fausch 2010, Wipfli and Baxter 2010). Because many species require distinct habitats for reproduction, early rearing, growth, and winter or summer refugia, some individuals require migrations of hundreds of meters to thousands of kilometers (Northcote 1992, 1997, Schlosser 1991, 1995) to survive and maximize productivity and fitness. Thus, the landscape they use must include "complementary" patches of habitat that are extensive, persistent, productive, and interconnected enough to allow completion of the full life cycle (e.g., Carlson and Rahel 2010, ISAB 2011-1).

Variation in patterns of movement and habitat use contribute to resilience as well (Healey and Prince 1995, Rieman and Clayton 1997, Healey 2009, Schindler et al. 2010; Sidebar III.4; Appendix IX.C). Temporal and spatial variation in growth can lead to variation in life history and movements. So, variation that occurs within populations (e.g., Narum et al. 2008, Johnson et al. 2010), within cohorts (Nielsen 1992), and even within the lives of individuals (e.g., Brenkman et al. 2007) depends on the patterns of accessible habitats. Variation in timing of movements is critical for juvenile salmon whose early ocean survival has been related to coastal upwelling (Scarnecchia 1981, Nickelson 1986, Pearcy 1992, Scheuerell and Williams 2005), to other ocean factors such as winter sea temperatures, spring transition date (Logerwell et al. 2003), and to large scale annual and inter-annual climatic events like El Niños and the Pacific Decadal Oscillation (Mantua et al. 1997). As a result it is important to consider the diversity, spatial array, and connectivity of habitats for conserving and restoring the diversity of movement patterns and life histories in this age of climate change. The suitability of different habitats will change due to increasing temperatures in both fresh water and the ocean (ISAB 2007-2), to changes in the timing and intensity of coastal upwelling, to rising sea levels and to increasing ocean acidity. This diversity is therefore a hedge against uncertainly and climate change that threaten the resilience and productivity of many populations (Hilborn et al. 2003, Tolimierei and Levin 2004, Waples et al. 2007, Crozier et al. 2008, Lindley et al. 2009, Appendix IX.C).

Dispersal, defined by movement away from the natal environments with successful reproduction elsewhere, can be essential to colonization of new habitats that are created even as others are lost. Dispersal contributes to the spatial structure or populations and communities (Falke and Fausch 2010, Appendix IX.D) and can enhance gene flow and demographic support or "rescue" of local populations, allowing them to persist in areas where they could not if fully isolated (Rieman and Dunham 2000, Costello et al. 2003, Quinn 2005). Homing or lack of dispersal can increase isolation and facilitate local adaptation, genetic and phenotypic differentiation, and expanded regional diversity among populations (Quinn 2005, Hendry and Stearns 2004, Appendix IX.C).

The growing understanding of fish and wildlife movements has led to more interest in tools to explore the controls on the dynamics and resilience of populations across scales (Matthews et al. 2009, Falke and Fausch 2010, Uchida and Inoue 2010). Metapopulation (Schlosser and Angermeier 1995, Falke and Fausch 2010) and metacommunity models (Falke and Fausch 2010) are being used to explore the role of broad spatial patterns on local population and community dynamics. Spatially explicit life stage models are being developed to consider the pattern and condition of habitats used at different life stages (Appendix IX.E). Knowledge of movement of salmon in relation to ocean habitats, and subsequent implications on populations too, has grown (Pearcy 1992). Both theory and empirical results suggest that broader spatial patterns and dynamics of habitats influence movement across landscapes, and that those patterns can be as important to resilience and persistence of populations as the quality of local habitat (Isaak et al. 2007).

Socioeconomic processes

Socioeconomic processes encompass insights from many disciplines (Sidebar III.5), each of which has detailed understandings of how socioeconomic systems work. Many groups of social scientists, economists, and ecologists have tried to synthesize the basic processes of adapting to environmental change (CIESIN 1992, Stern et al. 1992, Kempton et al. 1995, Gunderson and Holling 2002, Berkes et al. 2003, Brewer and Stern 2005, RA 2010, Reid et al. 2010, Susskind 2010). There is no single accepted answer, but most recommendations suggest better integration of socioeconomic processes. Here, we outline a conceptual framework that links socioeconomic process to a broader landscape context and its physical and biological processes.

Socioeconomic processes are underlain by values and goals. Knowledge about landscape ecology is also fundamental to getting actions that are more broadly considered and beneficial to people. Knowledge for most people is filtered by their values (Figure III.2, Kempton et al. 1995, Vaske et al. 2001, Dietz et al. 2005). Because people have values and goals, they add intention to addressing complex issues (Malle et al. 2001, Conte and Castelfranchi 1995). What people plan or intend to do can be converted into actions, but not all intentions become actions. An action that does occur results in feedback that becomes part of the knowledge pool, but knowledge is not always used effectively. First, values influence how knowledge is interpreted (Vaske et al. 2001, Manfredo and Dayer 2004). Second, knowledge can be lost (Bella 1997) and often lessons have to be relearned as reflected in the commonly heard Santayana (1905) statement "Those who cannot remember the past are condemned to repeat it." Nor does knowledge change easily (Vallone et al. 1985, Nyhan and Reifler 2010); it usually takes some type of "disturbance." Education is one of the common disturbances. Counterintuitive results, natural or socioeconomic events, collaborations, opinion surveys, voting behavior, and conflicts can change the knowledge base and people's willingness to accept it. One of the reasons for early socioeconomic engagement is for the resulting collaboration to help people understand the knowledge base that structures each participant's position.

Sidebar III.5. Socioeconomic Meaning

The socioeconomic sciences have differentiated into many disciplines and subdisciplines. Each has multiple and often competing theories to explain human action. In this report, "socioeconomic" is used to encompass the social and economic dimensions of landscape conservation and restoration. "Socioeconomic" includes cultures, social systems, people, institutions, governmental and nongovernmental organizations, markets, policies, values, preferences, objectives, intentions, projects, and actions. It encompasses such disciplines as anthropology, communications, economics, education, geography, law, philosophy, political science, social psychology, and sociology.

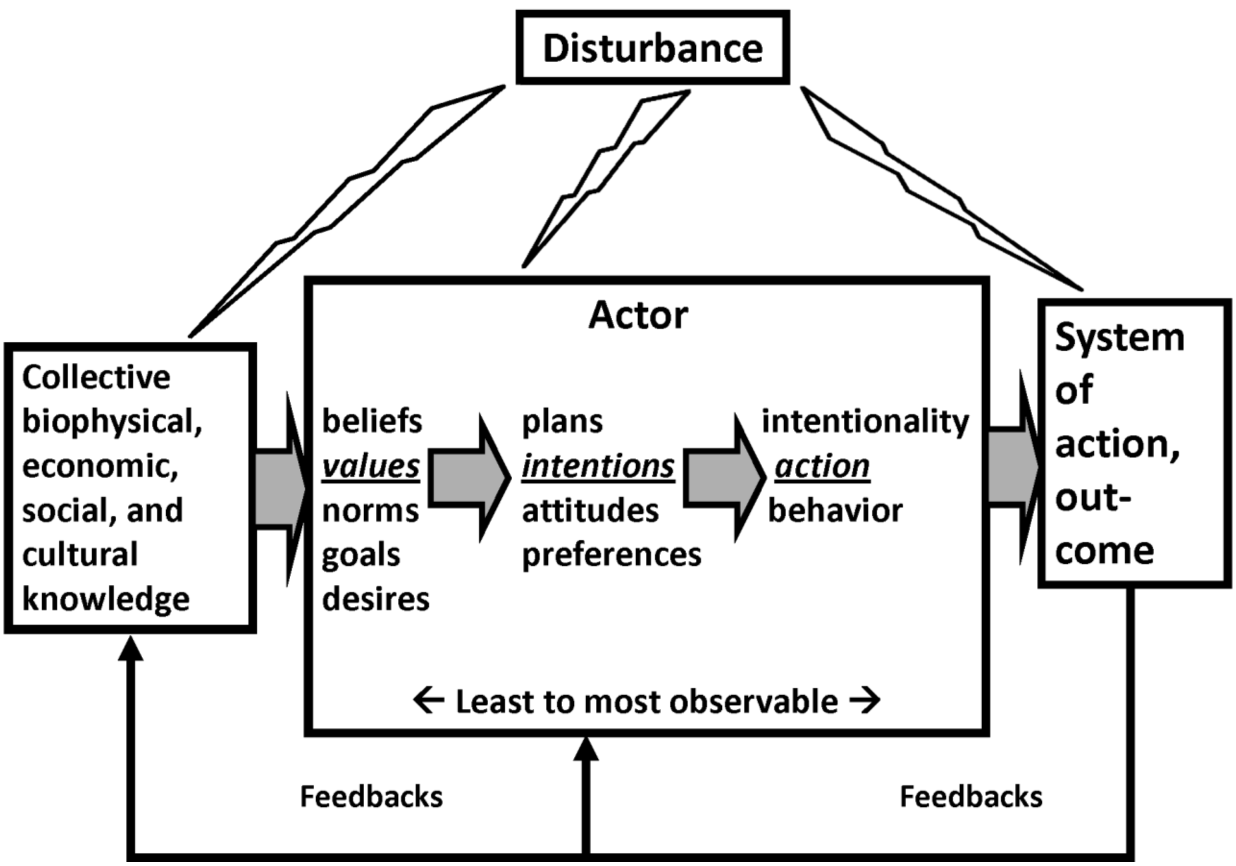

Figure III.2. Schematic of the knowledge, values, intentions, and actions process. Societal knowledge is filtered by values to create intentions that may become actions. The outcomes of actor choices and actions produce feedbacks that affect each of these domains. Ecological or socioeconomic disturbance are drivers for change in this system as are feedbacks (based on Stern 2000:412; Malle et al. 2001:17; Dietz et al. 2005:357).

The socioeconomic process involves gaining people's understanding and *engagement*, resolving *value* questions and differences, getting agreement on *intentions*, and identifying those who can and will take *action*. Values, which in Council publications are labeled "Vision" or "Objectives," have to be converted into intentions to act. Intentions are the strategies, plans, and measures included in the Fish and Wildlife Program (NPCC 2009-09), the Subbasin Planning,[7] the Multi-year Action Plans,[8] (NPCC 2011) and the monitoring programs (MERR, NPCC 2010-17). Intentions lead to desired actions. From a socioeconomic perspective, intentions derive from vision and leadership, rely on trust and partnerships, and generate the power and resources to act (Smith and Gilden 2002).

Socioeconomic understanding and engagement to develop and implement the Fish and Wildlife Program (NPCC 2009-09) involves actors and their values, intentions, and actions. The term "actors" is used to encompass all those who can take action. Actors bring diverse values and understanding of issues, competing social and political intentions, and conflicting actions to most situations where the path is unclear. Actors are the people or groups who formulate a plan or strategy that identifies measures and measurable goals to be achieved. Actors may be a formal organization or people with common interests. They can be any type of governmental or nongovernmental association, or corporate profit or not-for-profit organization. The NPCC (2009-13) maintains a list of over 200 organizations (actors) with which it collaborates. The organizations are grouped by federal managers, fish and wildlife agencies, state government agencies, associations, tribal associations, utility groups, agricultural organizations, public interest groups, building and code enforcement agencies, and politicians and related committees. Yet, not mentioned are hundreds of cities and counties that make land-use decisions daily affecting fish and wildlife. City and county road agencies and private road and water districts influence the landscape on a daily basis. In addition, there are hundreds of thousands of landowners, many of whom can have significant impacts on habitats and corridors for fish and wildlife. Each of these actors has distinct and limited temporal, functional, and spatial scale.

*Values a*re people's beliefs about what is right or wrong, good or bad (Karp 2000). The use of "values" is often related to goals, attitudes, beliefs, desires, objectives, perceptions, and world view. Rokeach (1973:122) argued that social psychologists have long been interested in values because they determine behavior. Scarnecchia (1988) points out that values determine actions in fisheries and hatchery management. People interpret facts based on their values and experiences (Dietz et al. 2005, Smith 2005, Nyhan and Reifler 2010). People may have to unlearn deeply held values and beliefs to accept new knowledge. Further, adults respond better to active learning (Meyers and Jones 1993) and being involved rather than just being informed.

Intentions convert values, goals, and objectives into behavior and action. The diversity of actors and their values lead to diversity of intentions. Some intentions are shared, some are complementary, and some are in conflict. The socioeconomic process begins by engaging people and organizations in the discussion and finding agreement on intentions. Early in a process of selecting an action, people may not be interested or engaged. As a potential action is perceived to affect an individual or group, engagement increases. Agreeing on intentions is context specific, time-consuming, and complex. The process is adaptive. Success requires connectivity among all potential participants, tolerance to others' ideas, and collaboration. It includes unlearning along with learning.

Policies such as land-use plans and building codes, regulatory requirements linked to endangered species and water quality, court decisions, and best practice prescriptions structure actor intentions. Policies are shaped by education, experience, chance events, and people with strong interests. The intent of

[7] www.nwcouncil.org/fw/subbasinplanning/default.htm
[8] www.nwcouncil.org/fw/lf/Default.asp

policies is to set a framework and synthesize rules for how people should act. Not every action can be controlled, so policies that have wide support are more likely to be followed. Policies that many people question are often ineffective.

Developing intentions to get action is helped by scientific, technical, and local knowledge. When developing intentions it is helpful to know the characteristics of effective organizations (Smith and Gilden 2002, Sabatier et al. 2005) that have moved successfully from vision to action.

Actions are the culmination of the visioning and planning processes (Smelser 2001, Hyman and Steward 2004). Before any actions can take place, people and organizations have to become engaged to understand the issues, to formulate plans to act, to implement actions, and to assess the results. Biophysical, economic, social, and cultural knowledge all provide important background and are the basis for getting people to act. Scientific knowledge about physical and biological processes is not the only form of knowledge. Yet, too often, it is assumed that merely informing people of scientific facts is enough. Local knowledge can often provide details important for conservation and restoration actions.

McKinney et al. (2010:2) note that land-use patterns often transcend the legal and geographic reach of existing jurisdictions and institutions. Large portions of the Columbia Basin come under the jurisdiction of states. The tribes have long temporal experience residing in the Basin. Some actors have very specific functions like the U.S. Fish and Wildlife Service and state and tribal departments of fish and wildlife. Private landowners have an interest in a specific land area. The temporal, spatial, and functional scope of those whose actions affect landscapes is typically limited so that no one organization or individual has enough power to affect the whole system. Cumulatively, however, thousands of uncoordinated actions can greatly damage a landscape.

The action process begins by identifying relevant knowledge (Figure III.2). Then a vision or set of objectives is identified. The execution of a vision and objectives requires leadership to gain support for a measurable goal (Smith and Gilden 2002). Since no group exists in isolation or has full control of actions, trust and partnerships bring diverse peoples and disciplines together to collaborate on commonly held, or at least complementary, visions, and to resolve conflicts over divergent ones. Actions require the power and resources to put strategies and plans into practice. Actions are based on knowledge, learning, and feedbacks through monitoring, modeling, and assessment to provide insights and the capability to change (Holling 1978, Walters 1986). Action should proceed along with a rigorous process of monitoring and assessment. Adaptive management and informing people through active learning can enable the Council, its partners, and the public to develop the capacity to cope with uncertainty.

Integration and an Interdisciplinary Process

Ecosystems, by definition, involve many interacting physical, biological, and socioeconomic processes and elements. An integrative approach will be required for their effective conservation and restoration. The conservation and restoration of aquatic ecosystems cannot be effectively isolated from management of terrestrial ecosystems, socioeconomic systems, and general human intentions.

Socioeconomic processes such as globalization, migration, markets, government policies, and new technologies will continue to shape landscapes (Stern et al. 1992, Kempton et al. 1995, Gunderson and Holling 2002, Reid et al. 2010). Climate change and invasions of new species add to uncertainty and create ecosystems with no historical precedent (ISAB 2007-2, 2007-3, 2008-4, 2011-1). Interdisciplinary socioeconomic and biophysical science increases understanding of these interacting processes (Gunderson and Holling 2002, Berkes et al. 2003). Collaborations that include a wider range of participants, more diverse organizations, and reach across ecosystems and socioeconomic processes improve intentions and actions (McKinney et al. 2010, Susskind et al. 2010). Governance systems that are more comprehensive and holistic are more effective (Sabatier 1999, Soden and Steel 1999, Boardman 2010). Capacity for adaptation increases with better knowledge, broader collaboration, and flexible governance for coping with change and unknowable futures (Sabatier et al. 2005). A process that integrates science, management, and socioeconomic interests, and builds teamwork across a range of natural resource disciplines, responsibilities, and capacities is necessary to support a landscape perspective. A goal of integration and interdisciplinary participation is to bring better collaboration and governance at the scales necessary for effective conservation and restoration.

The legacy of past human actions has led to significant alteration of landscapes, loss of habitats, expansion of hatcheries, and collapse of some fish and wildlife populations. Yet people love natural areas, untouched spaces, and places saved from human encroachment. Human actions also have the intention to conserve and restore, resulting in both positive and negative consequences for distinct environments (Gunderson et al. 1995, Williams et al. 1997). By taking a landscape perspective with more integrated participation and broader interdisciplinary teams—thinking more broadly, understanding interactions, preserving diversity, and improving landscape functionality using processes that already exist, Columbia Basin landscapes can support people as well as fish and wildlife. Recognizing that that the future has many unknowns and new challenges (ISAB 2007-2, 2007-3, 2008-4, 2011-1) implies a need for new flexibility, capacity to adapt, and a different way of thinking about the future.

Adaptive Capacity

Many organizations, including the Food and Agriculture Organization (FAO 2006), International Panel on Climate Change (Adger et al. 2007, Parry et al. 2007), Millennium Ecosystem Assessment (Ecology and Society 2007, USAID 2009), World Resources Institute (WRI 2009), RA 2010, and World Bank (2010) are working to integrate biophysical and socioeconomic science with environmental and resource management. This integration is intended to strengthen "adaptive capacity" and ultimately the resilience of natural-cultural systems faced with change. While the biophysical and socioeconomic concepts outlined above offer some scientific guidance, local knowledge also can clarify the appropriate direction and governance approaches (Kempton 1995, Sabatier et al. 2005).

Variability and change are inherent properties of landscapes, ecosystems, and fish and wildlife populations and may be accentuated by attempts to control or exploit them (Holling 2001, Bottom et al. 2010, Sidebar III.2). Attempts to manage for a specific benefit may disrupt adaptive capacity and resilience by simplifying the diversity of habitats, altering connectivity, and disrupting mechanisms for feedback. For instance, hatchery operations have the potential to reduce diversity by homogenizing the genetic composition and patterns of growth and migration in large numbers of fish, by collapsing local populations (“modules”) into a few large, homogeneous populations, or by overwhelming the influence of natural density dependence (an important ecological feedback) in wild stocks with the artificially elevated capacity of a hatchery environment. Such damage to the adaptive capacity of ecosystems also could significantly damage the communities and cultures that depend on salmon and other species for life and livelihoods.

Variability and change present environmental and socioeconomic conditions that are difficult to anticipate. Because of such factors as non-native species (ISAB 2008-4), climate change (ISAB 2007-2), and extensive land cover conversion (Tuchmann et al. 1996, ISAB 2003-2), many future ecosystems will have no natural or historical precedent (ISAB 2011-1). A mechanism is needed to learn about changing landscapes, ecosystems, and populations and revise our actions appropriately. Adaptive management of natural resources is suggested (Holling 1978, Walters 1986, Lee 1993) as this mechanism. The concept of resilience (see Sidebar III.2) also argues that *diversity, modularity, and feedback* lead to retention of adaptive capacity. Resilience includes anticipation that change is to be expected and there is a need for alternatives and flexibility to new situations and challenges (see Appendix X.A).

As for ecological systems, intention to create efficiency and wealth and to meet expanding demands through conversion, control, and exploitation of natural systems can contribute to diversity loss, instability, and increasing uncertainty for socioeconomic systems. Changing fire regimes associated with past fire suppression and catastrophic flooding resulting from past diking are important examples. Fazey et al. (2010) argued that resilience in human systems can be facilitated by focusing on action that maintains or increases the diversity of future options and by efforts that nurture and build human adaptive capacity to take up those varied options. Population growth, survival, and behavior of individuals, societies, communities, and socioeconomic institutions are mechanisms that provide feedback in socioeconomic systems; all of these are components of adaptive capacity. Socioeconomic processes mirror the feedbacks in natural ecosystems but can be dramatically enhanced through active learning, acquisition of new knowledge, and adaptive management.

Adaptive management is the process for deciding better approaches when science and policy are in conflict, when knowledge is incomplete, or when there is considerable uncertainty about future conditions. For example, some people have intentions that seek to control and stabilize ecosystems, which science shows can rob the biological and cultural diversity needed for adaptive capacity. Adaptive management uses what is learned scientifically from monitoring, modeling, and assessing actions to develop new goals and intentions to act. It can also benefit from innovation and comparison among groups engaged in similar activities. One of the primary goals is to improve resilience and adaptive capacity through an effective feedback of learning through experimentation, and innovation, and the sharing of new knowledge.

Principles for a Comprehensive Landscape Approach to Conservation and Restoration

Based on our review, we suggest a series of principles that underlay a *comprehensive landscape approach* and can be used to guide conservation and restoration of fish and wildlife and their habitat in the Columbia Basin. We organize these principles into four themes: *socioeconomic, landscape, integrative, and adaptive*. The principles are outlined in Table III.2 and summarized below.

Table III.2. Summary of 15 principles for a comprehensive landscape approach to conserve and restore fish and wildlife and their habitats. The principles are in alphabetic order by short name. These are key, but many more could be added.

Name	Principle	Primary References
Action	Values influence intentions, which influence actions	Malle et al. (2001), Smelser (2001)
Collaboration	Collaboration and partnerships increase the effectiveness and efficiency of actions	Wondolleck and Jaffe (2000), Sabatier et al. (2005)
Context	Context matters	Naiman (1992, 1996), Naiman and Turner (2000), Ball et al. (2010), Beechie and Imaki (In Press), Fausch et al. (2002), Gunderson and Holling (2003)
Diffusion	Acceptance of innovative actions occurs through the adoption-diffusion process.	Rogers (1995)
Diversity	Diversity is fundamental to adaptive capacity	Hilborn et al. (2003), Schindler et al. (2010); Appendix IX.C
Dynamics	Ecological and socioeconomic systems are continually changing	Reeves et al. (1995), Benda et al. (1998), Dale et al. (2000), Seastedt et al. (2008), Weinstein (2010)
Education	Active experiential learning is an effective form of education	Senge (1990), McKinney et al. (2010)
Experiments	Experimentation increases adaptive capacity by creating new knowledge	Holling (1978), Lee (1993), Walters (1997), Grantham et al. (2010)
Function	Ecological functions can be retained even when all native species cannot be conserved or restored	Calicott (1995), Kareiva et al. (2007), Seastedt et al. (2008), Humphries and Winemiller (2009), ISAB 2011-1, Noss (1990).
Governance	Aligning policies with the appropriate level of governance makes them most effective	MEA (2005)
Incentives	People respond better to positive incentives than disincentives	MEA (2005), Hanna (2008), McKinney et al. (2010)
Organization	Vision and leadership, trust and partnerships, and empowerment and resources promote the success of conservation and restoration organizations	Susskind et al. (1999), Smith and Gilden (2002), Sabatier et al. 2005, McKinney et al. (2010)
Populations	Populations are basic units of conservation and restoration.	Waples 1995, Wood and Gross (2008), McElhany et al. (2000), Dunham et al. (2002).
Structure	Spatial structure contributes to the dynamics and persistence of populations	Levin and Lubchenco (2008), McElhany et al. (2000), USFWS (2008), Appendix IX.D
Values	Values affect understanding and acceptance of knowledge	Dunlap et al. (2000), Steel et al. (2003), Dietz et al. (2005)

Socioeconomic Principles

Socioeconomic engagement will help key actors understand and act on the intimate interplay of societies with ecosystems. Effective actions within larger landscapes follow from the actions, incentives, and values of people who live in the area or are concerned about sustaining its resilient fish and wildlife habitats and populations.

Values influence intentions, which influence actions (Action). In anthropology, philosophy, political science, social psychology, and sociology, action theories view values as governing people's intentions which structure resulting actions. The theory is not all encompassing. Social structures can limit or dictate possible actions. For example, tax structures can provide positive incentives but also can create perverse incentives that work against desirable actions.

People respond better to positive incentives than disincentives (Incentives). While altruism is associated with conservation and restoration behavior (Dietz et al. 2005), for those not committed to conservation of fish and wildlife, other incentives can promote actions and behaviors that result in conservation and restoration. Considerable work on incentives has been done in economics (Hanna 2008) and sociology (Fetchenhauer et al. 2006). Some encourage "combining existing funding sources to create incentive for large landscape conservation projects" (McKinney et al. 2010). Incentives have to be created for individuals and organizations to adopt behaviors that influence actions compatible with conservation and restoration goals.

Values affect understanding and acceptance of knowledge (Values). People often make decisions based more on personal values and beliefs than on facts (Kempton et al. 1995, Stern 2000, Steel et al. 2003, Dietz et al. 2005). Research suggests that, when challenged with facts that they question, people fall back on their values to set their course of action, a phenomenon known as "backfire" (Nyhan and Reifler 2010). This is related to the "hostile media phenomenon" (Vallone et al. 1985) in which people reject information because it does not fit their values and beliefs.

Landscape Principles

Comprehensive landscape ecology underpins a broader approach for understanding and acting to conserve and restore the patterns and the processes that maintain resilient fish and wildlife populations and their habitats.

Ecological and socioeconomic systems are continually changing (Dynamics). Landscapes, ecosystems, habitats, fish and wildlife populations, and socioeconomic systems are influenced by disturbances, climate, social and cultural forces, internal interactions, and histories (Reeves et al. 1995, Benda et al. 1998, Benda et al. 2003). Thus, they are dynamic and changing. Dynamic conditions tend to support diversity but also contribute uncertainty in prediction of future conditions. Given current climate trends, the influx of non-native species, and changing human population and technology, uncertainty and surprise are inevitable. This emphasizes the importance of adaptive capacity, which reflects diversity in legacies of materials, organisms, and knowledge that are available to be drawn on in responding to change (Dale et al. 2000, Seastedt et al. 2008).

Context matters (Context). Higher-level constraints limit the potential conditions that can exist or be created in the future. For instance, the characteristics of rivers, streams, and their channels depend on the fluxes of water, sediment, wood, and materials from other parts of the landscape. Their habitats and populations are inextricably connected with, and dependent on, conditions in riparian areas, broader watersheds, and terrestrial ecosystems (e.g., Naiman and Turner 2000, Ball et al. 2010, Wipfli and Baxter 2010). Thus, management of riparian zones and uplands influences aquatic ecosystems, and management of aquatic ecosystems cannot be effectively isolated from management of terrestrial systems (Naiman 1992, 1996). Pattern and process operating at broader scales than the habitats or populations of interest often define the limits of their inherent potential (e.g., Fullerton et al. 2010). Similarly, socioeconomic systems are affected by higher-level governance, economic, and cultural structures and processes, and by existing social, cultural, and economic patterns (Bodley 2008).

Spatial structure contributes to the dynamics and persistence of populations (Structure). Spatial structure of habitat or other biophysical conditions, also called landscape pattern, is the template for the dynamic ecology and resilience of populations (Turner et al. 2001). Thus, spatial structure has become an important focus of ecological research (Appendix IX.D) and provides a fundamental element of NOAA's salmon recovery efforts in the Basin (McElhany et al. 2000, see Appendix IX.A). The sizes, shapes, numbers, locations, and connections of its elements (e.g., habitat units or populations) promote or constrain the diversity and resilience of a landscape and its inhabitants (Levin and Lubchenco 2008). The heterogeneity (diversity) and modularity of elements is particularly important to adaptive capacity and resilience. Some degree of "modularity," or independence and redundancy among elements, allows some elements to persist or even flourish when others fail. Linkages among redundant elements support movement of organisms and materials (i.e., "connectedness"). When elements are too loosely or too strongly connected, they are unable to provide adaptive feedbacks that can limit damage or support recovery from unfavorable conditions.

Populations are basic units of conservation and restoration (Populations). Implementation of the Endangered Species Act has focused on conservation of "populations" as evolutionarily significant units (ESUs) or distinct population segments (e.g., Waples 1995) that may extend across landscapes and persist indefinitely through time. Local populations, defined by low connectivity, often from distance or discontinuities in habitat, are the focus of assessments of viability, modularity, and diversity (e.g., Ruggierio 1994, McElhany et al. 2000, Dunham et al. 2002, Wood and Gross 2008, Schultz 2010). Restoration actions are most meaningful when they contribute significantly to positive change in population level processes. A population perspective considers the networks of habitats in which individuals can complete their life cycles (ISAB 2003-2, Lake et al. 2007, Honea et al. 2009, Jorgensen et al. 2009, Carlson and Rahel 2010). A population perspective considers whether habitat networks are large and complex enough to retain genetic diversity and to absorb disturbance (e.g., Rieman and Dunham 2000, Rieman et al. 2007, Neville et al. 2009, Isaak et al. 2010, Cook et al. 2010). Local populations are the basic elements of larger metapopulations and regional population dynamics.

Integrative Principles

An integrative approach develops scientific, socioeconomic, and interdisciplinary collaborations and governance to bring people, scientists, managers, political leaders, and landowners together. It supports a landscape perspective that accounts for and strengthens communities within that landscape. Integration takes place across broad spatial and temporal scales and across a range of ecological and social science disciplines, responsibilities, and capacities.

Vision and leadership, trust and partnerships, and empowerment and resources promote the success of conservation and restoration organizations (Organization). A review of watershed organizations (Smith and Gilden 2002, Sabatier et al. 2005) identified vision, leadership, trust, partnerships, resources, power, and knowledge as seven attributes associated with success. A leader with vision is essential; if the leader and vision can build trust, partnerships and collaborations will follow. When people feel empowered by the vision and the partnerships, the organization is able to obtain resources to act. Effective actions are based on knowledge derived from monitoring and assessment.

Collaboration and partnerships increase the effectiveness and efficiency of actions (Collaboration). Collaborations and partnerships build trust, increase understanding, and gain agreement among partners in projects where knowledge, values, or cultural differences create disagreement. Collaboration between scientific disciplines is useful where knowledge bases differ and greater interdisciplinary understanding is needed. Collaboration and partnerships become very useful where consensus to act does not exist and differing perspectives need to be understood. Collaborative approaches are expensive in terms of time and should be used when distrust is high, conflict prevents action, or confidence in the data is lacking (Sabatier et al. 2005). People come to collaboration to protect their interests and to prevent undesirable changes, to advance their values and general outlook, and to learn about issues and other people's views. Trust, fairness, legitimacy, and social capital are among the key variables making collaborations successful (Sabatier et al. 2005). Collaboration is not likely to change people's values, but understanding one another may allow for an agreement on courses of action (Wondolleck and Jaffe 2000, McKinney et al. 2010).

Aligning policies with the appropriate level of governance makes them most effective (Governance). Effective environmental policy is based on sound science (NPCC 2009-09). The Millennium Ecosystem Assessment Responses Working Group (MEA 2005:26) concluded that effective management of ecosystems requires substantial changes in institutions and governance; it requires the creation of practices and policies at all governmental levels that guide conservation and restoration. In the United States, governance is constrained by a division of powers to act. This division prevents any one body from having the power to exercise its will. Thus, every level of government creates practices and policies that govern actions. Policies identify the intentions of society and establish the rules, norms, and guidelines for action.

Adaptive Capacity Principles

Adaptation in cultural systems occurs through experiments, learning through education, and revision of values, strategies, and plans. Collectively, these lead to the maintenance of resilience and adaptive capacity in natural-cultural systems. The process of adaptive management is a major strategy to build adaptive capacity. Fundamental elements of adaptive capacity are diversity and function, experimentation, active learning, and diffusion, which is the process by which effective actions become more broadly accepted and used. Analogous ecological and evolutionary processes control adaptation, resilience, and adaptive capacity in nature.

Diversity is fundamental to adaptive capacity (Diversity). Biological diversity follows from landscape and habitat diversity. Diversity provides the raw material for reorganization following disturbance or for evolution in response to environmental change and allows persistence in varying environmental conditions (e.g., Waples et al. 2007, 2008). Diversity also is fundamental to the adaptive capacity of cultural systems (Healey 2009). For instance, diverse portfolios are one of the ways socioeconomic systems build adaptive capacity and hedge against risk (Fang et al 2008). Education, diverse cultural values and behaviors (Lansing 2003) and new technologies can help deal with existing or anticipated problems (Barnard 2011) and build adaptive capacity.

Ecological functions can be retained even when all *native* species cannot be conserved or restored (Function). Ecological health implies diversity in biological structure and function. Although the easiest way to maintain biological diversity, and often the most culturally acceptable way, is to maintain native organismal diversity, ecosystem function does not necessarily require this (Jones 2003, Meyer 2006, Palmer 2009). Most ecosystems have been substantially altered by people and often non-native species now are present or naturalized. Although "keeping the pieces" is a cardinal rule of intelligent tinkering, including in conservation and restoration, the loss of native species is sometimes irreversible. Some have argued that restoration of ecological function is now ascendant to conservation of native diversity (Young 2000), that we are not likely to conserve all endangered populations (Schlaepfer et al. 2011), but that we can still restore or maintain important ecological functions that support environmental health and ecological resilience, in part with ecosystems that include non-native species (e.g., Meyer 2006). Reintroduction of locally extirpated populations, such as wolves or salmon, even if from *non-native* gene pools, may restore critical ecological processes. Even landscapes highly altered by human use can still support important ecological functions (Colvin et al. 2009). Given that few, if any, landscapes retain purely native species or gene pools (Kareiva et al. 2007, Seastedt et al. 2008, Humphries and Winemiller 2009, ISAB 2011-1), a focus on understanding and restoring ecological functions is important.

Experimentation increases adaptive capacity by creating new knowledge (Experiments). Experimentation to actively learn about mechanisms and uncertainties is the essential feature associated with adaptive management. However, experimentation, or even the acknowledgement of uncertainty, is not central in most management efforts. Large-scale management experiments require the effective integration of research and management, policy and governance, and acknowledgement that more knowledge is needed. Experiments are needed to understand uncertainties, assess the results of actions, promote active learning, encourage public input, and adjust strategies and plans to create new or revised actions.

Active experiential learning is an effective form of education (Education). Active experiential learning is a proven technique for effective education, including adult education. Active experiential learning increases understanding of new principles and techniques (Ausubel and Robinson 1969, Senge 1990, Meyers and Jones 1993, McKinney et al. 2010) and improves the capacity to implement new ideas (Fazey et al. 2010). With better knowledge, people are capable of more effective action. Active experiential learning occurs when a group of learners participates together in an activity (sometime referred to as a "learning community"), evaluates the activity, determines what was useful or important, and uses this information to take action. Participants, after reflecting on results and sharing understandings, are then better prepared for a new round of joint planning.

Acceptance of innovative actions occurs through the adoption-diffusion process (Diffusion). Diffusion of innovation is the process of spreading knowledge and getting people to implement actions that have proven effective elsewhere. No one entity can oversee or control every action in a landscape that can aid or impede the strategies and plans for large-scale restoration. Diffusion of innovation is an approach that can spread lessons learned. Research shows that innovations diffuse from innovators to early adopters to early majority (Rogers 1995).

Summary

Fish and wildlife habitats and the populations that depend on them are shaped by a mix of biophysical and socioeconomic processes, influenced and constrained by landscapes and their history. Ecosystems are natural-cultural systems, and socioeconomic patterns and processes share these constraints and characteristics. *Comprehensive landscape ecology*, which takes these workings into account explicitly, is a necessary foundation for more effective conservation and restoration. Socioeconomic engagement and organization to promote integration and collaboration are needed to enable action from this perspective.

Actions that build adaptive capacity and resilience should be emphasized in conservation and restoration. Building adaptive capacity depends on the integration of diverse and interdisciplinary knowledge and on the capacity to learn and adapt through social organizations that can promote processes of innovation, diffusion, integration, governance, and collaboration. New goals, plans, and actions that build adaptive capacity will enable resilience of both the natural and the socioeconomic components of ecosystems.

As Moore's epigraph at the beginning of this section suggests, a larger and more comprehensive framework is challenging. Nevertheless, this framework is essential. In the next section, we suggest four basic Criteria that are required for successful large-scale conservation and restoration.

IV. Criteria to Evaluate Landscape Conservation and Restoration

A simple set of criteria for evaluating the effectiveness of conservation and restoration efforts can guide review and implementation of a comprehensive landscape approach. The Principles outlined above emerge from social and ecological sciences. Others have developed similar ideas to guide conservation and restoration (e.g., Naiman et al. 1992, Gunderson et al. 1995, NRC 1996, Stouder et al. 1997, Williams et al. 1997, Dale et al. 2000, McElhany et al. 2000, Gunderson and Holling 2002, ISAB 2003-2, Goetz et al. 2004, ISG 2000, McKinney et al. 2010, Reid et al. 2010, Susskind et al. 2010, Steel et al. 2010). Many of these provided summary recommendations that are reflected in the review and Principles above. Four general themes emerged from our review of the recent science, and these organize this report, including the Criteria below that we recommend be used to evaluate large-scale conservation and restoration efforts. The ISAB recommends consideration of whether proposals or existing efforts do the following:

- Engage the public and diverse social groups associated with the landscape and build socioeconomic understanding.
- Organize a strategic approach with a foundation in the concepts of comprehensive landscape ecology.
- Develop organizations that support collaboration, integration, and effective governance and leadership.
- Promote adaptive capacity based on active learning through assessment, monitoring, innovation, experimentation, and modeling, combined with a clear process to share new information and revise objectives, strategies, and actions in response to that information.

There can be no single best approach. Innovation and the diffusion of useful approaches build with experience. All efforts are examples of possibilities, but the best approaches will give attention to the general elements that are necessary for success. Below, each Criterion is briefly discussed, followed by several specific points to look for in review. Sidebars and/or more detailed appendices provide example case studies and links to further resources. We found no examples of large conservation or restoration efforts where all four Criteria were fully and successfully implemented.

Criteria and Examples

1. How well does the plan or strategy build socioeconomic understanding and engage the public and diverse social groups associated with the landscape? (Socioeconomic Engagement)

Landscape approaches require understanding and engaging individuals and groups who live on, are interested in, and derive wellbeing from an area. Landscape approaches are likely to proceed more easily when the interactions between socioeconomic and ecological processes and the landscapes in which they occur are broadly discussed and understood. People are parts of ecosystems, and a landscape perspective integrates both socioeconomic and ecological processes and patterns (McKinney et al. 2010, Victorian Landcare Gateway 2010). Biologists, ecologists, social scientists, mangers, landowners, and other citizens bring a diverse set of backgrounds, perspectives, perceptions of benefits, and values to decision making. Public and community knowledge about, and trust in, lead organizations are critical to engaging people in the discussion of plans to conserve and restore landscapes. The field of civic engagement can provide useful insights. The World Bank (2011) and National Parks Service (NPS nd) use civic engagement strategies in making decisions and resource allocations. The Institute for Civic Engagement at State University of New York College at Cortland and

The Aspen Institute (2009, Lasica 2009) also develop strategies for civic engagement.

It is helpful to evaluate values and incentives to see if they promote or obstruct conservation and restoration. Ecological principles, combined with socioeconomic ones, improve ecological as well as socioeconomic conditions. Organizations and efforts that offer insights in this area include the Lincoln Institute of Land Policy (McKinney et al. 2010), Landcare Australia (Victorian Landcare Gateway 2010), Blackfoot Challenge (USFW nd), King County (King County 2010), the Bonneville Environmental Foundation (B-E-F 2009), Ecosystem Economics, LLC , the Consensus Building Institute (Susskind et al. 1999), and The Solutions Journal.[9]

At times it may seem that there are too many organizations, with too many perspectives, trying to work on a particular issue. Since organizations thrive on their ability to engage people and obtain resources to continue their programs, an evolutionary process will select for those that capture public interest and resources for their programs.

What to look for:

- Broad engagement with citizens, landowners, and other groups that have diverse perspectives toward conservation and restoration. Activities and events that show in-depth communication about values, incentives, and actions; discussions that look for areas of cooperation, complementarities, and ability to develop beneficial strategies and actions.
- Breadth of engagement activities that include public meetings as well as print, radio, TV, and social media or web-based tools, to reach the largest possible audience.
- Early solicitation of public engagement that encourages debate and discussion of alternatives.
- Action plans that guide socioeconomic engagement with an outreach component, including advisory groups, university extension, volunteer programs, and learning activities for youth and adults.
- Measurement of effectiveness of socioeconomic engagement, that includes recognition of the organization's name and sponsored activities, success in public and outside funding, and trust among stakeholders.

The Willamette Valley, Oregon, provides an example of socioeconomic engagement across a large, heterogeneous area (Sidebar IV.1**;** Appendix X.A). The Willamette is of interest because there has been no sustaining organization working to stimulate socioeconomic engagement. With leadership from the City Club of Portland in the 1930s, concern over water quality in the Willamette River brought citizen support for the Oregon Sanitary Authority, whose mission was to improve water quality for people and fish. In the 1970s, Governor Tom McCall brought urban and rural interests together to begin land-use planning with the objective of preventing urban sprawl onto farm and forest lands. In the 1990s, Governor John Kitzhaber introduced the concept of watershed councils to engage private landowners in salmon conservation and restoration.

A second example is Moreton Bay, Australia (Sidebar IV.2; Appendix X.B). The Moreton Bay catchment covers 21,220 km^2, contains 14 major river catchments, and is highly diverse socially, economically and ecologically with over 2 million people. There, leadership and vision have come from collaboration among government, industry, and community; local political leadership; consensus regarding objectives and management actions; and decision making based on solid scientific information.

These two cases illustrate how values create intentions to act (see the Action principle). In

[9] www.thesolutionsjournal.com

the Willamette Valley, concern for urban sprawl aligned farm, forest, and urban interests with incentives to create land-use planning. Farmers and forestry enterprises received tax incentives and certainty about continuance of these land uses. Urban areas were bounded for more efficient development. In Moreton Bay, values for clean water created the coalitions to take a catchment approach to improving water quality. In both cases, people's values allowed the knowledge to act to be applied and aligned with incentives to accomplish generally agreed upon goals.

Sidebar IV.1 Willamette Basin, Oregon

The Willamette Basin is a useful example of socioeconomic engagement, a landscape approach, and organization for integration and collaboration in a large and diverse area (Appendix X.A). The area of the Willamette Basin covers 12% of the State of Oregon, has over two-thirds of the population, is the seat of State government, and has significant urban concentrations, the largest at the confluence of the Willamette and Columbia Rivers.

Two examples of leadership and public engagement are Governor McCall's 1970s work on land use planning to prevent urban sprawl and Governor Kitzhaber's 1990s initiation of the Oregon Watershed Enhancement Board (OWEB) and watershed councils to foster conservation and restoration on private lands and address threatened and endangered species listings for salmon and steelhead.

McCall led socioeconomic engagement to generate support for land-use planning statewide. He used a variety of media outlets (print, radio, and TV). Surveys of Oregon residents gauged support. Many debate forums were organized. Public participation was welcomed, and NGOs were encouraged to participate. Oregon land-use planning emerged as a result of collaboration between agricultural, forest, and urban interests concerned about the future effects of land-use change caused by immigration to the state.

Governor Kitzhaber's Oregon Plan for Salmon and Watersheds (OPSW) created new institutions without any governance authority—watershed councils. These local organizations served to gain consensus on plans and projects, to educate citizens on the role of watersheds in salmon conservation and restoration, to obtain funding for project implementation, and to foster participation by private landowners on whose land projects would be completed. Associated science collaborations developed among state and environmental agencies, Willamette Basin universities, and environmental NGOs and watershed councils to educate citizens and design projects.

A comprehensive landscape approach is seen in collaborative OWEB-guided planning, the Council's subbasin planning process, DEQ/EPA water quality standards and planning, the NMFS Upper Willamette River Conservation and Recovery Plan for Chinook Salmon and Steelhead, a Bonneville-ODFW joint habitat acquisition program, and collaboration with state universities and government agencies. The Oregon land-use planning approach and the OPSW are the governance foundation for the evolving Willamette Basin landscape approach. Much is being learned, but the tension between continued growth and development and landscape conservation and restoration remains a challenge. A continuing concern is that economic considerations continue to outweigh concern for ecological conditions in county land-use decisions. County governments often give greater weight to building economy than conserving and protecting ecosystems.

The goal of Oregon land-use planning is to stem the conversion of agricultural and forest lands by development and to foster restoration of fish and wildlife populations and good water quality. Land-use planning requires concentrating population in urban areas. This continues to require improved public education and application of development, zoning, and building codes. Limiting exceptions to land use rules, as well as better incentives to landowners for beneficial land uses, will improve success in reaching conservation goals.

Sidebar IV.2. South East Queensland Healthy Waterways Partnership (SEQHWP): Moreton Bay, Australia

Moreton Bay is home for 270 bird species, 740 fish species, 40 outstanding tropical corals, and several endangered sea turtles. While Moreton Bay represents only 3% of the Queensland coastline, it produces 13% percent of the state's commercial fish catch, provides ~30% of Queensland's recreational income, and is a major port.

An innovative and highly successful regional planning approach for managing the waterways and catchments of Moreton Bay addresses key environmental issues facing southeast Queensland (Appendix X.B). Based on needs to restore the ecological balance of both land and water, the plan aims to sustain waterways and the benefits they provide. It adopts a holistic approach, focusing attention on all catchments, from headwaters to the sea. The regional plan (the Strategy) is implemented by State agencies, local governments, industries, and community organizations. The Strategy provides a common vision and values, measurable water quality objectives, and scientific information to assist integration of local plans and legislation. Successful development of the Strategy is attributed to strong local political leadership and advocacy. A number of local government leaders provide effective support and, more importantly, these leaders accept key roles within the Partnership to oversee delivery of the Strategy (www.healthywaterways.org).

Stakeholder involvement results in over 60 organizations engaging in the Strategy. An Implementation Group consists of a range of stakeholders who regularly assess the status of actions and report progress to the Regional Coordinating Committee of the Queensland government. This arrangement provides an ongoing audit of stakeholder commitments, a step often overlooked in the resource management planning process.

Much time and effort are spent on technical feasibility and the social, cultural, and economic aspects of environmental choices. Methods include community consultations, feedback from stakeholders and government officers, decision analysis to determine priority management actions, and cost-benefit analysis of different management actions.

Using a mix of regulatory and voluntary measures, the partnership defines and implements a set of management actions to resolve catchment–coast issues. This case study demonstrates that linking the management of marine and estuarine areas with the management of catchments requires a broadly based program. That includes collaboration among government, industry and community, local political leadership, consensus among all stakeholders regarding the broad objectives and management actions, and decision making based on high quality information.

Scientific investigations reveal considerable knowledge of southeast Queensland waterways and highlight serious issues in the catchment. The latest scientific and modeling results are provided to stakeholders on a regular basis using a "report card," keeping them "in the loop" and facilitating timely decisions. Communication of information is based, as much as possible, on diagrams and conceptual models. Effective communication methods and skills increase confidence within the community and with decision makers.

Significance of the Moreton Bay Restoration Process. A strong body of scientific information was critical for supporting the call for effective management and for communicating that information drew stakeholders into the work and decisions.[1] One of the main drivers for change in Moreton Bay was increasing community expectations for improved water quality, along with growing recognition of the potential losses incurred by the tourism, fishing, and agriculture industries. A major coordinated scientific research program identified what assets were endangered and the potential of the Bay to improve the quality of life for the citizenry. Effective communication of scientific information to all stakeholders and decision makers increased confidence in the information presented to them.

[1] Moreton Bay Catchments, Report Card: www.healthywaterways.org/HealthyWaterways/2010ReportCardResults/CatchmentResults.aspx

2. How well does the plan or strategy incorporate the concepts of landscape ecology? (Landscape Approach)

ISAB (2003-2) argued that an effective restoration strategy must be spatially explicit and consider locations where conservation or restoration will be most effective; types of conservation and restoration most appropriate for a given location; and indication of the expected fish and wildlife response. Further, the ISAB argued that the foundation for an effective strategy should follow from an integrated three-step process: an inventory of conditions across the watershed (or landscape); an assessment to identify important processes and constraints, consideration of entire species' life cycles to identify critical habitat needs; and a strategy for conservation and restoration that guides priorities and considers future constraints associated with human development.

Similarly, the ISRP (ISRP 2008-4) argued for a "more specific set of habitat objectives, [and] a clear rationale that the sites selected for restoration are justifiable in terms of correcting factors that limit fish populations." We reiterate this guidance and note that landscape ecology that is now a focus of much of the current research in and around the Basin (e.g., Steel et al. 2010) can provide an important foundation. Salmon recovery planning is now based on the landscape, habitat, and population conditions that are required for viability (McElhany et al. 2000). New analytical tools (e.g., Isaak et al. 2010, Steel et al. 2010, Beechie and Imaki, in press) can clarify spatial pattern at many scales, and allow visualization of the interacting influences of local projects, and reveal the placement of projects within larger scale controls of landscape structure and function. Linked population and habitat models can directly support the analysis of restoration priorities and population responses in a life-cycle perspective. More effective restoration strategies incorporating a comprehensive landscape approach will include planning and analysis at a variety of spatial scales, including some much larger than has been typical. They will include recognition of the interplay of landscape pattern and process.

What to look for:

- Development of a broad spatial and temporal context for restoration actions based on the assessment of existing conditions, and critical processes and patterns shaping habitats and populations across the encompassing landscape.
- Efforts and analyses that link the abundance, productivity, and diversity of populations to existing and restored habitats; conceptual and analytical models that consider the size or extent, spatial pattern, and connections of habitats required for more resilient populations.
- Prioritization of restoration actions within this larger context that focus on sources of degradation, critical processes creating and maintaining habitats, and build from existing strengths or anticipated potentials.

Several efforts illustrate innovative applications of landscape ecology in restoration planning including the Pacific Northwest Ecosystem Research Consortium (PNWERC), the Skagit River, Snohomish River, and Oregon Coastal Coho recovery efforts. The PNWERC (Sidebar IV.3) provides an example of landscape analysis of broad patterns linked to both ecological and socioeconomic values. This project is a particularly good example of analyzing spatial structure to understand which scenario produces the best results. It clearly illustrates the value of a scenario-based approach. The status quo, development, and conservation scenarios allowed people to discuss alternative futures. The report of this approach (Hulse et al. 2002) has been a national model for scenario-based planning.

The Skagit Watershed Council and their collaborators (Sidebar IV.4, Appendix X.C) provide another example of a whole-basin approach to assessment of habitat conditions and prioritization of restoration to address limiting factors. Through broad-based collaboration the degradation of habitats and effects of higher-level constraints were addressed. These efforts have emphasized complete life cycles, recognition of the most limiting habitats, engagement of both research and management, and have produced a strategy that prioritizes basin-wide restoration efforts directed toward fundamental causes of habitat loss. Although the Skagit effort is based in a strong landscape perspective, stakeholder engagement has faced difficulties, particularly related to riparian management on private property and agricultural lands.

In the Snohomish River (Sidebar IV.5, Appendix X.D) stakeholders have collaborated in habitat-life-cycle modeling that provides context for actions across the entire basin to support the full life cycle of Chinook salmon. This effort used the Population principle as the basic element of conservation and restoration. The approach is data intensive, but the modeling framework could be adapted to the characteristics of any well-studied watershed.

A final example of Oregon Coastal Coho recovery includes a landscape approach and applies the population and structure principles in particular (Appendix X.E). In this case, monitoring and evaluation have focused on conditions that limit populations, especially overwintering habitats. Recovery planning applies metapopulation concepts and has distinguished dependent ('sink') and independent ('source') populations critical to the persistence of the entire system (Wainright et al. 2008, see also Appendix IX.D).

Sidebar IV.3. Pacific Northwest Ecosystem Research Consortium (PNWERC)

A series of loosely connected activities have dominated the first decade of 21st century efforts to conserve and restore environmental conditions and maintain economic health in the Willamette Basin:

- Willamette Restoration Initiative (www.oregonwri.org/),
- Pacific Northwest Ecosystem Research Consortium (http://oregonstate.edu/dept/pnw-erc/),
- Willamette Partnership (http://willamettepartnership.org/),
- Oregon Watershed Enhancement Board (www.oweb.state.or.us/),
- NMFS Upper Willamette River Conservation and Recovery Plan for Chinook Salmon and Steelhead (www.nwr.noaa.gov/Salmon-Recovery-Planning/Recovery-Domains/Willamette-Lower-Columbia/Will/Will-plan.cfm), and
- Meyer Memorial Trust's Model Watershed Program (www.mmt.org/news/willamette-river-initiative-strategies-announced)

Fundamental landscape science for the Willamette Basin was provided by an Environmental Protection Agency (EPA) sponsored Pacific Northwest Ecosystem Research Consortium (PNWERC) and the related Willamette Alternative Futures project (http://docs.lcog.org/wvlf/default.htm). The PNWERC research project included scientists from the University of Oregon, Oregon State University, and University of Washington. The project sought to understand the Basin's landscape history from the mid 19th century to 1990. PNWERC developed three alternative Basin futures to 2050. A program to gain input from stakeholders was coupled with the research. A focus group met monthly for 2 years with project scientists, concentrating on land use changes and associated socioeconomic and ecological issues. The research used scenarios for gauging preferred approaches to conservation and restoration for the landscape and accommodating a doubling of the Basin's population. The Willamette Valley Livability Forum (WVLF) and the Willamette Restoration Initiative (WRI) were two groups of stakeholders, selected by Governor Kitzhaber to represent a cross-section of Basin interests, including private citizens, industry and business, nonprofit organizations, and local, state, federal, and tribal governments (Baker et al. 2004).

Stakeholder input led to the design of three PNWERC future scenarios—plan trend that assumed continuation of current plans and policies, conservation that used ecological services to prioritize land and water use patterns; and development, where market-oriented approaches governed land and water use (Hulse et al. 2002:86-88). Several variables were used to evaluate each of the landscapes resulting from the three scenarios, run through 2050 (Hulse et al. 2002). These included percent composition of vegetation types in lowlands, uplands, and riparian areas; along with agricultural, forestry, urban, and rural residential land uses. In addition, water quantity, fish Index of Biotic Integrity, and other fish, wildlife, and habitat indices were included. Results showed that only the 2050 Conservation Scenario would change the present trajectory of fish and wildlife, improving abundance, productivity, and diversity over the 1990 base year. In general, indicators of natural resource condition show 2050 Conservation Scenario recovering 20 to 70% of the losses sustained since the mid 19th century (Hulse et al. 2002). Conservation 2050 is achieved largely with higher urban population and land-use densities and less conversion of farmland and natural areas to built land uses. Stakeholders preferred the conservation scenario (Mahmouda et al. 2009).

The PNWERC scientific work resulted in data, analysis, modeling, and riparian evaluations that continue to inform Willamette Valley residents (Guzy et al. 2008; Hulse et al. 2009). The PNWERC project has been a catalyst for studies of climate change, future water use, water temperature conditions, and decision support research. Social engagement, collaboration, and knowledge have grown from this project.

Sidebar IV.4. Skagit River

The Skagit River Basin, covering about 8,000 km^2 in northwestern Washington State, provides an important example of broad collaboration and a strong landscape perspective for watershed and habitat restoration (Appendix X.C). The Skagit supports all freshwater and estuarine habitats for nine species of salmonids with multiple life history types and local stocks. However, there has been considerable habitat loss associated with agricultural land conversion, highway construction and urbanization in the lower basin and river floodplain areas. In addition, dams and logging have had a significant influence in the upper basin.

The Skagit Watershed Council (SWC), a collaborative organization including private industrial and agricultural interests, state and federal agencies, local governments, tribes and environmental and citizen-based groups, has worked in the basin for over 15 years. The SWC is a “Lead Entity” guiding salmon habitat restoration planning. The SWC includes the Skagit River System Cooperative (a coalition of tribes, and the Washington Department of Fish and Wildlife), which is formally responsible for “co-management” of fisheries in the Basin. Planning and assessment have been supported by technical staff associated with the different groups and coordinated through the SWC.

A history of research and watershed analysis provides a foundation for restoration actions, with a focus on complete life cycles and patterns of habitat use and limitation. An important result is a tiered restoration strategy that prioritizes basin wide restoration efforts and targets the fundamental causes of habitat loss, degradation or constraint. Because the greatest impairments have occurred in the estuary, river delta and river floodplains used by Chinook salmon (the current target species for federal funding); these are considered the most limiting Tier 1 targets for restoration. Tier 2 targets are nearshore and floodplain rearing habitats used by important individual populations. Tier 3 targets are tributary watersheds that are generally less impaired overall, but have localized problems with elevated erosion or hydrologic conditions that influence incubation survival of Chinook salmon and other species.

Socioeconomic engagement remains a critical challenge. Land conversion has been extensive, while development and growth continue. The public supports habitat restorations in principle, but hard tradeoffs are resisted, particularly for agricultural and urban development and riparian conservation.

A landscape approach that considers the full expression and diversity of life histories and focuses on restoration of processes that create habitats for those provides a foundation for restoration. Methods of assessment and prioritization provide a useful template for other such projects. Prioritization based on limitations for Chinook salmon should also benefit a diversity of other species.

Organizing for integration and collaboration- The non-governmental SWC has provided an important framework for coordination of diverse interests. The scientific foundation has been particularly important, with the engagement of technical specialists and managers, and should provide credibility in the broader forum of county and federal land use planning. Although restoration can still be opportunistic, articulation of priorities, focus on critical processes, and some consensus within the cooperative could increase effectiveness, as well as leveraging additional resources for restoration and conservation.

Adaptive management and monitoring are recognized as critical elements and are addressed through several planning and strategic efforts; however, they have not been fully implemented as yet.

Sidebar IV.5. Snohomish River

Recovery of an imperiled species begins with identifying a set of actions that will ensure its persistence. Often, myriad causes of a species decline make it difficult to choose among potential recovery actions. In the Snohomish River Basin, a 4,780 km^2 watershed in northwestern Washington, a 42-member forum of scientists and stakeholders developed a quantitative and transparent modeling approach for identifying actions across the landscape to recover Chinook salmon, which are listed as threatened under the Endangered Species Act (Appendix X.D). This approach to salmon recovery planning encompasses actions across the entire watershed, including 62 subbasins, and throughout the life cycle of Chinook salmon.

The Snohomish approach is data-intensive, but used a published modeling framework that could be adapted to unique characteristics of each watershed. The approach linked salmon habitat conditions and river processes with land-use activities in the watershed; not all land-use activities could be linked to salmon habitat quality, so the model may have underestimated the overall benefit of habitat restoration activities.

The Shiraz model (Scheuerell et al. 2006) was used to compare improved and historic habitat conditions. These scenarios were evaluated for the salmon population attributes of abundance, productivity, spatial structure, and life-history diversity. The modeling effort provided the planning group with clear choices for strategies to recover Chinook salmon. Robust salmon populations in historical conditions provided evidence that habitat protection was needed. Sensitivity analyses suggested that restoration to improve juvenile rearing habitat in the estuary and lower mainstem reaches would have the best chance of improving population performance. However, the model findings indicated that the test case scenario for habitat restoration would only achieve 50% of the desired goal for Chinook salmon recovery.

Lessons Learned: Although habitat protection was identified as the top priority, the conservation plan did not establish a detailed protection strategy, and there is concern that essential habitat is not protected. A habitat protection strategy involving land use ordinances is being developed. The basin-wide funding goal was $15 million per year, but a review indicated $21 million per year is needed during the first 10 years. Only 34% of the habitat projects have been funded, some of which are lower priority projects that were identified by stakeholders. The funding shortfall makes it particularly critical that actions be prioritized and implemented, but authority to implement habitat projects has been constrained by local governments. Creative approaches, such as land trades, are being considered as a means to protect or restore important habitats, while also preserving agriculture. The county describes linkages between plan strategies, benchmarks, and implementation progress in order to re-evaluate priority actions, and the overall process is reviewed by an external panel

3. How well does the plan or strategy develop organizations that support collaboration, integration, and effective governance and leadership? (Develop Integration and Collaboration)

"Develop Integration and Collaboration" and "Socioeconomic Engagement" are related Criteria. "Socioeconomic engagement" is more about working with the public to develop awareness of the dimensions of a landscape approach, to resolve differences in values, and to formulate an approach that supports the goals of people and communities. Integration and Collaboration emphasizes relationships among the individuals, disciplines, institutions, and organizations that create and communicate visions, build trust, develop partnerships, develop and share knowledge and conceptual models, secure resources, and develop or implement plans of action. In creating institutions and organizations, it is too often assumed that only specific ecological science (e.g., fisheries or wildlife biology) is needed and that people, if they understood the science, would act 'appropriately' in accord with this science. For a landscape approach, all relevant science disciplines, and management, and the public must engage, collaborate, and find a mechanism for effective governance.

Conservation and restoration strategies and actions are often developed in isolated disciplinary, governmental, or social groups. Scientists and managers from different disciplines frequently fail to communicate effectively or work effectively with each other and the public; public or planning meetings are held; plans are revealed, but not necessarily debated, reviewed or revised; and parties talk past one another. Integration of disciplines in science and management requires extensive interaction, dialogue, and development of a commonly understood language, with the goal of understanding the views of others and seeking workable solutions. Sustained collaborative efforts require working across disciplinary, responsibility, community, government, philanthropic, academic, and public interests (Gunderson and Holling 2002, Goetz et al. 2004, McKinney et al. 2010), as well as understanding and respecting the points of view of others. Informative case studies and useful tools can be found at the Consensus Building Institute (CBI[10]) and Cooperative Conservation America,[11] a web site devoted to sharing the stories, lessons, knowledge, and tools of Americans engaged in cooperative conservation.). The Global Water Partnership Toolbox (www.gwptoolbox.org) lists additional case studies.

What to look for:

- Collaborations that have a sustaining structure, a clear vision, and the leadership and organization to carry out the vision. Collaborations should cover large areas, diverse ecologies, and varied interests that will allow the exploration of trade-offs among resource uses and conflicts.
- Organizations that work to build trust and partnerships between relevant sciences, between science and management, and between science, management, and the public.
- Organizations with the technical capacity and resources to implement the vision in the form of well-integrated landscape projects and actions.
- Governance that is inclusive, democratic, flexible, and based on interdisciplinary scientific, technical, and local knowledge and that uses what is learned to refine practices and policies for future actions.
- A process that adds new interdisciplinary scientific knowledge and incorporates it with agency and public perspectives to build trust and develop practices and policies that can implement landscape perspectives.

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[10] http://cbuilding.org/

[11] www.cooperativeconservationamerica.org

Examples of organization for integration and collaboration include the Willamette Valley, the Skagit Watershed Council, Upper Columbia Salmon Recovery Board, Fraser River Estuary Management Program, and Moreton Bay (South East Queensland Healthy Waterways Partnership). The Yakima Basin Aquatic Science and Management Conference also provides an example of effective communication to support integration.

The Willamette Basin and the State of Oregon (Sidebar IV.1) have a much less centrally controlled collaboration and governance process than the others mentioned above. The process is much less structured and more locally connected. Several independent planning efforts work together to affect the Willamette landscape. The Upper Willamette River Conservation and Recovery Plan for Chinook Salmon and Steelhead released in 2011 is a collaborative effort between NOAA Fisheries and the State of Oregon. The Recovery Plan is implemented through the Oregon Plan for Salmon and Watersheds, especially the watershed councils created under the OPSW. A second major component is funding from the Bonneville Power Administration through the Oregon Department of Fish and Wildlife. ODFW has a contract through 2025 to secure habitat important to salmon and wildlife. A third component is the Oregon land-use planning process in which land use decisions must take into account natural resource issues.

The Skagit (Sidebar IV.4) and the Upper Columbia Salmon Recovery Board (UCSRB, Sidebar IV.6, Appendix X.F) have more institutional power than is the case in the Willamette, where land-planning is designed to protect natural resources (though city and county-level decisions may favor development over protection of natural resources). The Skagit has developed integrated collaboration and governance through the local watershed council working with a broad array of partners. By contrast the UCSRB coordinates five watersheds and the associated Watershed Action Teams in a regional organization. Where the Skagit projects are informed by the recovery plan, the UCSRB is tied jointly to the Council and NOAA Fisheries efforts in the Upper Columbia.

The Fraser River Estuary Management Program (FREMP; Sidebar IV.7, Appendix X.G) is an inter-governmental agency that brings together federal, provincial, municipal, and port-associated governmental agencies. The FREMP coordinates wetland habitat mitigation and restoration. It maintains an online database open to all, thereby allowing people to identify areas open for development and areas protected for restoration, along with the rules for development and restoration.

The Moreton Bay (Sidebar IV.2) strategy is broader in scope than the FREMP, including catchment as well as estuarine plans and actions. The geographic area covers "19 major catchments, 18 estuaries, and nine zones within Moreton Bay." Moreton Bay is a "consortium of over 70 government, industry, research, and community stakeholders collaborating to develop a whole-of-government, whole-of-community approach to understanding and managing the region's waterways."

An ongoing example of effective communication to support collaboration across agencies, science, and management is the Yakima Basin Aquatic Science and Management Conference (www.ykfp.org/par.html). It began in 2003 and has grown into an annual program review exercise. It is well focused while at the same time involves a wide spectrum of stakeholders. An especially positive development in the 2011 conference was that presentations on fish ecology studies and hatchery efforts were integrated with presentations on habitat restoration.

In all of these examples, there were leaders who promoted the vision, worked to build the trust and partnerships, and assembled resources. These were Oregon governors, tribal leaders, the Brisbane mayor and business leaders, the executive directors and board members of the watershed council and recovery board. The organization principle to create collaboration, integration, and effective governance does not occur without someone taking the initiative to initiate partnerships, invite diverse interests to participate, and design governance structures.

Sidebar IV.6. Upper Columbia Salmon Recovery Board (UCSRB)

In 1999, Salmon Recovery Boards in Washington emerged to deal with endangered species listings of salmon and steelhead stocks (Washington Recreation and Conservation Office 2010). Early efforts to conserve and restore salmon populations led to contentious exchanges between locals and particularly federal officials. Recovery boards were designed to bridge the gap between managers and local groups to allocate recovery resources most effectively, accommodating both conservation and local economic needs. The UCSRB is one of the eight resulting boards and is comprised of representatives from Chelan, Douglas, and Okanogan counties, the Colville Confederated Tribes, and the Yakama Nation in the north-central part of Washington State (Appendix X.F).

The strength of the UCSRB is in governance that brings together county and tribal governments, citizens, and special interests in a collaborative process. The Implementation Team is made up of Regional Technical Team representatives (RTT); interested stakeholders; agency, tribal, and county representatives; and a Watershed Action Team (WAT) representative. WATs are citizen groups that are interested in conservation and restoration in each of the five watershed areas covered by the UCSRB. Members of each WAT are also opinion leaders in the watershed. An Implementation Team is responsible for habitat projects and programs in the region, monitoring the status of actions, assessing trends in outcomes, and reporting results. The Implementation Team will assist the monitoring program, host and maintain a Recovery Plan web site, and sponsor workshops the public can attend. Implementation of the plan has just begun and data on achieving the goals are yet to be consistently measured.

The biggest achievement has been the governance and collaboration structure that brings local entities together. Government, tribal, science, agricultural, fishing, and local participants in the UCSRB have come to better understand one another. The process has shifted from one of conflict and lack of participation to greater local engagement and better understanding of issues and actions. The UCSRB plan provides a vision for working together to delist salmon and improve environmental conditions, while also considering economic factors.

Navigating through the myriad organizations and regulations that play a role in salmon recovery (e.g., NMFS recovery planning, technical recovery teams, tribal restoration planning, Council subbasin planning, EPA water quality TMDLs, U.S. Fish and Wildlife interests, county governments, and local advocacy groups) to get projects that achieve outcomes is a continuing challenge.

Sidebar IV.7. The Fraser River Estuary Management Program (FREMP)

Located in southwestern British Columbia, the Fraser River is 1,375 km long, without mainstem dams, and is one of the largest salmon producers in the world (Appendix X.G). All five species of salmon, as well as steelhead and cutthroat trout, are found in the watershed. The estuary is a critical habitat for these species, as well as for shorebirds and migratory waterfowl of international significance.

The estuary is defined as the lower 42 km of the river, including about 16 km of salt wedge, and 26 km of freshwater tidally-influenced habitats. Wetland habitat is known to be important to juvenile salmonids, but limiting factors are not well understood. The inner estuary is extensively diked and channelized. Between 70-90% of the original wetlands have been converted to other uses, but intact extensive sand banks and eelgrass beds are found in the lower estuary. Opportunities for wetland restoration in the inner estuary are limited because of urban and industrial development, and urbanization is growing rapidly. The estuary delta at the river's mouth is the largest in western Canada. The estuary is also important for local water transport, especially of logs and wood products.

Established in 1985, FREMP is an inter-governmental group that coordinates wetland habitat mitigation and restoration, as well as other activities relating to sustainability. There are six partners – three Federal agencies (Environment, Fisheries and Oceans, Transport), one Provincial agency (Environment), Metro Vancouver (13 cities or municipalities), and Port Metro Vancouver. FREMP exists solely as a coordination and facilitation organization – the six partners hold the decision-making power in their legislative mandates. An overall estuary management plan, developed with input from the partners, the general public, and the five First Nations in the area, provides guidance. FREMP "provides … a framework to protect and improve environmental quality, to provide economic development opportunities and to sustain the quality of life in and around the Fraser River Estuary."

Socioeconomic engagement - The direct involvement of partners not focused on conservation has required FREMP to take a broad perspective. There are six action programs in addition to fish and wildlife habitat: Integration/Sustainability, Water and Sediment Quality, Dredging and Navigation, Log Management, Industrial and Urban Development, and Recreation. Some conservation groups have been frustrated by the process because FREMP is not an "action agency" or a decision maker. Direct engagement is through the partner agencies. FREMP mapping, reach overviews, the overall estuary plan and other projects are also open to public participation.

Landscape approach - FREMP provides an important landscape perspective, based on one of the earliest estuarine habitat classification systems in the region. It is based on inventories of habitats and vegetation and includes detailed GIS mapping of vegetation units. The possible de-emphasis of non-vegetated areas may be problematic, as the functions of this habitat are poorly understood. Unfortunately, FREMP area designations and municipal zoning and Official Community Plan designations are not always complementary.

Organizing for collaboration and integration - FREMP's coordinated project review process and registry are strong points. Available on line, a central database is open to the public and enables developers and conservation agencies to determine whether an estuarine area is classified for possible industrial use that is subject to compensation or mitigation. The partners collectively review proposals before a federal, provincial, or municipal authority makes a decision that would allow a project to proceed. Restoration may be funded through habitat compensation ratios applied to developers, under the Federal Government habitat policy, as well as through other fish and wildlife enhancement programs.

Adaptive management - The estuary management plan was written in 2004, but its vision ("A Living Working River") has not changed. Reach overviews, most recently addressing the extensive sand and mud flats in the lower estuary, are a mechanism for updating information. While a modest net gain in fish and wildlife habitat has been made, it is not clear if all ecological functions have recovered, because success in meeting stated goals has not been documented. A recent biodiversity forum for the area concluded that adaptive management was not fully implemented. Participants recommended building organizational capacity and developing champions within organizations to assist with the task.

4. How well does the plan or strategy promote adaptive capacity based on active learning through assessment, monitoring, innovation, experimentation, and modeling? Is it combined with a clear process to share new information and revise objectives, strategies, and actions in response to that information? (Foster Adaptation; Use Adaptive Management)

Conservation and restoration of landscapes require active learning. Uncertainty and continuing change require innovation and adaptation, while the large scales involved make traditional experimentation difficult. Projects and programs must be based on scientific, technical, and local knowledge that can never be fully replicated, complete, or adequate from the traditional scientific perspectives; learning is a goal; comprehensive monitoring provides insight; modeling helps to understand the dynamics and critical uncertainties; and innovation and diffusion of new knowledge strengthens the work of all involved.

What to look for:

- Assessments with statistically robust measurements of high-level indicators that assess specific project outcomes; an evaluative approach that includes deliberation and provides guidance for goal setting and future projects.
- Use of multi-objective, multi-level indicators, and efforts to weigh their importance that are integrative and include socioeconomic evaluations.
- An active, experiential learning element to help people gain knowledge about landscape structure and processes, and inclusion of procedures for the diffusion of innovation to a broad set of actors.
- Attention to an integration of efforts across scale; project, watershed, and regional strategies with common approaches to evaluation and a network of communication; efforts to synthesize results across temporal and spatial scales.
- A process that directly integrates new information into revised and improved goals, strategies, and actions.
- Recognition that landscapes are dynamic, have changing ecological and socioeconomic conditions, and face considerable uncertainty, so that society continually faces novel situations and surprises. Adaptations to these situations should be communicated using processes and strategies that enhance the adoption of what is learned.
- Development of adaptive capacity that shows attention to broader landscape processes; integrates socioeconomic and ecological outcomes; includes measures of such things as public trust, knowledge of scientific principles, and identification of individuals or groups that are potentially affected, beneficially or negatively, by plans and actions.

We found few examples of adaptive management that showed many of these characteristics. Most examples are deficient in experiments, education, function, and diffusion. Experiments, particularly ones that are designed to understand changes in social-ecological systems, are difficult to do at large scales and often are unacceptable to the public. Education could easily become part of the process. Oregon watershed councils use their projects for educational purposes, but much more could be done to use assessment, monitoring, and modeling, creating scenarios, and capturing the results of what is being learned.

Oregon coastal coho salmon management provides an example (Appendix X.E) of a monitoring program for both fish and habitat that encompasses the entire freshwater portion of the ESU. The recovery effort has well-defined habitat and population criteria for recovery, and it has a mechanism for evaluating progress toward these goals.[12] In a 2010 status review, the Biological Review Team (BRT) determined that the ESU was still "threatened" despite substantial increases in abundance. Monitoring showed limited improvements in habitat, supporting the conclusion that the upswing largely reflected cyclic ocean conditions. By taking a larger perspective, and integrating monitoring and restoration, the BRT showed that habitat restoration must be more effective to sustain coho during future downturns in ocean conditions.

Buhle et al. (2009) provide another example of a strong monitoring program that linked large-scale reductions in hatchery stocking along the Oregon Coast to improved survival of coho smolts. Whether that information can be effectively implemented in a broader landscape approach that integrates hatchery and habitat management remains an open question, but monitoring like this can identify effective practices that can be diffused to similar situations.

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[12] www.nwr.noaa.gov/ESA-Salmon-Listings/Salmon-Populations/Alsea-Response/OCC-ESA.cfm

Summary

Where does practice stand on the four Criteria? Implementation of comprehensive landscape ecology is supported by rapidly advancing technology and efforts to define and implement priorities through new and innovative analyses. Application of comprehensive landscape ecology has occurred most often where research and management have collaborated well. Integrated collaboration and governance, too, has advanced with a variety of different organizational structures. Collaboration is reflected in “cooperative” or “co-management,” partnering, structured decision making, community forestry, learning communities, and team building. Progress with socioeconomic engagement and adaptive management is less evident, but there are some examples. The four Criteria and the examples outlined above provide a framework for progress. In the next section we consider some of the primary challenges that must be addressed for continued progress in the Columbia Basin.

V. Implementing a Comprehensive Landscape Approach

Applying the four Criteria to guide landscape restoration requires using insights from the physical, biological, and socioeconomic sciences. Engaging the community, setting the vision, organizing to promote action, and linking science and management are the focus of implementation strategies. All of these have involved significant challenges, and all of these require significant engagement of all affected parties, including the public. Although many planners, the Council Fish and Wildlife Program, Tribal vision documents, and NOAA recovery documents have embraced many of the ideas discussed in this report, implementation overall has lagged, and coordination is far from complete.

Success requires resolving both technical and social issues, which include inconsistent or conflicting conceptual models (Lichatowich and Williams 2009, Reeves and Duncan 2009); conflicting or incomplete information (Gross 2010, McKinney et al. 2010, Steel et al. 2010); poor agency or public commitment (Cone 1995, Ridlington and Cone 1996, Smith et al. 1998); and limited public engagement (McKinney et al. 2010, Reid et al. 2010); competing preferences, values, or understanding of the larger vision (Smith et al. 1997, Catholic Bishops 2001, Bisson et al. 2009); a lack of science-management-public integration; and missions that conflict among, or even within, agencies (Bisson et al. 2003, Samson and Knopf 2001, ISAB 2003-2, Rieman et al. 2010). As a result, planning and regulatory mechanisms are often limited to individual projects or local habitats (Baron et al. 2002, Fausch et al. 2002, ISAB 2003-2, Rieman et al. 2003, Flitcroft et al. 2009, Beechie et al. 2010, Rieman et al. 2010, Schultz 2010). Despite an emphasis on broader planning, restoration activities tend to be narrowly focused and even lack coordination between adjacent landowners. Actions most often are opportunistic rather than integrated and strategic (Habron 1999, Gibson 2003, Flitcroft et al. 2009).

Within the Columbia Basin and the Pacific Northwest several authors have summarized critical issues that have limited broader efforts for conservation and restoration. Lackey et al. (2006) identify socioeconomic challenges that underlie life style choices and priorities, including the drive for economic efficiency; increasing scarcity and competition for natural resources, especially water; and rapidly increasing numbers of people. McKinney et al. (2010) suggest that many managers lack broad-scale information and analytical capacity, policy tools and capacity to coordinate broad interests, and a funding structure that facilitates the process. Lichatowich and Williams (2009) argue that the conceptual foundations of those involved in large-scale restoration are inconsistent or even at odds, that current institutional structures are incapable of supporting integration, and that political interference limits the implementation of the best science.

Upon review, we find several important challenges that we believe inhibit the effectiveness of large-scale habitat conservation and restoration in the Columbia Basin. To implement a comprehensive landscape approach, it is necessary to:

- Broaden engagement and build support for a landscape approach.
- Revisit, rebalance, and coordinate the vision for restoration.
- Organize to work across boundaries for coordinated action.
- Link science and management more effectively.

We explore each of these challenges and provide some thoughts and examples of how they might be better met in the future.

Adaptive management is also critical to effective implementation. Given its central role and its ability to move forward the other areas that this report identifies as essential for successful restoration of the Basin, we consider challenges with adaptive capacity and adaptive management in the next section (VI).

1. Broaden engagement and build support for a landscape approach.

One of the most important tasks for achieving successful implementation of large-scale conservation and restoration is refining and communicating a clear vision for the future. To build a vision increased effort is needed to engage, inform, and gain the trust of the public. We have discussed the need for effective socioeconomic engagement throughout this report. The Columbia Basin is socially, politically, economically, and ecologically complex. It is populated by people with diverse social and cultural backgrounds. Most of the population that benefits from the Columbia River hydrosystem, for example, live in urban areas west of the Cascade Mountains, while most of the Basin impacted by the hydrosystem and where considerable habitat restoration is needed, is to the east. Urban and rural, and cultural, social, and political histories lead to differences in values, intentions, and the conservation and restoration actions people will support.

Recent concern about the gap between the science of restoration ecology and the practice of large scale restoration action engaging real human communities underscores a challenge that is also widespread in native species conservation (Arlettaz et al. 2010, Cabin et al. 2010, Reeve et al. 2006) and river and watershed management (Rogers 2006, Williams 2011). Science and management, in one form or another, must energize the public. The public is often brought into discussions too late or in a way that limits their input. People are more likely to support actions they have been involved in crafting. When people are involved early, they learn about the issues and the science and technology required to address them. In research and monitoring, the public is usually engaged only in the discussion of results. The public often has knowledge and questions that could inform and adjust research design and monitoring. Managers usually come to the public after internal discussion and planning, when options are more or less resolved (Johnson et al. 1999, McGinnis et al. 1999, Leach and Pelkey 2001). Conscious efforts to address public skepticism early can help avoid costly delays (ICBEMP nd, Buck et al. 2001, Ramsey 2009) and lack of support to implement a vision.

Gaining a shared vision and public support for actions takes time and can have difficult periods, but progress can be made. Most people want to conserve the place where they live, and many depend on it for their livelihoods. Differences in values can be resolved and common ground sought with better socioeconomic understanding and engagement. Getting public support requires improved socioeconomic understanding and engagement and better techniques for communicating science to the public (Bessey 1943, ICBEMP nd, Flitcroft et al. 2009, McKinney et al. 2010, Schlesinger 2010, USFWS nd). The ISAB recognizes that tribal, state, and federal sovereigns are the final policy decision-makers. Actions, however, require the willingness of people who own, work on, live in, and have an interest in the landscapes being conserved and restored.

Often the best way of gaining sustained support for directed action is with stories. People identify with narratives, especially when they have an engaging character or compelling message (CRITFC 2011, House 1999, Waterson 2010). *Linking personal well-being with the integrity of watersheds and landscapes is important*. The more people share a vision for the future and understand how their actions can contribute to that vision, the more likely that knowledge will help guide actions. If people do not see benefits for themselves, their communities, and places important to them, they are not likely to support plans and actions. One approach has been to articulate how large-scale restoration can lead to benefits from ecological goods and services (Costanza et al. 1997, NAS 2005, deGroot et al. 2010, Jones et al. 2010). These include such benefits as clean water and air, the natural production of fishes and other organisms that people use, productive soils, and pollination of crops. Many such goods and services have been quantified in monetary terms, but these lack visceral and readily understandable connections to personal well-being. Better efforts are needed to improve understanding of the ecological benefits that matter most to people. Benefits that translate to personal health, education, overall well-being, and to jobs, salaries, healthy environments, clean water, and safety nets when disasters strike are more compelling. Benefits also may include payments for conservation and restoration through federal farm and energy programs, state incentives, federal and state tax deductions and credits, and land trusts. Finally, the aesthetic quality of landscapes has value to many. Look at the pictures used to describe places; most use a beautiful landscape scene. And listen to ranchers and growers talk about their lands, particularly those that were homesteaded or settled by family.

Comprehensive landscape ecology includes articulation of how the patterns of land types, covers, and uses can help to achieve what matters to people. Perhaps by following threads like these to ask what benefits follow from better landscape management one can identify benefits that become parts of the fabric of the regional culture. A comprehensive landscape approach provides an opportunity for beneficial uses of the land and water that maintain values and well-being that are important to people.

2. Revisit, rebalance, and coordinate the vision for restoration, in particular the vision for *restoring abundance, diversity, and resilience.*

Ecological foundations and the critical notion of resilience, with foundations in diversity, and restoration of process, have been embraced in the Fish and Wildlife Program and have provided much of the guidance leading to its current vision (ISG 2000, Lichatowich and Williams 2009). However, there are unresolved tensions within the Program vision and goals and, similarly, there are unresolved tensions between the visions of the major organizers of restoration of the Basin, including the Council's Fish and Wildlife Program, Tribal restoration plans, and plans for recovery from NOAA and other agencies (as well as with the views and beliefs of various citizens and other groups).

Although the Council's Program has a vision of abundant, productive, diverse, and self-sustaining fish and wildlife, most current actions to restore the Basin focus largely on abundance; abundance also is the overwhelming emphasis of monitoring and evaluation programs. Based on our review, the ISAB emphasizes that diversity is not given sufficient attention in strategies, actions, or evaluation of outcomes. Diversity is an essential foundation of resilience, and there is an ultimate trade-off between diversity and the long-term abundance of a particular genotype, population, or species. Diversity results from having many different genotypes, life histories, populations, and species. Consequently, more diversity goals, actions, and evaluations are needed to provide critical balance to actions that promote abundance as a means of recovery of species or harvest opportunities.

Hatcheries are one area in which a balance of actions to restore abundance versus actions to maintain diversity must be of high concern. Hatcheries have been a source of controversy in the Basin for decades, and hatcheries today are sufficiently many and large to be landscape features. Given their number and sizes, and the fact that the anadromous salmonids that are produced by most Basin hatcheries range from their spawning areas to the ocean, often using habitat over hundreds of river miles, they also have landscape-level impacts. The ISAB concludes that there has not been adequate attention to either the factors that are essential to the long-term resilience of the Basin's communities or to the landscape-scale effects of hatchery programs. Integration of hatchery production with habitat restoration is an essential part of realizing the Fish and Wildlife Program vision of simultaneously restoring *abundance*, *diversity,* and *resilience* of salmon and other species. The need to better emphasize diversity and resilience, along with abundance, was recognized in the 2009 artificial production strategies (NPCC 2009-09:18), but the challenge of doing so remains.

Salmon abundance and diversity have declined substantially in the Columbia River Basin in the past 150 years (Sidebar V.1; Section II; Chapman 1986). Hatchery augmentation of salmon to increase abundance for harvest began in the 1870s. Through the combined effects of subsequent hatchery expansion (Figure V.2) and habitat loss, a diverse landscape of salmon production has been replaced by a much more simplified one. Historically, increasing production from this simplified landscape has relied upon production of hatchery salmonids, rather than wild salmon that depend on diversity of habitats in a complex landscape. Large production programs initially created an expectation that hatchery production technology could return salmon to abundant levels for harvest, irrespective of habitat conditions. Clearly this has not occurred (Figure V.2). Nevertheless, many continue to think that hatcheries are an effective mitigation solution, which is reinforced by dramatic increases in returns and harvest opportunities since 1999.

Sidebar V.1 Salmon Abundance in the Columbia River

At one time total Columbia River fish runs "… were among the largest in the world, with an estimated average between 10-16 million naturally-spawning fish returning to the basin annually" (NPCC 2009-09:1). Historic run sizes provided context for current goals (NPCC 1986) of "… increasing total adult salmon and steelhead runs to an average of 5 million annually by 2025 in a manner that emphasizes the populations that originate above Bonneville Dam and supports tribal and non-tribal harvest …" (NPCC 2009-09:11). Average total adult return of all salmon and steelhead from 1938 to 2010 has declined to about 7% of estimated historic levels (NPCC 1986) and many of these salmon originate from hatcheries rather than natural spawners (www.cbfwa.org, ISAB 2011-1). Runs above impassable Chief Joseph, Hells Canyon, and the major Willamette flood control dams have been lost. Although past abundance is not necessarily an appropriate goal for the future, comparison of historical run sizes with more recent ones provides some context of losses across the landscapes of the Basin. A several fold increase in numbers since the lows of 1997 and 1999 have been attributed to large hatchery returns as well as more suitable conditions in migratory and ocean environments (Figure V.1.).

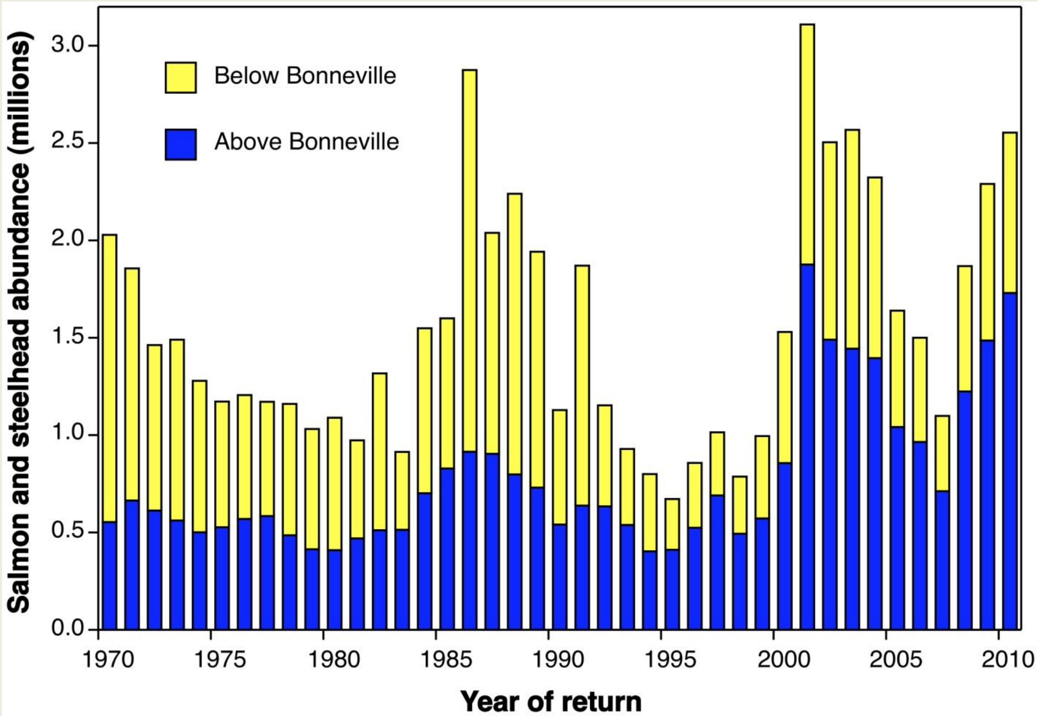

Figure V.1. Numbers of salmon and steelhead above and below Bonneville Dam, 1970-2010. Data source: Dave Ward, Columbia Basin Fish and Wildlife Authority, Status of Fish and Wildlife Resources in the Columbia River Basin. The current Council Goal is total returns averaging 5 million fish. Historical returns are estimated to have ranged from 10-16 million fish. The proportion of adults originating from natural spawners versus hatchery releases has not been estimated for all stocks in the Columbia Basin.

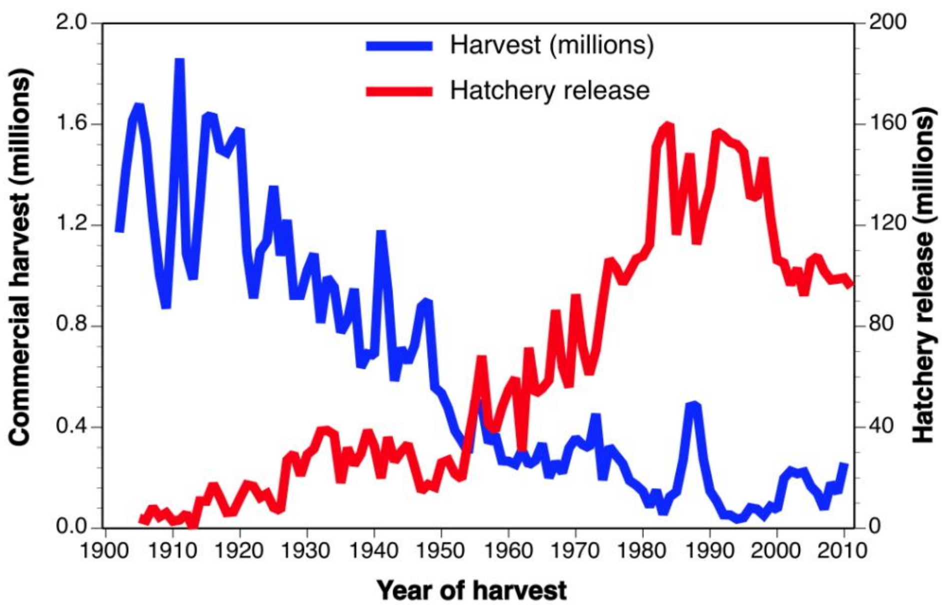

Figure V.2. Trends in commercial harvest (hatchery and natural) and hatchery releases of Chinook salmon in the Columbia River Basin. Hatchery release values pushed forward three years. Data sources: Mahnken et al. 1998, WDFW/ODFW 1999, PFMC 2011, FPC 2010.

The expansion of hatchery production has come under increasing scrutiny for its potential impacts on naturally-spawned fish (NRC 1996, ISG 2000, Araki et al. 2008, RIST 2009b, Bottom et al. 2010, Chilcote et al. 2011, Ward 2011), and cautionary guidelines have been offered (HSRG 2010, NOAA Fisheries 2010). The Council's Fish and Wildlife Program (NPCC 2009-09:18) says artificial production can be used to: "1) 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 native fish; or 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; or 3) to replace lost salmon and steelhead in blocked areas." The ISRP uses these criteria as part of their evaluation of proposed new programs. Recently, NOAA proposed a further shift in artificial production philosophy that would substantially reduce numbers of fish released from Mitchell Act hatchery programs, but this proposal has received strenuous objections from many parties (Clearing Up 2010:12-13).

Supplementation of natural stocks with genetically similar hatchery fish attempts to meet the goals of abundance for harvest while protecting and rebuilding diversity and productivity of naturally spawning populations. At present, there are few if any data to demonstrate that this can work in the long term (Ward 2011). A major flaw in improvement of understanding is the lack of clear information on what has been, or is being, lost, because there is little information on, and little monitoring of, diversity of naturally spawning populations (e.g. RIST 2009, Ward 2011). Additionally, the effects of supplementing one species on the population dynamics of other native species have received little attention in the Columbia River Basin. Based on general ecological understanding of the relationships of abundance, habitat complexity, diversity (of genes, populations, and species), and resilience, the ISAB thinks that it is time to balance actions to promote and evaluations to assess abundance of salmonids with actions to promote and evaluations to assess diversity and resilience.

The future diversity of fish and wildlife depends on conservation and restoration of habitats across large areas and the maintenance of a broad array of natural variation of both habitats and populations (Burnett et al. 2007, Crozier et al. 2008, McClure et al. 2008, Schindler et al. 2010). Hatchery programs can change the growth, survival, reproduction, and life-history traits (e.g., age/size of smolting) of both hatchery and naturally-spawned fish (Buhle et al. 2009, RIST 2009b, Berntson 2011). Current science dictates that we should proceed with caution when promoting abundance and should complement that approach with active efforts to maintain and restore diversity through natural processes. Recent research indicates that supplemented populations may experience significant intra-specific competition (a negative density dependent effect; ISRP 2011-14). This suggests that habitat quality and quantity, and the existing food web, are not always sufficient to support supplemented fish populations, even though current fish densities are likely much lower than they were historically. This is not just a theoretical issue. A recent collapse of the Sacramento River fall Chinook salmon stocks has been attributed to changing ocean conditions and the loss of genetic and ecological diversity in response to habitat loss and consolidation in hatchery production (Lindley et al. 2009).

To address these issues, the ISAB recommends that the Council develop goals for diversity, based in measures that can be monitored as High Level Indicators along with the abundance and in-river survival. Progress in evaluation of large-scale patterns in genetic (e.g., Matala et al. 2011, Hess and Narum 2011), phenotypic (Miller et al. 2010, 2011), and functional (Moore et al. 2010) diversity support such an approach. The ISAB also concludes that it is essential to make a concerted effort to develop a balanced vision and goals that consider abundance, diversity, and the processes that maintain resilience of salmon (and other) populations for the long term.

3. Organize to work across boundaries for coordinated action.

Implementing a comprehensive landscape approach requires that conservation and restoration work across a large number and diversity of social and economic boundaries (Table V.1). For example, the Council's responsibility for the U.S. portion of the Columbia River Basin encompasses boundaries of two countries, seven states, 15 tribes, 11 ecological provinces, 62 Council-designated subbasins, more than 100 counties, many more towns and cities, and other entities representing patterns of ownership, management, or regulatory jurisdiction (e.g., Forest Service Regions, Forests, Districts), as well as a great variety of habitats and ecosystems. The responsibilities for management of natural resources (including forests, water, fish, and wildlife), conservation of threatened and endangered species, and regulation of land use (including setbacks, zoning, and development) are scattered across many agencies and jurisdictions that have different missions, goals, authorities, scientific capacities, and conceptual foundations (Samson and Knopf 2001, Rieman et al. 2003, Reeves and Duncan 2009).

There has been progress in the representation, collaborative planning, and engagement of broad authority in the Columbia Basin. The tribal sovereigns have been well integrated into the visioning and organizing processes and provide a model for engagement. But implementation of a landscape perspective also requires integration with cities and counties, which appear less well represented in these processes. City, county, and tribal political units have major responsibility for mid-level land-use decisions, (Table V.1; Smith 2002) jurisdiction over land-use planning, road design and maintenance, and development or protection of sites such as riparian zones that are critical to salmon and other fish and wildlife habitats. The public often has greater trust in local than in higher levels of government (Steel et al. 2003), and extension and other county-level outreach programs exist in most Columbia Basin counties. Involvement of private property owners in the planning process that counties generally lead can be important as well. Private lands, overseen by cities and counties, are critical to landscape diversity and connectivity characteristics (e.g., OPSW 1998, Dale et al. 2000, and see section III), but often these are not engaged in large-scale planning. Rural counties may have limited funds for land-use planning and use of development codes, and not all states require county land-use planning. Engaging cities and counties that make decisions to help conserve habitats and foster development that is compatible with comprehensive landscape ecology, and with both socioeconomic and environmental-ecological goals, could save the much more expensive costs of restoration

Even where private lands are not predominant, planning for conservation and restoration that works across ecological, jurisdictional, or value-dependent boundaries remains a challenge. At best, poorly coordinated restoration is piecemeal and opportunistic, inefficient, and often too limited to be effective. At worst it can be ecologically costly, creating situations where conflicting actions negate the intended benefits of projects. By working across traditional boundaries, managers might create important synergies, leverage limited resources, or at least avoid unnecessary conflict (Rieman et al. 2010).

Table V.1. Human, ecological, and political scales for a landscape perspective (after Holling 1986). Categories are general patterns, designed to illustrate parallels. Numbers in parentheses are Council identified divisions.

Human	Ecological (salmon)	Political
individual	stream, stream reach	individual rights and private property rights
family, household	stream, stream reach	tax lot, residence
band, association, neighborhood	sub-watershed, stream-river, deme, local population	unincorporated community, interest group, water district
tribe, community, corporation	watershed, small river basin, population	city, county, tribal government; watershed organization, soil and water conservation district
state, province	subbasin, river basin, major population group, distinct population segments, evolutionarily significant units	multi-county, state, province governance, tribal associations (4/1)
region	ecoregion, major river basin, lineages, races, types, sub-species , species	multi-state
nation, regional council	bioregion, species, genera	nation state, national interest group
regional conventions and treaty organizations	continent, species groups, genera, families	multi-national organizations and treaties

While states, cities, counties, and other entities are important partners for planning, watershed and regional organizations are needed to produce action at the appropriate scales. Watershed councils, salmon recovery boards, soil and water conservation districts, and some non-governmental organizations may have the ability to engage the broad range of actors needed to implement large-scale projects. Large landscape conservation is gaining interest among some public and private organizations like these, but the policy tools, funding strategies, and capacity for any group to effectively organize and implement large-scale actions, foster innovative experiments, and coordinate independent efforts remains limited (McKinney et al. 2010). The watershed and associated organizations promoted by the states are the primary units for action. The Council needs to be careful in overlaying subbasin organizations (Figure V.3).

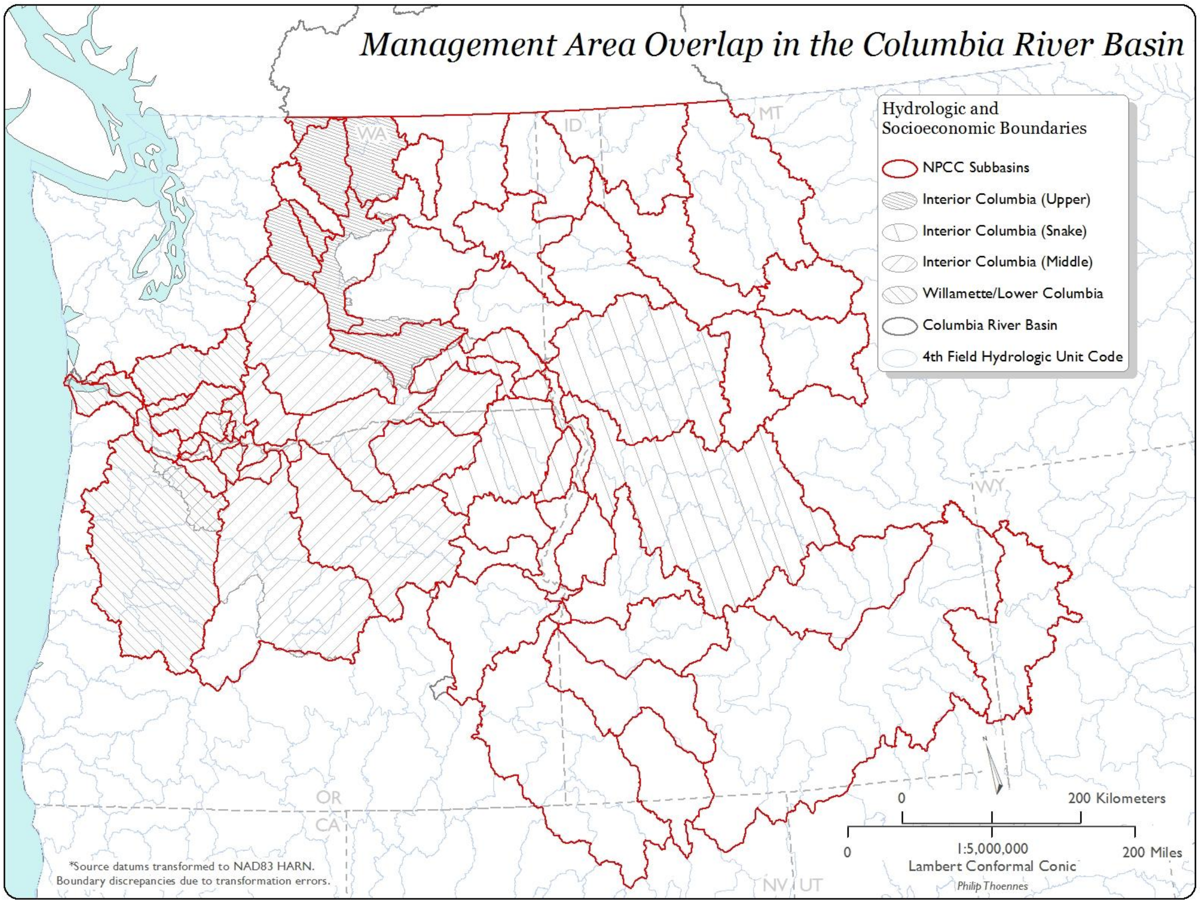

Figure V.3. Management Area Overlap in the Columbia River Basin. The implications of the map are that the Council's subbasins are intermediate layers of planning. The Council's subbasin planning units (dark red lines) are at a level that is bigger than the typical watershed (light blue watershed lines) 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.

Collaborative efforts that engage multiple agencies, ownerships, and responsibilities are growing. Non-governmental organizations such as the Blackfoot Challenge (McKinney et al. 2010), the Skagit Watershed Council (Sidebar IV.4), and some small watershed groups provide examples of progress that does not depend on a traditional agency or interagency process to bridge boundaries. The Forest Service Collaborative Forest Landscape Restoration Initiative is a current experiment where an agency has tried to create incentives for new collaborative approaches. Funding to Forest Service units depends on their capacity to engage and support broader collaboration with partners that are needed to implement large-scale restoration. Salmon recovery efforts supported by states and recovery planning efforts coordinated by NOAA are other examples that have bridged agency responsibilities and engaged a diversity of

partners. It is important to continue and strengthen such efforts.
Although many would like to see more integrated and centralized authority to act, the political culture in the United States favors fragmented authority (Bessey 1943, Hutchcroft 2001) over management of large areas, conservatism in experimenting with social policy, limitations on policy tools, and funding that often is inadequate for success (e.g., Reeve et al. 2006, McKinney et al. 2010). Management direction is mixed and sometimes contradictory, since it is constrained by different mandates and philosophies. For a landscape approach to be effective, integrated collaborations, partnerships, and effective governance are required. After reviewing seven large landscape conservation efforts, McKinney et al. (2010:18) concluded, “These and other examples suggest that the currency of large landscape conservation is regional collaboration.” Certainly regional collaboration is needed, but collaboration, partnerships, and governance must build from the individual up through regional organizations to incorporate the landscape.

Governance and partnerships need the collaborative support of managers, scientists, and the public. Since no single governmental, nongovernmental, corporate, or private organization controls decision-making at the landscape level, the importance of partnerships and collaborations cannot be overstated. Early public engagement would begin a process of public education and involvement. Earlier and better integration of the socioeconomic and natural sciences would add to the effectiveness.

Successful collaboration also can lower costs. Costs can be reduced by winning public support for proposed actions and lessening litigation and other actions that can impede progress. The conservation and restoration process works best with early development of interdisciplinary teams and coalitions of land users. It takes considerable time for newly formed groups to develop understanding of one another and to get to the point of action (Kenney 1999, Leach and Pelkey 2001, Smith and Gilden 2002, Flitcroft et al. 2009), but getting to actions and projects still is usually faster and more cost effective than with the common processes of stonewalling and litigation.

4. Link science and management more effectively.

Landscape science has advanced dramatically in the last two decades, with a growing body of theory, remarkable sampling and technological advances, and new analytical methods to visualize and evaluate management alternatives. Clearly, all the science questions are not resolved (e.g., Steel et al. 2010), but the science and technology that exists today dramatically enhances our capacity to understand and implement restoration with a comprehensive landscape perspective.

Nevertheless, the link between science and management can still be problematic for several reasons. One is that scientists often fail to directly engage with management (e.g., Rogers 2006, Arlettazz et al. 2010). Scientists typically are rewarded for publishing papers and creating knowledge and tools. Working with managers to design and implement restoration based on that knowledge in the complicated and uncontrolled real world can be messy, and funding is rarely easy to find. A second reason is that managers may lack interest, or they may not have time, finances, or analytical capacity to use existing science. In many cases, management cannot afford to employ tools or information that exists or could be generated. Funding mechanisms that favor on-the-ground actions over assessment and planning complicate this issue (McKinney et al. 2010). A third is that managers are often faced with conflicting values and objectives or with political interference that can obscure or muddle the science; for any landscape, many agencies and missions, or resource values and science disciplines, are likely to be involved (e.g., Samson and Knopf 2001, Lichatowich and Williams 2009, Rieman et al. 2010). A fourth is that working across management jurisdictions to address large landscapes brings together agencies and actors with different quantities or qualities of information, different science capacities, and perhaps also conflicting natural resource values and conceptual models (Lichatowich and Williams 2009, Rieman et al. 2010).

Although many factors can weaken links between science and management, integration and collaboration of scientists and managers provides the opportunity to bring the best possible science to large-scale restoration. Scientists, managers, and the public benefit from a richer conversation and interchange of knowledge. There are good examples of progress where some of the traditional barriers are being crossed. For instance, attempts to operationalize the science behind salmon recovery are using formal modeling (e.g., Steel et al. 2010, McElhany et al. 2010, Sidebar IV.5) to articulate the conceptual models and help guide discussion and prioritization across jurisdictions and disciplines. Even when quantitative information is limited, simpler models may be used to explore and communicate current understanding of important processes, dynamics or constraints (e.g., Gross 2010). There now are many analytical tools, but the capacity to implement a useful, clarifying analysis requires interdisciplinary technical and financial support that can be limiting. Some scientists, tribes, and non-governmental organizations are now bringing more of these tools to real world settings. The Columbia River tribes are revising their plan, Wy-Kan-Ush-Mi Wa-Kish-Wit, and communicating its tribal science vision at scientific conferences. The Lewis River[13] is another example of effective use of modeling to communicate science issues more broadly. NGOs like Trout Unlimited also are applying large-scale analytical methods (e.g., ISG 2000, Dauwalter et al. 2011). A formal "restoration extension service" could be useful in bridging the "science-practice gap" (Cabin et al. 2010) where funding or capacity is limited. Arlettaz et al. (2010) suggest that a reluctance of researchers to participate in direct application

[13] www.nwfsc.noaa.gov/research/divisions/fed/wpg/lewis_river.cfm

of their work is an important constraint, but they provide an example where scientists have engaged with the public, local governments, and managers to recover a functional landscape for a threatened species. Rogers (2006) emphasizes the building of "learning communities" as key to any progress with truly adaptive management. It is essential to create incentives to continue efforts like these.

More effective cross-disciplinary work can be facilitated through the collaboration among agencies and responsibilities outlined above. Intentional support for interdisciplinary research such as the Long Term Ecological Research program (Johnson et al. 2010) is promising. It could be helpful to fund interdisciplinary assessments that explore tradeoffs in conflicting objectives and opportunities for simultaneous solutions (Noss et al. 2006, Rieman et al. 2010). However, any progress will require a long-term commitment. (Reeve et al. 2006, Reeve 2007). The Interior Columbia River Basin Ecosystem Management Project (Quigley and Bigler Cole 1997) struggled with substantial costs and other challenges of large scale interdisciplinary science and management more than 15 years ago. Only now are serious attempts emerging to bridge the long-term conflicts of terrestrial and aquatic management on National Forests based on that work (e.g., Bisson et al. 2003, Rieman et al. 2010, USDA 2010).

McKinney et al. (2010) suggest that the investment in science and technical support that is needed to realize such interdisciplinary collaboration should be thought of as investment in future resilience and be evaluated in terms of the ecological services that are provided to society in general. Encouragement and refinement of funding strategies that facilitate innovative and collaborative planning, effective prioritization, and long-term learning based on the best current science require incentives that directly engage science and management in long term partnerships.

The Path Forward

Each of the challenges above can be resolved through strong leadership and collaboration, sharing experience, science based experimentation, innovation, application of the available information and tools, and effective and active learning. A growing body of science deals with the interfaces of socioeconomics and ecology and with the principles that lead to progress in conservation and restoration (NRC 1996, USDA 1996, Stouder et al. 1997, Williams et al. 1997, Dale et al. 2000, McElhany et al. 2000, ISAB 2003-2, CRITFC 2011, ISG 2000, ISAB 2008-4, McKinney et al. 2010, Steel et al. 2010, Susskind et al. 2010). Helpful designs are available for integrated collaborations and governance (McKinney et al. 2010, Reid et al. 2010, Susskind et al. 2010). This knowledge is the basis for strategies, plans, and actions. In addition, scientific knowledge has to be integrated with technical and local knowledge. The understanding, engagement, and trust of people who are interested in conservation and restoration must be improved. Thus, the general recommendation of this report is for a broader foundation that includes (1) socioeconomic engagement, (2) a landscape perspective, (3) integrative collaboration and governance; (4) and promotion of adaptive capacity, both ecological and social. Building adaptive capacity to address conservation and restoration needs while remaining flexible to future changes is an overarching need; the next section of this report addresses that topic.

VI. Adaptive Capacity and Adaptive Management

"However beautiful the strategy, you should occasionally look at the results." - Winston Churchill

Recently the Salmon 2100 Project engaged respected scientists and policy makers "… to assess the policy options for protection and restoration of wild salmon runs …" (Lackey et al. 2006:345). When asked about the role of science, Lackey (2008) said, "There is no scientifically correct approach to restoring runs of wild salmon, but rather a suite of alternatives with 'best' largely being a function of which vision of salmon restoration one accepts. The choice of the preferred policy option is a public choice in which the contribution of science is to evaluate the consequences of each policy option." This is equivalent to the adaptive management process, with science as a compass and the public as gyroscope (Lee 1993). People are parts of, and stakeholders in, ecosystems. They require the capacity to adapt to ever-changing situations, and people must work together at all levels of organization to define and choose among options for conservation and restoration of fish and wildlife.

Adaptive capacity results in the ability to respond to future change.

Adaptive management is the process of monitoring, modeling, and assessment that supports learning and insight for change.

Adaptive management is a way to build **adaptive capacity**. Adaptive capacity can be developed by advances in understanding and application of landscape ecology, socioeconomic engagement, integrated collaboration, and governance to help people and organizations work together, and by adaptive management where learned results are used to adaptively adjust actions.

The Council's Fish and Wildlife Program recognizes adaptive management as a basic element of the framework for implementing the Vision, Biological Objectives, Strategies, and Plans through Council-sponsored and collaborative projects (NPCC 2009-09:3). Adaptive management is increasingly used in the Columbia River Basin, having been central to the NOAA recovery plans (NOAA 2007), Northwest Forest Plan (FEMAT 1993), the Oregon Plan for Salmon and Watersheds (Kitzhaber 1999), the Oregon Department of Forestry management of state forests (ODF 1995), and many other resource management processes. However, recent ISRP (ISRP 2007, 2008, 2010) reviews suggest that adaptive management implementation can be substantially improved.

Monitoring and evaluation are critical steps in the adaptive management cycle (Figure VI.1). Knowledge produced from monitoring and evaluation is used to adjust plans and practices. Typically, monitoring and evaluation are the province of scientists. It is appropriate that scientists take a lead role so that the indicators apply broadly; are accurate, reliable and precise; are based on adequate sampling and repeatable; and are kept in data bases available to current and future users. However, an additional critical component is citizen engagement, which has been part of the adaptive management cycle since its beginning (Holling 1978). Citizens should be invited to help design hypotheses and research studies, help design and implement monitoring protocols, become involved in monitoring tasks and interpretation of evaluation of monitoring results, and thereby become part of the team that applies results to assess and adjust actions. Experience shows that involvement of citizens helps create better monitoring protocols, educates people about the dynamics of natural-cultural systems, and changes land use behaviors (Wright 2000, Flitcroft et al. 2009). It is the view of the ISAB that the public should be better engaged so that their insights can be considered, they can be informed, and the results of experiments can be used both for learning and revision of plans and actions.

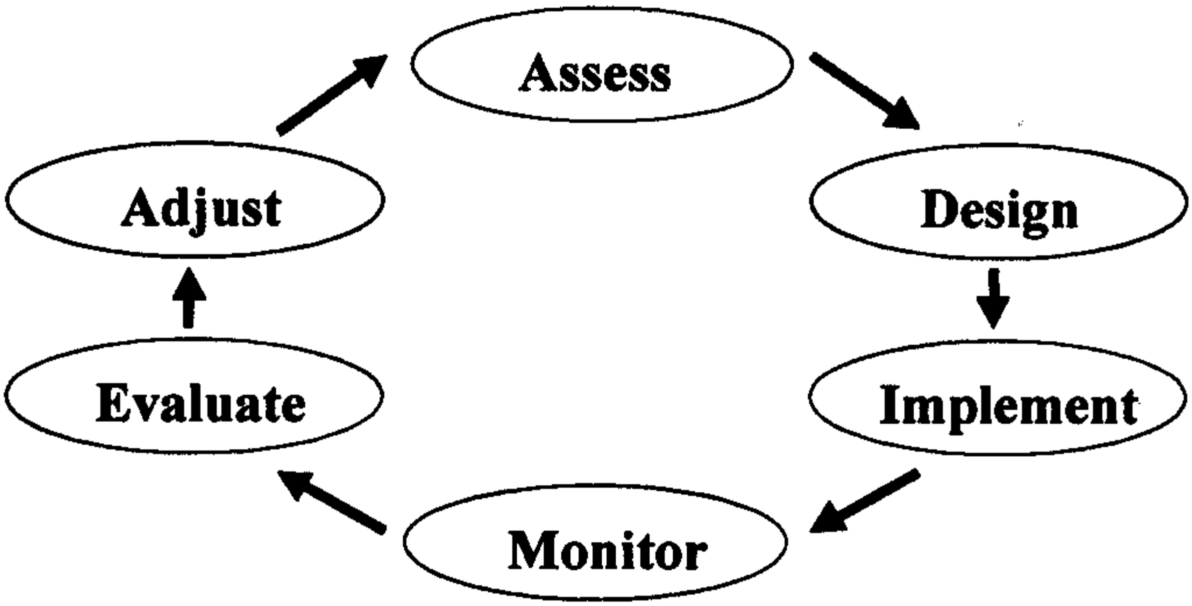

Figure VI.1. The adaptive management cycle (from NPCC 2006-4).

Lee's (1993) metaphor of compass and gyroscope, in which science, "linked to human purpose, is a compass, a way to gauge directions when sailing beyond the maps," and democracy, "a way to maintain our bearing through turbulent seas," is the gyroscope. Most adaptive management activities focus on the compass but largely ignore the gyroscope. Further, the results of large-scale adaptive management and its applications are not encouraging (Gunderson et al. 1995, Walters 1997, 2007, Smith et al. 1998, Stankey et al. 2005, Stringer et al. 2006, Duncan and Wintle 2008, Allen and Stankey 2009, Keith et al. 2011). Walters, both one of the major developers (Walters 1986) and one of the major critics (Walters 1997) of adaptive management, notes that Adaptive Environmental Assessment and Management (AEAM) has not used experiments to test the behavior of complex natural-cultural systems often enough.

Adaptive management experiments are difficult for several reasons. Often, people are unwilling to assume the risks that such experiments entail (though one can argue that the risks of lack of knowledge are greater). Additionally, ecosystems and socioeconomic systems are dynamic and influenced by many factors that are difficult to assess, even with the strongest and most creative experimental designs. It may be difficult to design adaptive management experiments that have the important elements of experimental design, such as treatment and control protocols, probabilistic selection of location and assignment of treatments, and replication. Nevertheless, experimentation to learn more about the operation and uncertainties of ecosystems, or other complex systems, is the essential feature associated with adaptive management. "Adaptive management is an inductive approach, relying on comparative studies that blend ecological theories with observation and with the design of planned interventions in nature and with the understanding of human response processes" (Gunderson et al. 1995:491). Adaptive management is flexible, encourages public input, leads to better understanding of uncertainties, requires monitoring the results of actions, promotes learning, and includes adjusting strategies and plans to create and test new actions. It is important that adaptive management experiments be allowed to be creative in order to promote learning about landscapes and their social-ecological dynamics.

Many of the Fish and Wildlife Program projects that address passage, bypass, habitat, supplementation, and hatcheries have adaptive management components. However, these involve specific actions at specific sites, not examples of a landscape approach.

The ISRP reviews adaptive management protocols as required by principles of sound science and evaluates the use of adaptive management in projects to learn about patterns and processes pertinent to the Basin. However, if adaptive management is to be helpful for planning and management, it also has to engage the public gyroscope in assessment of actions, revisions to plans, and making policy. Processes for this should be more clearly specified in the Fish and Wildlife Program.

Additionally, the Fish and Wildlife Program (NPCC 2009-09:40) states the goal, "The procedures for implementing this program should ensure that planning results in on-the-ground actions and that those actions feed information about their results back to the region to guide future decisions." More emphasis should be given to identifying how knowledge about the effectiveness of an action will be evaluated, disseminated, and, most importantly, *used*.

As restoration of the Columbia Basin moves forward, it is increasingly important that the Council have legitimate measures of landscape status and trends, and that these measures are quantitatively linked to ecological and socioeconomic conditions. These need not be overly complex measures, but they need to be revealing of integrity or progress, intuitively understood by a diverse audience, and cost effective.

Ideally, all restoration projects should be monitored at large spatial scales, for long time periods, and with high levels of detail (NRC 1992), but that approach becomes cost-prohibitive and not possible when the area of interest is large and restoration actions are extensive. Decisions about how intensively to monitor must be balanced and made to agree with funding constraints and agency mandates (e.g., McDonald et al. 2007).

Where to Measure?

Considerations of spatial scale arise again and again in establishing an effective monitoring program. Local habitat and biological diversity are strongly influenced by landform and surrounding land use, and these influences arise at many different landscape scales, as detailed in Section III. Landform operates at the larger scale of watersheds and regions, through its influence over geology, climate, vegetation, and topography, whereas the influence of land use operates across all scales, depending on the response variable. It is often not possible to identify pathways of influence from observed associations between land use and biological response. Reasons for this include confounding variables, such as the existence of many simultaneous mechanisms of influence, covariation of land-use and natural biophysical gradients in the landscape, and the presence of both legacy effects from past land-use or disturbance and present-day influences. For instance, mechanisms by which land use influences stream ecosystems include sedimentation, nutrient enrichment, contaminant pollution, hydrologic alteration, riparian clearing/canopy opening, and loss of large woody debris – not only today but also in the past (Allan 2004). These influences often act in concert, underlining the need to quantify responses to land use under contrasting management strategies.

McDonald et al. (2007), drawing on previous ISRP/ISAB monitoring and evaluation reports, have made several useful suggestions. They include a focus on Intensively Monitored Watersheds to test mechanisms; use of inexpensive techniques that are low-resolution but spatially expansive to monitor status and trends; and application of probabilistic samples designs with as few constraints as possible to make data more likely to be useful over the long-term. It is the opinion of the ISAB that these suggestions should be implemented.

What to Measure?

A key challenge is selection of what to measure from among the many aggregate measures in current use; response variables must have diagnostic value. The Fish and Wildlife Program has made a good start in this direction with the selection of High Level Indicators (HLIs; NPCC 2010-17), but to date these are focused on fish, with little consideration of the landscape or its inherent diversity. Further, it is well established that measurement of stream health and its responses to environmental stressors, including land use, requires well-tested indicators of ecological integrity; this also should be added to HLIs. While composite measures such as the Index of Biological Integrity (IBI), percent assemblage similarity, and the AREMP protocols being implemented in Region 6 of the Forest Service (Reeves et al. 2003) are useful in detecting overall stream degradation, their aggregated nature can make them less easily interpreted than individual response variables. Monitoring metrics must diagnose cause as well as assess harm, and this requires improved understanding of mechanisms by which land use affects stream or landscape condition. Integrative measures of condition are useful for assessing overall ecosystem health because they integrate many influences. However, species traits, feeding and reproductive guilds, taxa of known tolerance to particular stressors, and other less aggregated measure are likely to prove more useful in evaluating mechanisms (Allen 2004, ISAB 2011-1).

Effective measures of diversity and resilience are needed and should be monitored along with the more traditional measures of abundance and in-river survival needs. Progress in measurement and evaluation of large-scale patterns in genetic (e.g., Matala et al. 2011, Hess and Narum 2011), phenotypic (Miller et al. 2010, 2011), and functional (Moore et al. 2010) diversity would support rapid development of new approaches and decrease costs by reducing use of less effective approaches.

Landscape restoration requires integrated monitoring of physical, biological, and socioeconomic processes, including measures that reflect cultural diversity and well-being. Inclusion of attention to people, cultures, and economies with the more conventionally considered elements of landscape and biota is essential for success (Naiman 1992, Rogers 2006, Susskind et al. 2010).

While it is difficult to establish causal linkages at the landscape scale, a number of statistical techniques are useful for inferring cause and effect. These include randomization-based tests of null hypotheses, probability modeling, repeated sampling randomization-based inference and repeated sampling model-based inference (Rubin 1991) and Bayesian techniques in which the collection of fresh evidence repeatedly modifies initial confidence in the truth of a hypothesis. Bayesian techniques have been used in stock assessments (Hilborn et al. 1994[14]) and have been suggested for more landscape-oriented processes (Ellison 1996). Additionally, several practical actions can be taken to improve the likelihood of identifying causes. Gadbury and Schreuder (2003) recommend evaluating explicit cause-effect

[14] see also www.ices.dk/InSideOut/August10/Insideout2010-No.3article%204.pdf

hypotheses. For example, one might examine the effect of a landscape-level manipulation on habitat abundance and the effect of that habitat abundance on salmon density. Since data quantity and quality limit ability to detect effects, it is best to involve statisticians early, collect high quality data, attempt to evaluate all reasonable explanations for the data, and submit the findings to critical review. It is generally not possible to infer cause and effect relations based solely on observational studies; experiments, statistical analyses, and modeling typically are required to corroborate observations and implicate causal mechanisms.

Composite measures of social conditions and well-being also must be used. Effective landscape perspectives embrace social conditions as fundamental components of long-term success. Integrated measures, including economic vitality and human health, are gauges of program effectiveness. These may include per capita economic measures, health indicators, means and distribution of wellbeing and quality-of-life statistics, and demographic variables. Much of this information is publicly available but needs to be assembled and analyzed. Since census data are available by block, which is smallest geographic unit for which the Census Bureau collects and tabulates 100-percent decennial census data, socioeconomic data can be aggregated into landscapes using GIS. In effect, these measures take the human population's pulse. These tend to index the ability and willingness of the population to be supportive of, and even advocates for, conservation and restoration.

Often it is not financially feasible to mount large or comprehensive monitoring programs. However, this is not an impediment to implementing an effective program. One can use citizen monitoring (see below), "thresholds of probable concern" or a focus on "sentinel" sites or processes that are anticipated to be particularly sensitive to environmental changes (Isaak et al. 2009, 2010, Venter et al. 2008). These approaches may be especially applicable to the Columbia Basin in that they set realistic limits on characteristics and sites that can be collectively monitored on a regular basis (Biggs and Rogers 2003, Rogers 2006, Isaak et al. 2009). If specific limits are exceeded, researchers, stakeholders, and decision makers convene to discover the causes and propose remedies. This approach has been shown to be quite effective in situations where the involved parties are committed to the long-term vitality of resources.

How to Measure: Citizen Science

Citizen participation in the identification of research topics, study design, data gathering and analysis, and evaluation of results is what social science calls "collaborative research." Collaborative research is used to increase people's understanding of the problems they face, for improving teaching and learning, and for active river restoration (Brierley and Fryirs 2008). One example from British Columbia is a collaborative research program with local citizens "…to share a wealth of natural resource information and maps with communities" (CMN 2011). CMN develops capacity within communities to collect and store resource information about watershed management, stream ecology, fish and wildlife habitat, and restoration opportunities while promoting active stewardship. With local collaboration from field naturalist clubs, DFO Stewardship Groups, and First Nations, eelgrass beds in 11 areas of British Columbia have been mapped (CMN nd) to document not only the location of eelgrass, but also research sites, conservation efforts, and the ecological values of the eelgrass ecosystem (Dunster 2003). Another example from Oregon is the watershed councils that routinely engage citizens in water quality monitoring. In Montana, the Flathead Basin Commission[15] and the Clearwater Resource

[15] http://flatheadbasincommission.org/programs/monitoring/

Council[16] engage volunteers to monitor the trophic status of dozens of lakes. A recent statistical approach to national ecosystem assessment demonstrates the effective integration of scientific and local knowledge by involving citizens in science (Herrick et al. 2010). Quantitative and qualitative observations serve as baseline data for monitoring policy and management initiatives.

Citizen science has several important benefits. First, citizen labor provides more data from more locations at more times. Citizen engagement also can expand ability to monitor on private property by enabling cooperation from private landowners. Citizen data could 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 the ecological processes from the observations. Most importantly, citizens become engaged in learning about a project and its outcomes. In effect, they have more knowledge to participate in decision making and ask valuable questions (Buck et al. 2001, Curtis et al. 2002).

Language can be an initial barrier to engaging citizens in science. Scientists and citizens use different terms, and it takes time to develop mutual understanding. Quality control also can be more difficult with citizen data collection. Successful citizen science requires investments in training volunteers, gaining the willingness of scientists, and addressing liability and safety issues and data management (Litle 2009). Examples of successful citizen science include the Puget Sound Partnership, which has built and continues to improve citizen science programs (PSP 2010). Likewise, the nongovernmental Columbia Riverkeeper organization, which focuses on the entire Columbia Basin, uses community-based grassroots for organizing, public education, legal enforcement, and hands-on citizen involvement, while conducting independent science and enforcing water quality, toxics, and habitat regulations (CRK 2011). The Willamette Riverkeeper is a similar organization intent on improving conditions in the Willamette River (WRK 2011). Activities such as the Columbia Habitat Monitoring Program (CHaMP[17]), Aquatic Riparian Effectiveness Monitoring Plan for the Northwest Forest Plan (AREMP; Reeves et al. 2003), and Integrated Status and Effectiveness Monitoring Program (ISEMP) contribute to protocols that can be applied basinwide using citizens as monitors.

Monitoring Approaches and Philosophies

Monitoring contributes to assessing the status and trends of the ecological and socioeconomic components of ecosystems, the impacts of land use and other activities of people, the refinement of understanding of critical processes, and the evaluation of restoration (Downes et al. 2002, RIST 2009a). The reasons for monitoring dictate the choice of approach and philosophy. Basic principles of experimental design, including probabilistic sampling, replication, and use of controls or reference sites, should be applied to landscape-level monitoring whenever possible. Randomized-treatment experiments with true replication and effective blocking of experimental units may not be possible at very large spatial scales, but approaches with some similarity to a perfect, but unattainable, design may be used. The maxim "Perfect is the enemy of good" applies.

[16] www.crcmt.org/projects/aquatics/watermonitoring.html

[17] www.nwcouncil.org/fw/budget/2010/rmeap/2011_02champ

The better approaches for monitoring clearly connect scale to the dominant processes influencing the ecological and socioeconomic components for which one wishes to draw inference. For example, a traditional approach in fish ecology is to monitor the abundance of individuals and track the growth rates or population dynamics of local populations at a few sites on a yearly basis. Important inferences might be drawn about how growth and survival relate to the quality of local habitats directly influenced by restoration. Extending this intensive measurement approach to an entire river basin is not feasible. An alternative is to focus on patterns of occurrence and the processes of extinction and colonization for local populations in stream segments, as these require less effort to measure and can be monitored effectively with fewer visits at longer time intervals. The latter approach recognizes that extinction and colonization reflect the size, geometry, and quality of habitats (e.g., Isaak et al. 2007) and is being applied in large-scale monitoring of bull trout recovery (USFWS 2008, Isaak et al. 2009).

A full review of monitoring approaches and philosophies is beyond the scope of this report. However, the ISAB and ISRP have reviewed various monitoring approaches in the past (e.g., ISRP 2007, 2008, 2010, and various Three-Step reviews) and we refer to these documents for general guidance. McDonald et al. (2007) suggested steps for accomplishing large-scale monitoring and evaluation, and the ISAB recommends that they be used:

- Begin by creating a list of attributes for large-scale habitat trends that are suitable for remote sensing.
- Prior to any on-the-ground population or habitat monitoring, develop common site selection procedures and common data collection methods.
- Reach a consensus on a study design that incorporates as much of the principles of **replication**, **randomization**, and **validation** as feasible.
- Use existing data to build predictive models to investigate likely outcomes of alternative management strategies.
- Use intensively monitored watershed projects when causal mechanisms require elucidation.

These steps are consistent with the call by Allan (2004) to examine land-use responses to various management strategies and to use better response variables with greater diagnostic value. The identification of high level indicators (HLI) by the Northwest Power and Conservation Council (NPCC 2010-17) is an advance. The Council's HLIs are designed to communicate the Fish and Wildlife Program's progress to the region's Governors and to Congress, but are, at this time, focused mostly on salmonids and not the larger integrated natural-cultural system.

Steps outlined by McDonald et al. (2007) allow for monitoring and assessment based on both large-scale and small-scale sampling efforts. In addition to direct monitoring and evaluation at large spatial scales, it sometimes is possible to aggregate or "roll-up" samples taken at small spatial scales. Multi-scale designs also can be used and may be particularly helpful when sampling spatially heterogeneous areas (Urban 2002). As an example, monitoring and assessment of nonpoint-source pollution in large river basins has been done using a two-stage approach, first using coarse resolution data to identify watersheds that are the most significant contributors of pollution, followed by higher resolution distributed modeling from smaller watersheds that reflect specific management actions. Understanding how data resolution and geographic extent influence landscape characterization and how terrestrial processes affect water quality are important for model development and translating research results from experimental watersheds to management of large drainage basins (Hunsaker and Levine 1995). It is the view of the ISAB that there remains a basic need for cost-effective background monitoring (as noted by

McDonald et al. 2007), the lack of which currently limits our ability to foresee problems and adapt to them.

Models and Methods for Monitoring

While there are many philosophies and approaches to landscape-scale monitoring, there are many more methods and models. A detailed review of this field is outside the scope of this report. The approaches range from statistical design and analysis strategies, to modeling, portfolio analyses, and the uses of remote sensing and broad-scale indicators. Tools for understanding natural resources at large spatial scales are improving rapidly and becoming more readily available. These tools, combined with thoughtful evaluation techniques and the proactive engagement of citizens, can greatly improve understanding and management in the Basin over the next decade as long as investments are made in both.

Evaluation

Despite many attempts to restore habitats throughout North America, there is only ambiguous evidence that restoration efforts have increased fish abundance and biomass (House and Boehne 1985, Frissell and Nawa 1992, Hilborn and Winton 1993, Reeves et al. 1997, Williams et al. 1997, Ward 2000, Thompson 2006, Stewart et al. 2009, Whiteway et al. 2010, ISAB 2011). Identifying cause and effect relationships between specific restoration actions, habitat improvements, and fish population or aquatic community responses is a difficult challenge (Hunsaker and Levine, 1995). In the Columbia Basin, relationships between management practices designed to improve physical stream conditions and biotic change need to be evaluated.

The ISAB acknowledges that studies evaluating the causes of changes that result from many actions, and at many spatial scales, are uncommon. While such studies are technically difficult, they are necessary. Allen (2004) evaluated various methods to evaluate cumulative and collective effects and one promising approach involves combining qualitative observations and quantitative data. The approach features a statistically based application that integrates *scientific* and *local* knowledge (Herrick et al. 2010). A related strategy, collaborative adaptive management, combines adaptive management and collaborative planning to simultaneously support management, engage the public, and improve understanding of tradeoffs among ecological, economic, and social welfare objectives (Buck et al. 2001, Susskind et al. 2010).

A positive step has been the Council's initiation of the Monitoring, Evaluation, Research, and Reporting plan (MERR), which contains an Evaluation and Reporting Approach to provide information on progress toward basin-wide biological objectives (NPCC 2010-17). The approach includes ISRP evaluations of the overall Fish and Wildlife Program, as well as reviews of individual projects funded through the Program. Other components of the Evaluation and Reporting Approach designed to enhance evaluation of progress toward basin-wide needs are the Science Policy Exchange, the Proponent Exchange, High Level Indicators, Fish and Wildlife Indicators and Program Synopsis.

A variety of ongoing Columbia Basin projects are developing methods for evaluation. For example, the Integrated Status and Effectiveness Monitoring Program (ISEMP), a project funded through the Fish and Wildlife Program, has an objective to develop tools to evaluate monitoring programs and approaches (ISEMP 2010). Another project funded through the Council Program explores methods for evaluating past habitat restoration actions and their effect on fish populations to provide a foundation for multi-watershed designs for habitat restoration (Marmorek et al. 2004). In the future it may be useful to apply Bayesian networks for cost-benefit evaluation of flow and catchment restoration actions (Stewart-Koster et al. 2010,) but this approach may need more development before application to the Basin.

Several other general approaches may be of value at the landscape scale. For large-scale regional assessment, periodic status of temporal trends may be sufficient. The trade-off is that trends can be inferred only at a coarse-scale from periodic data collection or analysis, giving little ability to detect small changes. Rotating panel designs may offer an efficient approach to detect trends of large areas (Urban, 2002) but suffer from substantial constraints in the sampling design.

Another approach to evaluation is to sample a large number of sites using a relatively quick and low-resolution set of metrics – following the recommendation of McDonald et al. (2007). For instance, multi-species monitoring relies on surveys of presence/absence for a large number and breadth of species at a large number of sites (e.g., Manley et al. 2004). A coordinated multi-species monitoring effort, collecting presence-absence data on a broad range of species, may be a good alternative to intensive monitoring of a few species.

Monitoring frameworks based on levels-of-evidence for assessment of the cumulative landscape effects of individual restoration actions at different locations have considerable potential to improve understanding (Diefenderfer et al. 2011). This framework involves synthesis and evaluation to facilitate assessment of cumulative landscape effects of individual restoration actions. The levels-of-evidence approach features construction of an inferential case for the occurrence of cause-and-effect in a complex ecosystem. It is a semi-quantitative approach designed to provide evidence for a cumulative ecosystem response to multiple restoration projects. It includes sampling at project and reference sites to develop predictive ecological relationships, detection of synergies at larger scales through statistical tests, and hydrodynamic modeling of paired, clustered, and sequenced sites.

Overall, despite recent advancement, the science of ecological evaluation at large scales is at an early stage of development. There is much to learn from the social (Bernard 2000), political (Johnson 2005), and medical sciences (Miller and Salkind 2002), all of which have considerable experience in large-scale sampling and evaluation.

Designing Best Practices

Best practices are intimately linked to the adaptive management process. However, when the adaptive management process is truncated (e.g., no experimentation or citizen involvement), what people think is best practice often is not. Even if there is general assurance that a treatment is the best one, it should be tested and monitored to be sure. That said, building on what is learned from existing experience and adaptive management, program leaders should develop a preliminary list of best practices to support implementation of a comprehensive landscape approach. A best practices approach can expand adoption of effective actions and broaden the impact of strategies to conserve and restore fish and wildlife. Not all innovation processes take hold, but when best practices are in place, the potential to make significant change is driven by personal incentives guided by best practices. Monitoring can determine effectiveness of best practices and identify modifications to make them more effective as greater experience is obtained.

Continuous oversight to align people's actions with goals is difficult, time-consuming, and expensive in a complex system like the Columbia Basin. One way to more efficiently get this alignment is through policy. Policies are the laws, administrative rules, and local codes that try to align people's actions with societal goals. Ideally, state and local policies should align with Council goals. Clear policies can be helped by each of the State Council Members being knowledgeable of how the policies at all levels of government in their state support or inhibit the Council's Fish and Wildlife Program. Council Members can then identify areas where local, county, regional, or state policies can be revised to better coordinate with the vision of the Fish and Wildlife Program.

A less prescriptive way to achieve alignment with Council goals is to develop best practice guidelines on how to perform actions that are useful. This means developing a set of best practices designed for specific groups of actors, such as resource managers, county and city planners, and various types of landowners and households. Council program leaders with assistance from ISRP, ISAB, IEAB, and topical specialists could begin with best practices for counties and cities. In designing best practices, seek those that restore critical processes, are intuitive, clear to implement, are flexible, improve landscape functioning, include monitoring, get people thinking more broadly, and accept that habitats, streams, and watersheds are dynamic.

When program leaders and advisory groups work on best practices, the following items are suggested for consideration. A **best practice** is a short, preferably no more than a one-page summary of the practice that includes the information necessary to get started. Best practice summaries could be handouts or web pages, and assembled in folios according to user group. Fortunately, best practices have already been established for a number of land uses. What is often missing is a landscape perspective that encourages thinking about how implementing a best practice locally affects other areas, groups, and individuals.

VII. Recommendations

Recommendations are organized in two sections: *general recommendations* that are relevant to any group working toward a more comprehensive restoration strategy and recommendations for *implementing a comprehensive landscape approach* through the actions of the Council and others influencing policy and direction for large scale conservation and restoration in the Columbia Basin. The recommendations draw together the four criteria (Section IV), with the implementation (Section V) and adaptive management (Section VI) discussions. These sections provide background on challenges that have to be solved for a landscape approach to be successful.

General Recommendations

A comprehensive landscape approach will support effective and efficient resource management and restoration, more so than the fragmented and opportunistic activities commonly practiced. Keys to a successful landscape approach are achieved through socioeconomic understanding and engagement, applying the concepts of landscape ecology, collaboration and shared governance, and the use of true adaptive management – the four central themes of this report form the basis of our main recommendation to use these criteria for evaluation as well as serving as general recommendations for implementation (Section IV):

- **Broaden Socioeconomic Engagement**
- **Build from Landscape Ecology**
- **Organize for Integration and Collaboration**
- **Foster Adaptation; *Use* Adaptive Management**

This guidance is not entirely new. The basic foundations of ecosystem management and the need to consider larger scale pattern and process in habitat conservation and restoration are considered in some of the principles and guidance from the ISAB, Council, NOAA Fisheries, Tribes, and other syntheses. But our understanding and implementation must be expanded, refined and continue to evolve. Much of the distillation to more effective practice occurs as scientists, managers, administrators, and the public review, compare, apply, and modify approaches, as new knowledge develops, and as experience is shared.

We encourage *rules of thumb* to expand understanding and adoption of the most current knowledge and guidance. The details of complex recommendations may not be useful to many practitioners, while rules of thumb may be incorporated more easily into the language, discussion, and practice of those directly conducting or influencing restoration actions. An example has been the focus in bull trout recovery on recreating "*Clean, Cold, Connected*, *and Complex*" habitats. The phrase distills a substantial body of science and management into an essential framework that is easily understood and remembered. We summarize key points behind each recommendation to encourage that process (Table VII.1). The idea is to capture understanding that will help build a common foundation and culture of comprehensive landscape restoration in the Columbia River Basin.

Implementing a Comprehensive Landscape Approach

Successful implementation of the general recommendations faces important challenges. We identified four that are key in Section V—building broader support, clarifying the vision, developing leadership in science and management, and working across boundaries.

The Council and region have worked to embrace the adaptive management process with some success; in Section VI, we identify additional changes to make the adaptive management process more effective. Meeting the challenges will require broader support and specific actions at many levels of engagement – from individual scientists, managers, and landowners to county and city governments to managers of large programs and large areas of the Columbia Basin. As these concepts are incorporated into project design, implementation, and review and as a landscape approach becomes more familiar, other actions not mentioned or recognized here will be necessary. Exploration and innovation, as well as the sharing and revision of new ideas, are some of the key ingredients for success. Much of this can be conveyed in development and continued revision of *best practices* for those responsible for guiding restoration (Section VI).

Effective recommendations identify the people who can act and provide insights on how to proceed. Actions rest on intentions and require actors, and actors often need suggestions on where to begin. The recommendations for implementation offered below include general guidance for actions and a foundation for development of best practices. Many levels of actors will be needed to be effective. Council Members are responsible for framing and communicating the Fish and Wildlife Program vision and the plans to implement that vision. Program leaders and managers direct actions to implement the Council's vision in the Fish and Wildlife Program. Scientific guidance and review are provided by the ISRP, ISAB, and IEAB and the normal peer review process in research. Ultimately, the Council, public and private land managers, scientists, landowners, cities and counties, businesses, corporations, recovery planners, leaders of watershed councils, and non-governmental organizations, as well as the general public, need to agree on a vision and the strategies for achieving the vision. The use of the phrase "land managers and program leaders" in our recommendations is a generic heading meant to encompass those in leadership positions of conservation and restoration planning and action. In the Council context, program leaders might be those with the title of manager, coordinator, director, or officer. The recommendations for implementation are:

1. ***Build Broader Public Support***
   Enlist the public and diverse social groups associated with the landscape to build socioeconomic understanding and support for comprehensive restoration.

A crucial, but commonly missing, element of a comprehensive landscape approach is early engagement of the people who live on, use, and care about the land. Typically, engagement comes too late, often in an attempt to implement an already-formed plan which often leads to less effective outcomes. Socioeconomic understanding and engagement is required before effective actions can even be recognized.

Improve involvement of county and city planners and governments. While local governments are part of some recovery efforts the effectiveness is variable, ranging from strong to nonexistent. County and city government through land-use planning, where it exists, and through developing and enforcing building and other codes, significantly impact landscape patterns and conditions. We recommend that fish and wildlife restoration planners, Council Members, and Program leaders seek substantial involvement from county and city government leaders and agencies. Collectively, they should collaboratively review the impact of county actions on conservation and restoration goals. Establish an ongoing liaison with county and city government leaders and agency heads.

Increase diversity of public engagement. A landscape approach brings more (and more diverse) sets of actors. It requires diverse socioeconomic engagement, thereby leading to the possibility of increasingly integrated actions. Key goals are to increase the diversity of participants and the level of trust for conservation and restoration programs. This may include efforts to increase the efficiency and effectiveness of the Fish and Wildlife Program by using resources to promote Council goals in collaborative efforts with organizations that are successfully mobilizing inclusive landscape perspectives.

Increase active and experiential learning. Through active experiential learning, people better understand and communicate practices that have proven successful for conservation and restoration. We recommend that Council and Program leaders facilitate and create expanded learning experiences – for both children and adults – and citizen science associated with research, conservation, restoration, and monitoring projects. Active experiential learning includes public participation in all phases of adaptive management, and it builds adaptive capacity. Programs such as "Salmon Watch" and "Kids in the Creek" should extend to landscape concepts and might be linked with other efforts (Forest Service "Kids in the Woods" and "Forest in Every School") in the Basin to infuse the Vision articulated in the Fish and Wildlife Plan and a broader landscape perspective.

Encourage the use of scenarios, modeling, and assessment to put restoration actions in context. The public needs to understand how programs influence future conditions and whether projects will achieve goals. Modeling, assessment, and scenarios can more effectively prioritize limited resources. While scientists develop scenarios, models, and assessment measures, public organizations (e.g., the Council Public Affairs Division) can communicate these to the public and land managers. The ISRP and Program leaders can use scenarios and modeling to help prioritize actions.

Align ecological and socioeconomic incentives. People respond to incentives. It is important to align the benefits of ecological actions with socioeconomic desires and wellbeing. In other words, we recommend the Council seek to affiliate the benefits of conservation and restoration with the desires of people living on the landscape. Think in terms of ecosystem services, direct benefits, community improvements, amenities, and local goals. This requires an ongoing understanding of how Basin residents view salmon recovery efforts, their perception of recovery success and understanding of restoration concepts, and their satisfaction with recovery goals and progress.

Embrace the concepts of a landscape approach in the Fish and Wildlife Program direction and project reviews. The vision and strategies of the current Program reflect many of the concepts outlined herein for a comprehensive landscape approach. Nevertheless, these need to be updated, refined, *and acted upon* to reflect growing knowledge and practice. Work with the ISAB and ISRP to refine and incorporate these concepts directly in Vision, Principles, Objectives, and Strategies of the next Fish and Wildlife Program revision. Work with the ISRP to refine these concepts to best practices in project guidance and proposal and project review (see 6 below).

2. *Rebalance the Vision for Restoration.* *Organize a strategic approach with a foundation in comprehensive landscape ecology that balances abundance, diversity and resilience – all within the carrying capacity of the ecosystem.*

Diversity and resilience in salmon populations conveyed by functioning landscapes and diverse habitats will be critical to maintaining productivity *and* abundance in a changing world. Although these concepts are embraced in the Vision and strategies of the current Fish and Wildlife Program, they are less commonly embraced as a critical element of successful restoration by many in the Basin, and this needs to be rectified.

Improve and expand the High Level Indicators (HLI). Develop HLI that include measures of diversity, resilience, and carrying capacity – as well as abundance and survival – in assessments of the program, perhaps working with the information generated through recovery status reviews but also with measures of the returns to the entire system and measures of productive capacity of specific habitats. This can be initiated with the ISAB and Council staff working collaboratively. New research and development may be required to create and refine appropriate, quantifiable measures, but emerging science and recovery efforts should provide a foundation.

Develop goals for diversity and resilience comparable with the goals for abundance. Embrace and practice a comprehensive landscape-scale ecological approach in the Fish and Wildlife Program as well as in the actions of the Council. Specifically, bring the concepts of diversity, spatial structure, productivity, and resilience to a level of visibility and understanding in the public and in the science and management communities that are comparable with the current focus on abundance.

Integrate hatchery production with habitat restoration. Artificial production is important in restoration as well as for public perceptions of well-being. Nevertheless, artificial production requires balancing abundance with the maintenance of diversity and, as well, taking care not to exceed the carry capacity of the ecosystem for wild fish. While the Fish and Wildlife Program recognizes these issues, the ISAB concludes that there has not been adequate attention to either the factors that are essential to the long-term resilience of the Basin's communities or to the landscape-scale effects of hatchery programs.

3. Establish Leadership in Linking Science and Management

Support and facilitate a strong engagement of landscape science in assessment, restoration planning and actions

This will require recognizing and embracing the diversity of scientific and organizational interests in the Basin, synthesizing and communicating scientific findings broadly (including the result of large-scale programs, and Council goals, plans, and actions), building outreach, collaboration, and partnerships, and supporting development for technical, analytical, and support teams. The experience of scientific support in recovery and restoration planning, and monitoring partnerships, are important examples to extend as possible.

Support communities of practice and peer learning networks. This will be essential, and effective, for diffusion of innovative applications and examples. Council support can come in many forms, but one of the most effective will be to provide incentives and forums for work across programs with common approaches and challenges. While intuition may suggest that a few well-chosen experts can design effective programs for landscape conservation and restoration, such programs cannot proceed without local knowledge and local support and must also be informed by a diversity of opinions and experiences from other settings. A landscape approach requires a broad range of experienced participants as well as common learning processes.

Explore options for restoration extension services. Similar to that practiced in agricultural communities, extension programs for restoration landscape science can bring state of the art tools and consistent application for planning, implementation, and assessment to efforts or communities that lack the technical or financial capacity. This may include continued support for regional collaboratives emphasizing development and/or implementation of landscape analytical tools, approaches, and examples. Working through an extension service supported by the Council and other groups with common large scale interests, land managers and Program leaders could create regional teams with broad expertise to support and guide local projects and tie these projects to a landscape approach. The interagency Joint Fires Sciences program provides an example that funds development of critically needed tools for managers dealing with common issues. Other examples include NOAA Fish Recovery efforts, numerous NGO activities, Sea Grant programs, and existing University extension services (e.g., Washington State University, University of California-Davis) and Soil and Water Conservation Districts. Extension services provide the synergies and simultaneous solutions that have a high probability of reaching those actually planning and implementing restoration.

4. Work Across Boundaries.

Support or extend existing and non-traditional efforts and develop more, cost effective partnerships.

Effective leadership and coordination across ownership, authority or responsibility, and resource values are essential. Accomplishing conservation and restoration goals, creating plans, and implementing actions requires combining the latest scientific and technical knowledge with the values, beliefs, goals, and intentions of Basin residents. This is a socioeconomic process that will require improving the breadth and effectiveness of existing organizations. Some existing approaches will need to be modified, while embracing the emergence of new organizations and institutions to build, support, and coordinate landscape-oriented intentions and acts.

Explore strategies for subbasin-scale planning – is a prescriptive approach necessary? While continuing to support mid-scale (e.g., subbasin) planning and assessment there is a need to revisit the necessity for prescriptive direction. More effective partnerships may emerge by supporting, funding, or highlighting local and regional collaborative and non-traditional alliances that are bridging the capacities and authorities of existing groups, particularly those that are effectively engaging the public in the process of planning and adaptive management. We encourage continued large scale planning efforts but support the evolution of new planning boundaries and structures that emerge from local participation and natural processes and partnerships rather than any pre-designated structure or process.

Expand partnerships and collaborations with individuals, leaders, and groups. Landscape conservation and restoration will bring much greater interest and engagement in the development of plans and actions for the conservation of fish and wildlife. Farm and forest landowners and managers will need to coordinate actions. County and city officials will need to be aware of the impacts of development decisions on land use and adjoining land and riparian areas. Groups focusing on water quality, environmental health, natural resource education, and like areas will have to become partners and collaborators. Use cooperative management, consensus building, civic engagement, effective communication, social network techniques, structured decision making, and related techniques to create these partnerships and collaborations.

Examine other collaborative experiments in large scale restoration. Periodically review progress and challenges of other larger restoration collaboratives that are experimenting with new models. Examples include the Forest Service Collaborative Forest Landscape Restoration Program, the states of Oregon and Washington, which use two different institutional structures for their salmon restoration programs, and the Lincoln Land Institute. There remains a need to learn from these experiences and apply successful techniques and approaches to the Columbia Basin.

5. Reinvigorate and Extend Adaptive Management.

Fully develop adaptive management to develop and support adaptive capacity.

Adaptive management is a basic element for implementing the Vision, Biological Objectives, Strategies, and Plans of Council-sponsored and collaborative projects. Advances in the understanding and application of landscape ecology, socioeconomic engagement, integrated collaboration and governance, and adaptive management where learning results from and is used to adaptively adjust actions, are the keys to building adaptive capacity.

***Implement adaptive management experiments*.** While large experiments are difficult for several reasons, they are vital to the adaptive management process. Experimentation to learn more about the operation and uncertainties of ecosystems, or other complex systems, is an essential feature associated with adaptive management. It is important that adaptive management experiments be creative in order to promote learning about landscapes and their social-ecological dynamics.

Revisit guidance on where and what to measure. Previous ISRP/ISAB monitoring and evaluation reports have made useful suggestions on where to measure; we support their recommendations. Effective measures of diversity and resilience should be monitored along with the more traditional measures of abundance and in-river survival. Progress in measurement and evaluation of large-scale patterns in genetic, phenotypic, and functional diversity would support rapid development of new approaches. Further, including currently available measures of social conditions and wellbeing, along with surveys and focus groups will be useful to show the perceptions of the benefits from landscape actions. Effective landscape actions embrace social conditions as fundamental components of long-term success.

Provide options for "citizen science" in the restoration program. The public needs to be better engaged so that their insights can be considered, they can be informed, and the results of experiments can be used for both learning and revision of plans and actions. Invite citizens to help design hypotheses and research studies, help design and implement monitoring protocols, become involved in monitoring tasks and interpretation of evaluation of monitoring results, and thereby become part of the team that applies results to assess and adjust actions. Experience shows that involvement of citizens creates better monitoring protocols, educates people about the dynamics of natural-cultural systems, and changes land-use behaviors. In effect, citizen science engages the public gyroscope in assessment of actions, revisions to plans, and making policy.

Evaluate restoration efforts in a landscape context. In the Columbia Basin, relationships between management practices designed to improve physical stream conditions and biotic change need to be quantified at the landscape scale. A nagging concern is whether restoration efforts are increasing fish abundance, biomass, and resilience of populations. A positive step is the Monitoring, Evaluation, Research, and Reporting plan (MERR), which contains an Evaluation and Reporting Approach to provide information on progress toward basinwide biological objectives and the Integrated Status and Effectiveness Monitoring Program (ISEMP). Nevertheless, despite many attempts to restore habitats throughout North America, there is only ambiguous evidence that restoration efforts have increased fish abundance, biomass, or the resilience of populations.

6. *Develop Best Practices*.

Support the development and diffusion of best practices to guide more consistent actions.

Best practice summaries can be handouts or web pages, assembled in folios according to target group, preferably as one-page summaries. Fortunately, best practices for a number of land uses already are established. However, what is often missing from these is a comprehensive landscape approach. The Council, tribes, states, and federal partners should work together to:

Develop a preliminary list of best practices. The list will help implement a comprehensive landscape approach building on what is learned from experience and adaptive management. The rules of thumb outlined above can provide a starting point. As greater experience is obtained, monitoring and evaluation can determine the effectiveness of best practices and identify modifications needed to make them more effective.

Use policy to align actions with goals. Continuous oversight to align people's actions with goals is difficult, time consuming, and expensive. One way to more efficiently get this alignment is through policy. Policies are the laws, administrative rules, and local codes that try to align people's actions with societal goals. Ideally, state and local citizens and policy makers should know if policies at their levels support or inhibit the best practices for implementation of the Council's Fish and Wildlife Program.

Develop best practices that are useful to specific actors. This is a less prescriptive way to achieve alignment with Council goals. This means developing a set of best practices designed for specific groups of actors, such as resource managers, county and city planners, and various types of landowners and households. Council program leaders with assistance from ISRP, ISAB, IEAB, and topical specialists could begin with best practices for counties and cities.

7. *Strengthen Social Science participation in ISAB and IEAB.*

> *Increase formal cooperation and collaboration between the two bodies to improve the integration of ecological and socioeconomic perspectives.*

Consistent with much of the discussion in this report, stronger integration of biological-ecological and socioeconomic considerations is needed for efficiency and success of conservation and restoration.

Integrate the ecological and human sciences on advisory boards and the interactions between ISAB and IEAB. The ISAB recommends that the Council increase collaboration between the ISAB and IEAB, increase the social science representation on the ISAB and broaden it on the IEAB, and promote sustained interaction and cooperation of these two advisory bodies. The recommendations above and much of that outlined in Table VII.1 are examples of activities that could significantly improve efficiency of Fish and Wildlife Plan actions and that could be supported jointly by the ISAB and IEAB.

Table VII.1. Foundations for Rules of Thumb in a Comprehensive Landscape Approach. Key points behind each of the general recommendations provide starting points for rules of thumb for a landscape approach to restoration in the Columbia Basin. While many of these recommendations are already in practice or being explored, we need to embrace them, build on them, and make them part of the culture of restoration.

Broaden Socioeconomic Engagement

- *Develop broad engagement with citizens, landowners, and other groups with diverse interests.*
    - Include diverse perspectives toward conservation and restoration
    - Use meetings and events for in-depth communication about values, incentives, and actions
    - Look for areas of cooperation, complementarities, and ability to develop beneficial strategies and actions
    - Use a breadth of engagement activities that include public meetings as well as print, radio, TV, and social media or web-based tools to reach the largest possible audience
    - Solicit public engagement early and encourage debate and discussion of alternatives
    - Include advisory groups, university extension, volunteer programs, and active/experiential learning activities for youth and adults
- *Measure effectiveness of socioeconomic engagement.*
    - Include indices that include recognition of the organizational names and sponsored activities
    - Consider program or project success in generating public support and outside funding
    - Consider measures of trust among the general public and specific stakeholders
- *Create positive incentives for people to engage with and care about their landscapes.*
    - Use narrative and stories linking personal wellbeing to the integrity of watersheds and landscapes
    - Emphasize and explore the ecological goods, services, and aesthetic qualities that society depends on for their livelihood and sense of place
    - Work to develop and extend the financial incentives through tax structures, easements, water rights and other mechanisms available with an eye toward expanding conservation management

Build from Landscape Ecology

- *Develop a larger spatial and temporal context.*
    - Support the implementation and application of linked or integrated models, scenario planning, and similar analytical and conceptual tools
    - Explore and communicate a basic understanding and questions of pattern, process, and tradeoffs across landscapes, and their importance to resilience of fish and wildlife populations
    - Work across the full landscape influencing the systems of interest; work across non-ecological boundaries such as land ownership or jurisdiction
    - Recognize that important processes play out over time; actions now are long term investments in to the future
    - Consider landscapes as templates that constrain the potential for habitats and populations

    - Use landscape classification as a foundation to understand habitat potential, primary drivers or processes influencing habitat conditions and constraints on successful restoration
    - Recognize that we cannot fully anticipate how systems will change; they are likely to be very different in the future. Favor strategies supporting diversity and adaptive capacity over those that attempt to recreate structural conditions of the past
- *Link landscape ecology to population productivity and resilience.*
    - Consider spatial structure and work toward a distribution of habitats that are large enough to support persistent populations, redundant and widely distributed enough to minimize vulnerability to individual disturbance events, and connected enough to support each other
    - Maintain or restore the range of habitats to allow re-expression of the fullest possible range of phenotypes
    - Maintain existing genetic diversity and seek to prevent further loss of genotypes that are not well adapted to current conditions but that might be favored in restored habitats or future climatic condition
    - Consider quality and complexity of habitats needed to support strong survival and population growth rates
    - Consider complementary landscapes and habitats needed to support complete life cycles
- *Prioritize limited conservation and restoration resources within the larger context.*
    - Build from strengths. Secure functioning landscapes and core habitats before restoring more degraded ones. It is far more efficient to conserve existing systems than create new ones. Focus resources where the greatest benefits can be gained with the least cost
    - Focus restoration where it will resolve critical bottlenecks or constraints in survival and population growth
    - Favor a modular approach. When possible, focus efforts to secure or restore a complete habitat, habitat network, patch, or local population rather than working on many simultaneously
    - Balance size, diversity, redundancy, and complementary habitat elements or "modules"
    - Favor restoration of process rather than structure. Focus on the landscape conditions that are sources or causes of degradation rather than the habitat condition
    - Use broad-scale assessment to identify conflict, and opportunity for synergies and tradeoffs, with other resource uses and issues (e.g., aquatic vs. terrestrial restoration)

Organize for Integration and Collaboration

- *Support or create organizations that can build trust and partnerships between relevant sciences, between science and management, and between science, management, and the public*
    - Develop a sustaining structure, a clear vision, and the leadership and organization to carry out the vision
    - Create a governance that is inclusive, democratic, flexible and at the scales necessary to address the landscape and ecosystems of interest
    - Find a common language and common conceptual foundation; use decision tools and models to visualize the system and alternative scenarios
    - Work across large areas, with diverse ecologies, and varied interests, values, and objectives to explore trade-offs among resource uses and conflicts in time and space
    - Bring counties and cities into the restoration process, including longer term maintenance

    - Facilitate and support non-traditional organizations and “cost effective partnerships” that include NGOs, non-profits, and local collaboratives that can bridge traditional boundaries and bring key players to the process
- *Find and support the technical and organizational capacity and resources to bring implement the vision in the form of science based landscape projects and actions.*
    - Require a scientific, technical, and local knowledge that builds on existing knowledge
    - Create a process that values interdisciplinary scientific knowledge
    - Facilitate and support non-traditional organizations that include NGOs, non-profits that can bring new capacities especially where they are dwindling in traditional agencies
- *Create incentives that support science engagement with management and the public*
    - Consider incentives for collaboratives similar to the Long Term Ecological Research Program
    - Develop science collaboratives or restoration extension service to support managers where resources are limited

Foster Adaptation; Use Adaptive Management

- *Scale Up Monitoring*
    - Recognize large scale pattern and underlying process
    - Recognize the issues of scale and dominant process, the focus of monitoring may change with scale
    - Consider a mix of sentinel sites and intensively monitored sites to understand both process and emergent pattern
    - Use “citizen science” to reduce costs and help people gain knowledge about landscape structure and processes; consider the National Park Service model
    - Develop high-level indicators of ecological and social and economic conditions
    - Includes measures of such things as public trust, knowledge of scientific principles, and identification of individuals or groups that are potentially affected, beneficially or negatively, by plans and actions
- *Experiment and Innovate*
    - Consider a mix (or diversity) of restoration and funding strategies in order to compare and contrast
    - Use models to help focus on critical questions or where experiments are logistically or financially impossible
    - Formalize a regular process of review, feedback, and revision or refinement
- *Learn through diffusion, collaboration and sharing*
    - Develop procedures and incentives for innovation through a broad set of actors including “communities of practice” and “peer learning networks”
    - Share ideas, information, and results across similar projects and develop common or coordinated watershed and regional strategies with common approaches to evaluation
    - Develop mechanisms and networks for communication, sharing, and review
    - Regularly synthesize results of common efforts across temporal and spatial scales

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VIII. Concluding Remarks: What Does Success Look Like?

"...I address myself ... to the general intelligence of observing and thinking men; and ... my purpose is rather to make practical suggestions than to indulge in theoretical speculations ..."
- George P. Marsh (1864)

It has been well over a century since George Perkins Marsh wrote his highly influential book *Man and Nature* (1864). The book is a classic reminder that civilizations have collapsed through environmental degradation, but they need not do so if societies adopt a landscape perspective and develop sustainable philosophies toward land and water. The messages contained in Marsh's book eventually launched the modern conservation movement in the United States because, even at the time of its publication, there was great concern for holistic management of the Nation's lands and waters. Stewart Udall later wrote that Marsh's book was "the beginning of land wisdom in this country." While other great works have espoused a landscape perspective, with *A Sand County Almanac* (Leopold 1949) and *The Sea Around Us* (Carson 1951) perhaps being the epitome of such works, none has been quite so influential.

Acting on the words and works of Marsh, Leopold, Carson, and other leading writers is more critical than ever for stewardship of the Columbia Basin. Changes to land, water, and the cultures they shape and support, have been profound and are accelerating at alarming rates. If adequate resources are to remain for future generations, a comprehensive landscape approach is needed. This is perhaps the grand challenge for the Council and its partners in this decade. At their core, the principles and recommendations in this report are only elaborations of principles and recommendations made by others over the previous century. Yet, while thousands of people are well-versed in science, management, politics, and industries, the people of the Basin do not share a common landscape perspective or have the shared leadership, ethics, philosophies, and visions to carry us successfully toward the future. The Council, working closely with its partners and collaborators, can play an essential role in developing the skills, ethics, and vision necessary for a sustainable future.

What will it take to be successful? The path will require continual learning and adaptation. This and recent ISAB reports emphasize a future for the Basin that is outside the bounds of previous experience – a serious social-environmental issue that lives with us today. There are, however, ways to prepare for an uncertain future. These require the integration of local with Basin-wide decisions and actions, and these have been presented in this report. Collectively, there are opportunities to be successful when we recognize that:

- Success is a process, not a state of completion, and it demands unparalleled communication and cooperation
- Change is continual: sustained monitoring and active learning will be always required
- Early and extensive public engagement is needed at all scales of social organization e.g., (homeowners, counties, subbasins, and above)
- Socioeconomic and ecological issues must be addressed simultaneously and with an integrated approach, keeping in mind that the Basin's natural environments sustain the personal wellbeing of its people.

A landscape perspective is what Marsh, Leopold, Carson, and others envisioned. Communities are asking for an understanding of what Nature needs in order to adapt and efficiently produce useable resources (Williams 2011) -- what will it take to maintain ecosystems that provide life-sustaining benefits? It is time to move beyond isolated management and restoration actions to broadly integrated actions based on a comprehensive landscape approach. Such an approach is just as important for local sustainable economies and cultures as it is for Nature and healthy ecosystems. There are many opportunities to implement a comprehensive landscape approach - and the time to begin is now.

IX. Appendices Supporting Material for Section III

A. Viable Salmonid Populations

The Vision and the Scientific Foundation and Principles of the Columbia Basin Fish and Wildlife Program highlight fish and wildlife *abundance, productivity, and diversity* to guide habitat restoration (NPCC 2009). A similar focus emerges from a NOAA guidance document (McElhany et al. 2000), which defines a “viable salmonid population” as an independent population that has a negligible risk of extinction over a 100-year period. McElhany et al. (2000) identify four factors, three of which mirror the focus of the Columbia Basin Fish and Wildlife Program (*population size, population growth rate, and diversity*), plus one additional factor, *spatial structure,* within and among populations. All of these ultimately require a landscape approach.

Population size is the number, or *abundance*, of individuals in a population averaged over time. Small populations are more vulnerable than larger populations to environmental variation and disturbance, loss of genetic and phenotypic diversity, and depensatory effects (negative changes in population growth rates that occur at low numbers). Population size reflects the quantity and quality of habitats. Habitat extent or area can be an important determinant of population size and risk of extinction (see Appendix IX.D).

Population growth rate, or *productivity*, is the rate of increase in population size over a generation. Population growth rate is typically highest at low population size, when intra-specific competition is negligible, and provides a measure of the capacity of a population to recover from disturbance or added mortality. Population growth rates vary through time, as abundance and environmental conditions influence individual growth, survival at different life stages, fecundity and reproduction. However, populations with consistently negative population growth rates are doomed to extinction. From a landscape perspective population growth rates depend on habitat quality and capacity, and on connections among staging, spawning, rearing, refuge, and migratory habitats that must be linked through space and time to complete the life cycle.

Diversity refers to the variety of genetic and phenotypic characteristics among individuals within populations and among populations. Diversity allows a species to use a wider array of environments, contributing to higher abundance and productivity and greater stability as environmental conditions change. Diversity is the raw material for adaptation to future environments (Appendix IX.C). Diversity depends on the range and spatial distribution of habitat conditions, which are the template against which diversity evolves and is expressed.

Spatial structure refers to the geographic distribution of individuals in a population and that of the environmental conditions and processes that generate that distribution. Most Pacific salmon exist as *metapopulations* made up of a number of partially, geographically, and reproductively isolated subpopulations that are connected by moderate levels of movement or migration (e.g., straying may link subpopulations of a salmonid metapopulation). Thus, spatial structure depends on the dispersal abilities of individuals, as well as on the spatial configuration, quality, and dynamics of the habitat (Appendix IX.D).

As described above, abundant, productive, and diverse fish and wildlife populations depend on the spatial and temporal patterns of distribution of habitats and on the processes that create and maintain those. Thus, effective conservation and restoration require a landscape approach.

B. Classification Systems for Land and Water

Four integrative approaches promise to fundamentally change management in the near future. They are NetMap (www.netmaptools.org/), River Styles (www.riverstyles.com/publications.php), the insightful use of remote sensing, models and statistical analyses (Beechie and Imaki 2011, Whittier et al. 2011), and the use of catenae in the estuary (Si Simenstad, University of Washington, personal communication. Equally important, the emergence of an essential regional database provides links of commonality among various classification systems.

NetMap is an integrated suite of numerical models and analysis tools (Benda et al. 2007). NetMap develops regional-scale databases in support of watershed science and resource management, automates numerous watershed analyses for diversifying resource management options, and improves tools and skills for interpreting watershed-level controls (e.g., disturbances) on aquatic ecosystems. Hillslope attributes, such as erosion potential, sediment supply, road density, forest age, and fire risk are aggregated down to the channel habitat scale (20–200 m) allowing unique overlap analyses, and they are accumulated downstream in networks revealing patterns across multiple scales. Watershed features are aggregated up to scales of ~10,000 ha, allowing comparative analyses across large catchments and landscapes. NetMap contains hyperlinked users' manuals and reference materials, including a library of 50 catchment parameters. Collectively, NetMap and the hyperlinks provide decision support for forestry, restoration, monitoring, conservation, and regulation at large spatial scales and for complex situations.

Developed in Australia, the "**River Styles**" approach is receiving some international acceptance (Brierley and Fryirs 2008, Brierley et al. 2008). In this approach, streams and rivers are considered the focal points for all land-based changes, as they are the lowest-elevational features of the landscape. The River Styles approach attempts to maximize prospects for improving stream and river conditions while maintaining or enhancing the provision of nature's services. It uses science to inform river management, provides a coherent set of guiding principles, and emphasizes cross-disciplinary understanding built on a landscape template. Collectively, River Styles offers a positive, practical and constructive focus that directly addresses the major challenge of a new era of river conservation and rehabilitation — that of bringing together the diverse and typically discipline-bound sets of knowledge and practices that are involved in repairing rivers. A drawback is that the same classification may result from several contrasting driving forces.

The use of **remote sensing, models, and statistical analyses** is fundamentally transforming the scope of classification efforts. As an example, these have been applied In the Columbia River Basin to evaluate the roles of slope, discharge, valley confinement, sediment supply, and sediment calibre in controlling channel patterns and stream across the entire ~600,000 km^2 landscape (Beechie and Imaki 2011). Channel classification at this spatial scale is unprecedented, representing an important advance for habitat restoration. For instance, using linear discriminate analysis (LDA), Beechie and Imaki quantitatively determined that the straight, meandering, island-braided, and braided channel patterns are best distinguished by a model including all variables listed above except valley confinement, with 73% overall accuracy.

The use of **remote sensing, models, and statistical analyses** is equally important in classification, based on natural features and human alterations, of Pacific Northwest hydrologic units (Figure IX.1). This type of classification is central for guiding salmonid research and management at the scale of the

Columbia Basin (Whittier et al. 2011). Due to the highly diverse character of the Basin's landscapes and the large geographic freshwater ranges of Pacific salmon, it is not clear whether restoration practices that resulted in increased salmon production in one Intensively Monitored Watershed (IMW) will be effective in other places. A landscape classification based on natural features known to be associated (either positively or negatively) with salmon production can define areas of similar natural potential. The classification approach developed by Whittier et al. (2011) indicates areas that are sufficiently similar that particular restoration actions could be expected to have similar results, as well as areas that are sufficiently dissimilar for there to be less certainty about the chances of success. This framework is also useful for evaluating whether IMW projects are well distributed among the natural-feature landscape classes or whether any "salmon landscapes" are not currently included. For instance, for Basin areas east of the Cascades, this approach revealed that projects tended to be located in transitional ecological zones. This suggests the need to place additional IMWs in areas more centrally located within Eastside landscape classes (i.e., non-transitional areas).

The impetus for a modern landscape classification system in the Columbia River estuary has arisen from the lack of a clear accounting of the diverse ecosystems that comprise the estuary and from requirements under the 2008 FCRPS BiOp to establish a hierarchical classification system (S. Simenstad, University of Washington).[18] Thus, the recognition of the estuary "ecoscape" as a dynamic feature, affected especially by fluvial and sedimentary forces which in turn influence vegetation, has required reference to the classical topographic description of areas where different soil types erode and deposit in relationship to the direction of water flow. Milne (1936) coined the term **catena**, from the Latin for chain, for these areas. While the term has been used by botanists and soil ecologists for decades, it has been applied only recently to flood-plain salmon habitat. Catenae are the fifth level in the classification hierarchy of estuary landscapes (ecosystem province, ecoregion, hydrogeomorphic reach, ecosystem complex, *geomorphic catena*, primary cover class). A complex of 27 geomorphic catenae has been described for Reach F in the Columbia River estuary (Figure IX.2). Geomorphic catenae include, among others, deep channels, floodplain channels, floodplain islands, natural levees, side channels, tributary channels and wetlands. Ongoing research by the USGS and University of Washington, in collaboration with the Lower Columbia River Estuary Partnership (BPA Project 2003-007-00: Lower Columbia River Estuary Ecosystem Monitoring), is testing relationships between these catenae and juvenile Chinook salmon residency and feeding.

[18] www.nwcouncil.org/fw/program/2009spe

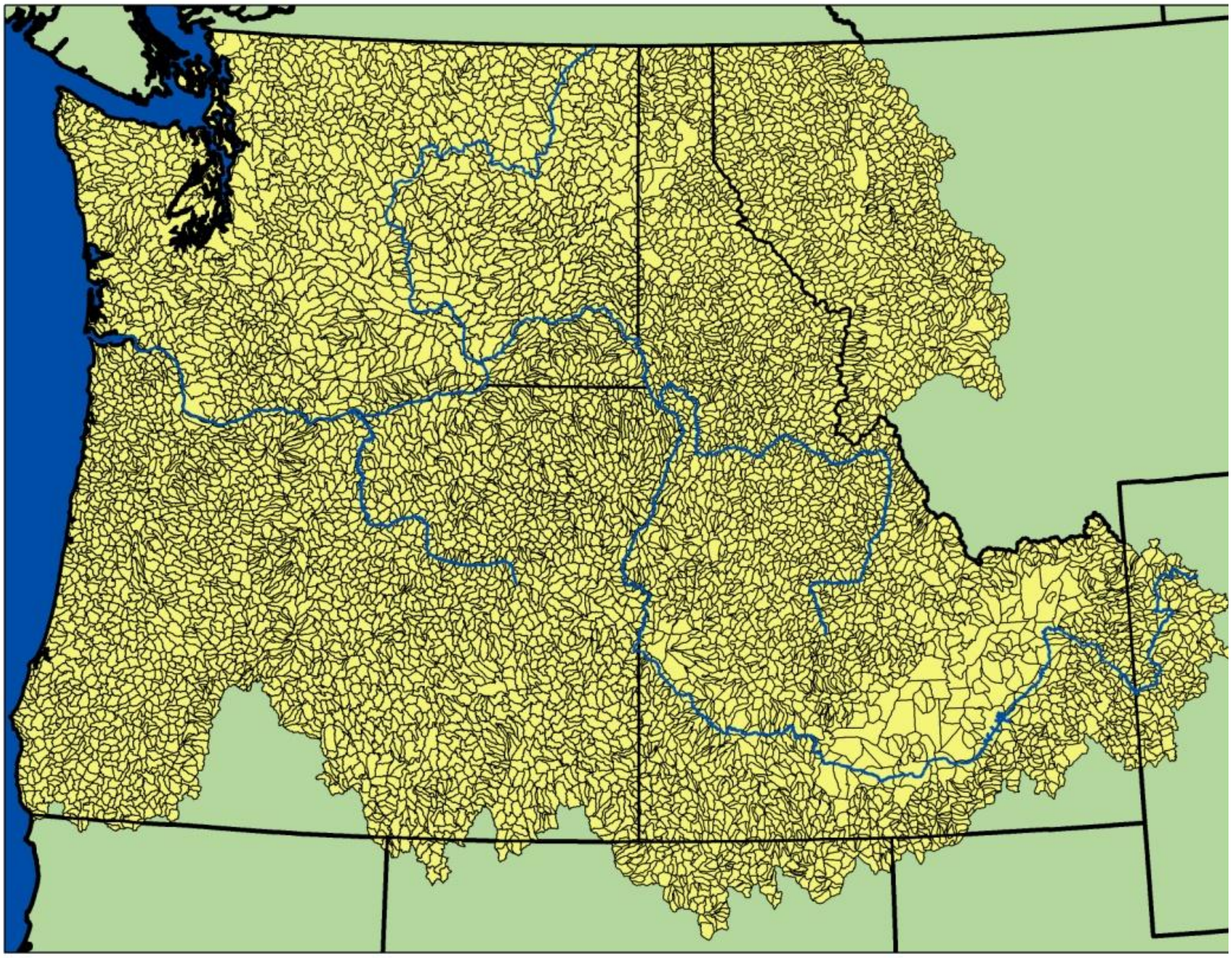

Figure IX.1. Map of the 8,438 sixth-field hydrologic units (HUC6) in the Pacific Northwest (from Whittier et al. 2011).

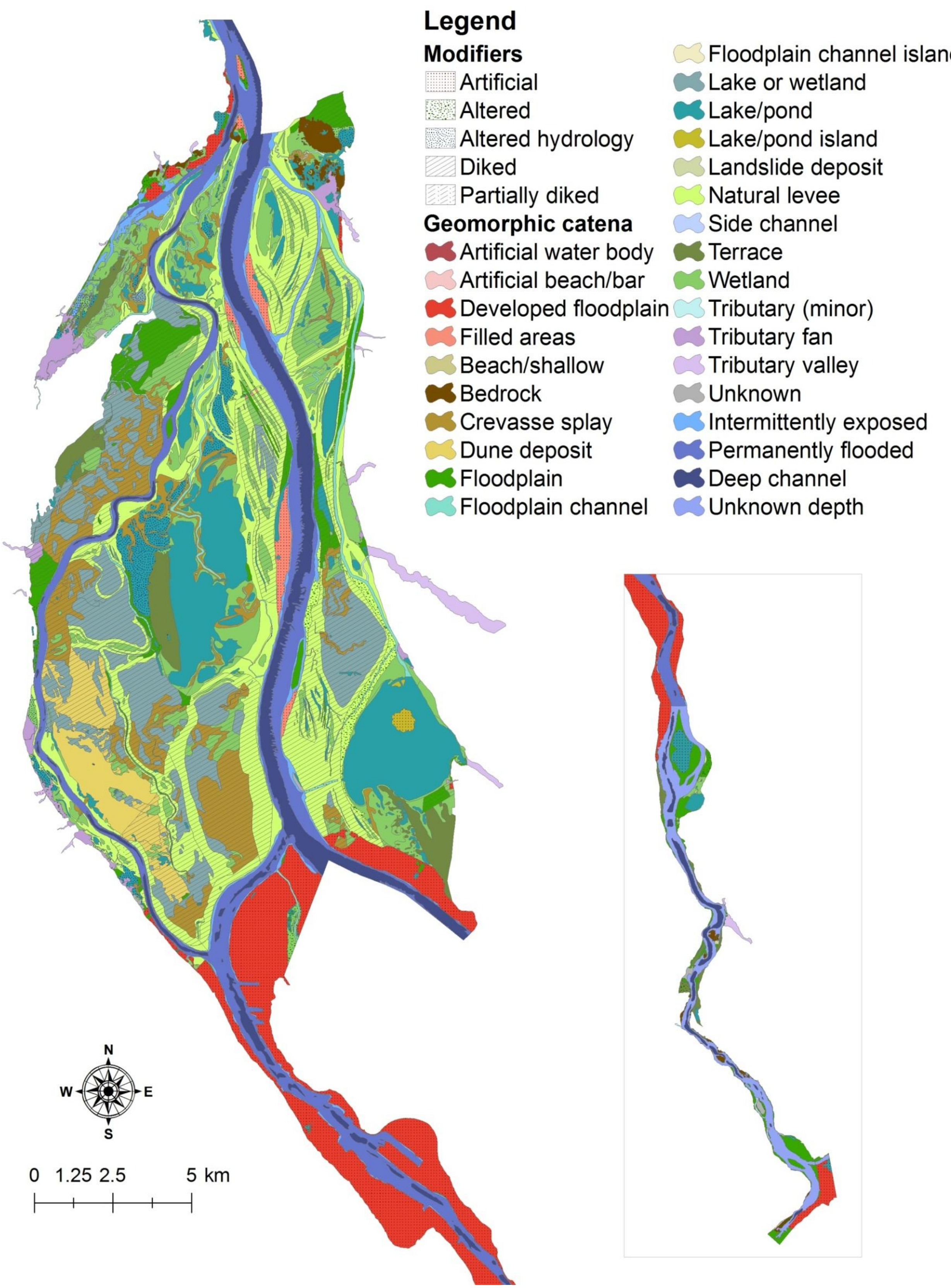

Figure IX.2. Geomorphic catenae described for Reach F in the Columbia River estuary (from S. Simenstad, University of Washington).

An Essential Database

A valuable addition to aid in habitat classification has been the PNW Habitat Classification Systems (PHaCS) Database. This is a component project of the Northwest Environmental Data-Network, an information portal sponsored by federal, state, tribal and non-governmental entities to improve the quality, quantity, and availability of regional fish, wildlife, and water data. It is hosted by the Northwest Habitat Institute in partnership with the National Biological Information Infrastructure (NBII).

Habitat classification systems differ greatly throughout the Pacific Northwest, often complicating data-sharing and collaboration. The PHaCS database attempts to crosswalk and establish threads of commonality among the different habitat classifications within the region. Crosswalking is a process of mapping elements from one standard or schema to another based on definitions or semantics. It has been used to establish connections between different Habitat Classification Systems and the Interactive Biodiversity Information System (IBIS), which was developed by the Northwest Habitat Institute and used as the common reference system for this database. The database tool provides, when available, information about the habitat classification systems in the PHaCS; the habitat categories and definitions of the systems; associated and complementary systems; and IBIS habitat types, structural conditions, and key environmental correlates, including crosswalks from each system to IBIS.

The Columbia River Estuary – A Special Case?

The various goals of specific management agencies in the Columbia River Estuary often require their own classification systems. As a result, the relatively simplistic habitat classification schemes of earlier decades have fallen by the wayside. Further, satellite imagery, LIDAR, side scan sonar, geopositioning and Geographic Information Systems have all advanced mapping in the Columbia River Estuary (Garono and Robinson 2003). Still unknown, however, is the functional importance of habitat units to juvenile salmon – a major data gap that hampers the use of mapping results (Diefenderfer et al. 2011).

The catena concept (described above) is now being applied to a tidal freshwater reach in the Columbia River Estuary and appears to be an advance in framework for a landscape planning and management. Currently, progress is being made on the quantification of relationships between catena and juvenile Chinook salmon residency and feeding. Most importantly, this approach involves the broader research and stakeholder community, which harbors well for its eventual acceptance.

C. Adaptation, Diversity, and Restoration

An organism's ability to survive, grow, and reproduce in a particular environment (its "fitness") depends on its physical traits and behavioral repertoire (its "phenotype"). Some aspects of an individual's phenotype are flexible enough to allow rapid acclimation to changing conditions (behavior and physiological responses), whereas others change only slowly (developmental responses) or not at all. Some phenotypes can thrive in a wider range of habitats than others or can tolerate greater changes in environmental conditions. Such "phenotypic plasticity" accounts for much of the phenotypic diversity observed within species inhabiting heterogeneous landscapes where they are exposed to a wide range of habitats and climatic conditions (Healey and Prince 1995). However, an organism's phenotype ultimately is determined by genetic adaptations that have evolved over many generations, through natural selection in particular habitats and environmental conditions (Williams 1966). Thus, a genetically determined "norm of reaction" controls how phenotypic plasticity is expressed in different environments (reviewed by Pigliucci 2001) and phenotypic plasticity is itself an adaptation to environmental conditions. Ultimately, it is the heterogeneous environmental template that generates and maintains the diversity of genetic and phenotypic specializations that determine fitness.

By enhancing the average fitness of individuals, genetic adaptation to local conditions ("local adaptation") can increase the productivity of the population as a whole (Lannan et al. 1989). Typically, adaptation to a particular habitat results in a population that is more productive in that habitat than would be other populations of the species that are not adapted to those conditions. Thus, the collective productivity of organisms in a landscape comprising heterogeneous habitats will be greatest when they have evolved (and are maintained) as a diversity of spatially-separated populations, each locally adapted to their particular habitat.

Productivity enhances a population's abundance, long-term viability, and capacity to provide ecological goods and services (Lande 1988). Continuing local adaptation in a heterogeneous landscape results in the evolution of diverse life histories that maintain productive populations and can result in new species (Lande and Shannon 1996). This concept of continuing evolution can explain why, for example, prior to human activities in the last century, salmonids had been able to inhabit virtually every freshwater body on the west coast of North America that was accessible to anadromous migration (McPhail and Lindsey 1970, 1986).

Diversifying the "portfolio' of local populations (i.e., the diversity of genotypes and phenotypes) also provides at least two additional benefits. First, an aggregate of populations, each with its specialized adaptations, has a wide variety of phenotypic characteristics (e.g., migratory habit and timing, longevity and size, color, etc.). This diversity provides practical and aesthetic benefits (Diaz et al. 2006). For example, diversity in migration timing can enhance ecological services by extending the seasonal availability of salmon to food webs and fisheries. Within each life history type, spawning salmon are typically available to natural predators and fisheries for only about one month each year, but the overall period of availability is typically much greater for the collection of populations in the landscape (Figure IX.3). For instance, Chinook salmon historically were found spawning somewhere in the Sacramento River in each month of the year (Healey 1991) and adults entered the mouth of the Columbia River almost continuously between February and late November (Waknitz et al. 1995).

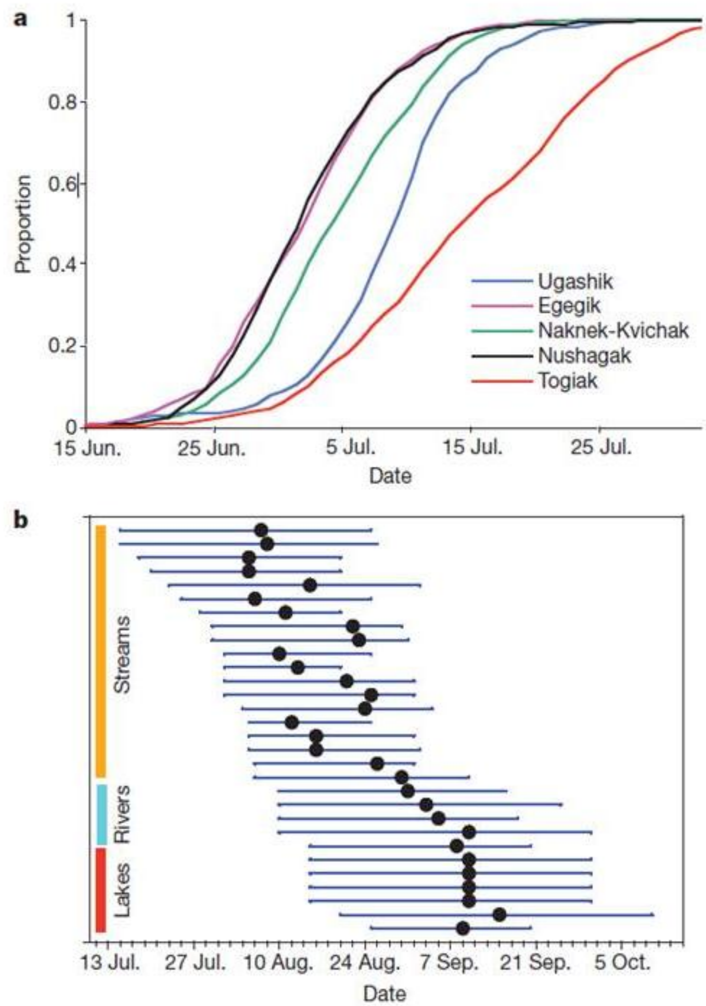

Figure IX.3. Annual run timing to fishing districts and streams. a. Cumulative returns (catch plus escapement) to each of the major fishing districts in Bristol Bay for 2000–2007. b. Comparison of the dates of occupancy (dot, peak; line, occupancy period) in spawning habitats where sockeye salmon are available to predators and scavengers for 30 populations in the Wood River system (from Schindler et al. 2010).

Second, a diversified portfolio of local populations provides "insurance" against changing environmental conditions. Populations with different adaptations are likely to have distinct responses to changing environmental conditions, such that productivity increases for some and decreases for others (reviewed by Schindler and Rogers 2009). This "response diversity" generally reduces temporal variability in productivity summed across all populations in the landscape (Elmqvist et al. 2003), producing a beneficial "portfolio effect" (Isaak et al. 2003, Moore et al. 2010). Loss of unique, isolated populations through local extinctions or homogenization through straying among populations (such as may result from hatchery releases or transportation of smolts) tends to increase synchrony among remaining populations and so decrease stability (ISAB 2005, Aylon et al. 2006, McClure et al. 2008).

As an example, adaptive diversity within and among sockeye populations reduces year-to-year catch variability in the Bristol Bay salmon fishery (Hilborn et al. 2003, Schindler et al. 2010). In contrast, recent high year-to-year variation in returns of Chinook salmon to the Sacramento River is blamed on loss of the high diversity of local populations (and habitats) that once buffered their overall abundance; current fisheries are supported largely by only four hatcheries that produce mostly fall Chinook salmon (Lindley et al. 2009).

Gustafson et al. (2007) conclude that historical levels of salmon abundance in the Columbia River Basin probably would not have been sustainable without a diverse assemblage of populations adapted to a variety of local conditions. They estimate that about 29% of an estimated 1,400 populations of Pacific salmon in the U.S. Pacific Northwest and California have gone extinct since Euro-American contact and that these extinctions have removed significant proportions of the original ecological (33%), life history (15%), and genetic (27%) diversity. That substantial diversity still remains (albeit much of it endangered) is testimony to the past resilience of these species (Gustafson et al. 2007).

Loss of historical genetic diversity and spatial structure likely constrain the potential for restoring abundance and productivity in the Columbia River Basin. Genetic diversity is the raw material of evolution, and genetic drift due to random events in very small populations limits the ability of natural selection to generate or maintain adaptations (Adkison 1995). Thus, loss of genetic diversity and increased genetic drift in depleted populations can be expected to limit adaptive capacity, as well as to reduce average productivity and viability of populations. Future conditions in the Columbia River Basin will be shaped by the continuing anthropogenic change in physical and biological (e.g., non-native species) aspects of habitat and by global changes in climate (ISAB 2007-2, 2007-3, 2008-4). Evidence is accumulating that Pacific salmon populations in the Columbia River have already responded differently to climate change (Levin 2003, Tolimieri and Levin 2004, Crozier and Zabel 2006) and will continue to do so (Waples et al. 2008).

In such circumstances, it seems unlikely that all biodiversity can be protected. Demographically isolated populations are basic units of conservation and restoration, and decision makers need scientific advice about the likely ecological and evolutionary consequences of losing populations (Wood and Gross 2008). Past efforts to transplant or re-introduce organisms from one population to another indicate that "ecological exchangeability" varies widely among populations. Some fish populations can be transplanted easily, both within and beyond their natural range (e.g., rainbow trout and largemouth bass, Gozlan et al. 2010). Other populations can be transplanted only with great difficulty or not at all (e.g., anadromous sockeye salmon, Wood 1995).

Phenotypic plasticity can enhance ecological exchangeability. For example, anadromous sockeye runs extirpated 90 years ago by hydroelectric dams on the Alouette and Coquitlam rivers (tributaries to the lower Fraser River) were recently restored (adults returning every year since 2007) by spilling water to promote the seaward migration of "sea-run kokanee," which are the progeny of non-anadromous sockeye in populations that managed to persist in the reservoirs behind the dams (Godbout et al. 2011). A similar experiment in progress on the Deschutes River produced sea-run kokanee smolts in 2010. These results underscore the message that both habitat and genetic diversity are essential for restoring phenotypic diversity.

In sum, a landscape approach to restoration should:

- *maintain or augment the range of habitats to allow re-expression of the fullest possible range of phenotypes*. Response diversity will be lost if the range of habitats encountered becomes restricted because phenotypic plasticity has a genetic basis (the “norm of reaction” that triggers development), which evolves in response to prevailing environmental conditions (McClure et al. 2008).

- *maintain existing genetic diversity and seek to prevent further loss of genotypes that are not well adapted to current conditions but that might be favored in restored habitats or future climatic conditions.* Genetic diversity is the raw material that constrains the rate of adaptation and, hence, average productivity under future conditions. A diversified portfolio of local populations also increases the odds that at least some populations will remain viable and persist under future conditions (McElhany et al. 2000).

D. Spatial Structure

Spatial structure of habitats influences biological processes at the levels of genes, individuals, populations, and communities (Kareiva 1990). As early as 1931, Sewall Wright suggested that evolution might proceed faster in spatially separated populations that were subject to local extinctions and recolonizations. Andrewartha and Birch (1954) described wildly varying insect populations characterized by local patch extinctions frequently followed by reestablishment of the population in the vacated patch. Richard Levins (1969) introduced the term "metapopulation" to describe a spatially distributed population whose dynamics were determined by extinction and recolonization of local subpopulations. Island biogeography expresses the idea that both the likelihood of persistence of a population and the number of species (which are persistent populations) increase with the area of an island or habitat patch (MacArthur and Wilson 1967). Until recently, most studies of fish and wildlife habitat associations have been at the scale of local habitat units (e.g., from pools and riffles to reaches of stream). However, since movement is a primary mechanism by which fish and wildlife can respond to changes in their local environment, spatial structure of habitat is important to the dynamics and viability of a population. Since population viability has become of great concern, spatial structure of habitats and populations is a leading concern for conservation and restoration (McElhany et al. 2000).

Levins (1969) originally defined a metapopulation as a set of subpopulations of a species that occur as local populations in patches of similar habitat among which there is some movement of individuals, which causes their population dynamics to be partially uncorrelated. The different patterns of growth and decline among the local populations mean that all do not experience bad environmental conditions (e.g., from bad weather or a disease epidemic or a forest fire), decrease dramatically, or become extinct at the same time. Populations that experience better conditions can serve as sources of dispersing individuals that recolonize or replenish the populations of areas that have experienced bad times. Following this logic, the reserve design for northern spotted owls recommended by Thomas et al. (1990) used spatial structure of patches in a larger landscape to promote the long-term viability of a population. Rieman and McIntyre (1993) proposed a similar design for bull trout. Fishing exploitation that ignores the spatial structure and differing productivities of local populations in a larger metapopulation can result in the lost of genetic diversity and threaten the whole metapopulation (NRC 1996:145-163).

"Source-sink" metapopulations inhabit patches of habitat that differ in quality. Habitat patches of good quality that support reproduction more than sufficient to replace adults with young are "sources," because their growing populations can serve as sources of emigrants that leave and settle in other patches. Habitat patches of quality too poor to support reproductive rates sufficient for replacement, in contrast, are "sinks," because their populations decline unless they are supplemented by immigrants from "source" patches. Thus, source patches can be functionally independent, but sink patches are dependent on immigration from elsewhere. Whether a local population can be maintained by its local habitat (i.e., is independent) is an important consideration in recovery planning (e.g., Oregon Coho salmon, Wainright et al. 2008)

In "island-mainland" metapopulations, one expects the "islands" (new or smaller patches) to contain some subset of the species present on the larger "mainland" because the number of species in a habitat patch increases with time for species to have located and colonized it (in the case of new patches) and size of the patch (larger areas can support more populations). Schlosser (1995) and Schlosser and Angermeier

(1995) explored the implications of these ideas for conservation of species like Chinook salmon.

Most natural populations occur across a network of semi-isolated or isolated habitats so are spatially structured, but it is probably rare that they perfectly fit the definitions of an island-mainland, source-sink, or classic metapopulation (e.g., Dunham and Rieman 1999). Nevertheless, current usage loosely identifies all such populations in which local subpopulations interact as metapopulations. The metapopulation concept emphasizes the importance of pattern of habitat patches (i.e., their size and locations) and movement of organisms among those patches.

Size of habitat patches is important because larger areas can support larger populations, which are less vulnerable to extinction (Lande 1993). Populations spread over larger areas (or spatial extents) are less vulnerable to localized environmental disturbances (White and Pickett 1985). Studies of fish and wildlife have confirmed the importance of both the amount and the spatial arrangement of habitat to the persistence of populations (Lamberson et al. 1992, Dunham and Rieman 1999, Flather and Bevers 2002, Isaak et al. 2007).

Bull trout in the Boise River (Dunham and Rieman 1999) and Chinook salmon in the Middle Fork Salmon (Isaak et al. 2007) provide examples of populations that appear dependent on spatially structured stream environments. The most important predictor of the presence of bull trout was habitat patch size, followed by distance to the nearest occupied patch, and then road density in the patch, which is thought to reflect habitat quality (USFWS 2008). The strongest predictor of Chinook salmon nest occurrence was the connectivity of a patch to neighboring occupied patches (Isaak et al. 2007), followed by size of the patch. In this case, both connectivity and patch size exceeded the importance of local habitat quality.

Habitat fragmentation is one of the major threats to populations and it poses significant issues for managers of vulnerable populations occupying fragmented landscapes. Climate change may aggravate those problems, particularly for fishes where habitat suitability is constrained by water temperature and flow (Rieman et al. 2007, ISAB 2007-2). Theoretical studies have shown that the optimal strategy in protecting habitat for a vulnerable species depends on metapopulation parameters (local rates of birth, death, immigration, and emigration). Such models can be used in restoration to consider whether to increase the size of existing patches so as to influence local demography or to create new patches that influence the connectivity of populations (Isaak et al. 2007, Hodgson et al. 2009).

There is a need for better models to assess the relative importance of habitat attributes and provide guidance as to the effectiveness of increasing habitat size, improving habitat quality, or changing connectivity among existing patches (Isaak et al. 2007, Nicol and Possingham 2010). Even when the details cannot be refined, actions must be guided by recognition of the importance of spatial structure to the resilience of populations (ISAB 2005-2).

E. Linked Habitat and Life History Models

An important step in large-scale conservation and restoration is evaluation of the relative benefits of different actions and potential locations for implementation of those actions (ISAB 2003-2). Population models offer a useful way of exploring such trade-offs, particularly models that incorporate effects on life stage-specific survival or production capacity in response to habitat characteristics that may vary with landscape context and restoration action. Nonetheless, linking life history characteristics to habitat remains a challenge. Management for wide-ranging species must include vast spaces, such as watersheds and regions. This requires managers and decision makers to consider many quantitative and qualitative models to develop large-scale multispecies management strategies.

It has been nearly a decade since the ISAB reviewed the models used for habitat improvement decisions in the Columbia River Basin (ISAB 2001-1). Since then, models such as Ecosystem Diagnosis and Treatment (EDT) have been widely used to develop subbasin plans and continue to play significant roles in setting restoration priorities. Further, the Columbia Habitat Monitoring Program (CHaMP, project 2011-006-00) and the Integrated Status and Effectiveness Monitoring Program (ISEMP, project 2003-017-00) rely on habitat data to calibrate fish-habitat models to evaluate restoration effectiveness.[19]

Modeling fish–habitat relationships is not a new endeavor. For salmon in particular, a rich literature dates back at least 30 years, describing how changes in the quantity and quality of habitat affect the survival of specific life stages (e.g., Tappel and Bjorn 1983, Chapman 1988). Although some have modeled the influence of in-stream habitat attributes on the survival of salmon at specific life stages (e.g., McHugh et al. 2004), only recently has this been done for the entire life cycle, demonstrating the importance of various habitat changes to overall population dynamics (e.g., Greene and Beechie 2004, Sharma et al. 2005). Additionally, changes in land use continue to affect salmon through their indirect effects on habitat-forming processes. Predicting the impacts of such changes to salmon habitat requires a holistic modeling perspective that captures not only the expected future population size, but also information on stock productivity, spatial structure, and the diversity of life-history types (Lichatowich et al. 1995). Further, many stream fishes require a landscape that contains a mosaic of habitat types, and the diverse array of foods they produce, to complete their life cycles (ISAB 2003-2, 2011-1, Wipfli and Baxter 2010).

Many basic questions remain: Do models produce accurate results? Are they useful for prioritizing restoration actions at the landscape scale? And which of the thousand potential sources of imperilment are most likely to improve species status (Bartz et al. 2006)? Several recent advances are helping to answer these questions. These include the Shiraz model, improvements to and a sensitivity analysis of the Ecosystem Diagnosis and Treatment (EDT) model, a framework that combines a population viability analysis (PVA) model for one or more species populations with a reserve site selection (RSS) model to define alternative habitat improvement activities, and scenario planning. Other modeling frameworks potentially useful in landscape scale analyses are being explored as well (e.g., Peterson et al. 2008, Peterson 2011) but have not been widely applied within the Columbia Basin, so we focus consideration on the first four.

The Shiraz Model is a tool for incorporating anthropogenic effects and fish–habitat relationships into conservation planning (Scheuerell et al. 2006). It uses detailed information on density-dependent population

[19] See www.nwcouncil.org/library/isrp/isrp2011-10.pdf

growth, habitat attributes, hatchery operations, and harvest management to support conservation planning in a time-varying, spatially explicit manner. The model relies on a multistage Beverton–Holt model to describe the production of salmon from one life stage to the next and uses information from the literature to construct relationships between the physical environment and productivity and capacity parameters. It has been applied to a threatened Chinook salmon (*Oncorhynchus tshawytscha*) in the Snohomish River basin, Washington (see Sidebar IV.5), with data on hatchery operations and harvest management for the basin's stocks, to show how proposed actions to improve physical habitat throughout the basin would translate into projected improvements in four important population attributes: abundance, productivity, spatial structure, and life-history diversity. It has also been used in the Wenatchee River basin to convert suites of restoration actions into expected changes in habitat condition, enabling evaluation of alternative combinations of proposed actions (Jorgensen et al. 2009). Further, it provides inputs to models that relate population status to habitat conditions. In the latter case, it was discovered that Chinook population status could be significantly improved by restoration that reduced the percentage of fine sediments in the streambed, which has a large influence on egg survival, more so than by opening access to habitat in good condition (Honea et al. 2009).

The Ecosystem Diagnosis and Treatment (EDT) Model, which predicts salmon productivity and capacity as a function of ecosystem conditions, is complex and uses almost 50 environmental attributes to characterize habitat conditions, each attribute requiring a quantitative relationship with population performance. It has been subjected recently to a ''structured sensitivity analysis'' (McElhany et al. 2010), and the results suggest that EDT productivity and capacity predictions lack the precision needed for many management applications. However, EDT prioritization of reaches for preservation or restoration was robust to given input uncertainties, indicating that EDT may nevertheless be useful as a relative measure of fish performance. As is true for all large models, output of EDT should be as input to other models or tools only if the uncertainty in the output is incorporated into the secondary analyses.

While the EDT model is often used as a sole decision-making tool in the Pacific Northwest, Steel et al. (2008) have demonstrated that this model can be incorporated into a more robust decision-making scheme that includes alternatives such as expert panels or GIS-based landscape analyses. It can be included in a scenario-based decision-support process to aid in evaluating watershed-scale management plans for many species. The concurrent use of many types of models and a spatially explicit approach enables analysis of the tradeoffs among types of habitat improvements and among improvements in different areas within a watershed.

The modeling framework combining PVA and RSS helps identify the most cost-effective set of watersheds to protect when the conservation objectives include the long-term persistence of one or more salmon stocks (Newbold and Siikamaki 2009). Substantial gains in cost-effectiveness can be achieved using a fully-integrated optimization approach that accounts for the spatial interactions between sites and uses all available information on biological benefits and economic costs. For instance, the results for three Columbia River subbasins suggested 79% of the biological benefits could be obtained at 10% of the cost of protecting all upstream watersheds, compared to 20% to 64% of the biological benefits from using contemporary methods. The approach does not consider some elements identified in this report as critical, e.g., spatial linkages or the influence of habitat area on persistence. Nevertheless, the approach has strong potential for improving site selection for restoration.

Scenario Planning has gained appeal for conservation planning by forecasting alternative futures under different management scenarios. Used to predict how habitat and fish will respond to potential future trends in land use due to human population growth and riparian conservation policies, it provides useful insights into paths for cost-effective restoration (Fullerton et al. 2009, 2010). Most importantly, evaluating alternative future scenarios using simulation models is useful for planning over large spatial and temporal scales. Such an approach is still useful when predictions cannot be validated empirically; however, evaluating the sensitivity of scenario-based approaches to important uncertainties is necessary so that the impact of real-world constraints on results can be considered.

X. Appendices Supporting Materials for Section IV

A. Case History: Willamette Basin of Oregon

The Willamette Basin is an example of socioeconomic engagement, a landscape perspective, and governance and collaboration of very large and diverse populations. The example of the Willamette is one of an emergent process in contrast with something that is more centrally directed. The socioeconomic engagement techniques are broadly based. Two examples are the leadership and public engagement of Governor Tom McCall to initiate land-use planning for the purpose of preventing urban sprawl in the early 1970s (McCall 1977) and Governor John Kitzhaber's initiation of watershed councils to get conservation and restoration actions on private lands to help restore habitat for endangered salmon populations (Kitzhaber 1999). A landscape perspective is incorporated in both land-use planning and the Oregon Plan for Salmon and Watersheds (OPSW). The land-use planning process and watershed councils provide the structure for governance and collaboration. Adaptive management is widely emphasized but is still in a developmental stage.

The Willamette Basin is home to over two thirds of Oregon's population, is the seat of State government, and has a significant urban area at the junction of the Willamette and Columbia Rivers. The Willamette Basin is over 29,000 km^2, provides 15% of the Columbia River's flow, and is a diverse landscape of urban, suburban, and rural residential, agricultural and forest land uses. The main river is 275 km with 12 major watersheds that have 371 dams and a federal project of 13 major flood control and multipurpose dams (Figure X.1, NOAA 2011). The Willamette "… is one of the first proposals to consolidate multiple habitat restoration actions under an overarching umbrella that potentially offers administrative efficiency and a landscape-based strategy" (ISRP 2010-28:4).

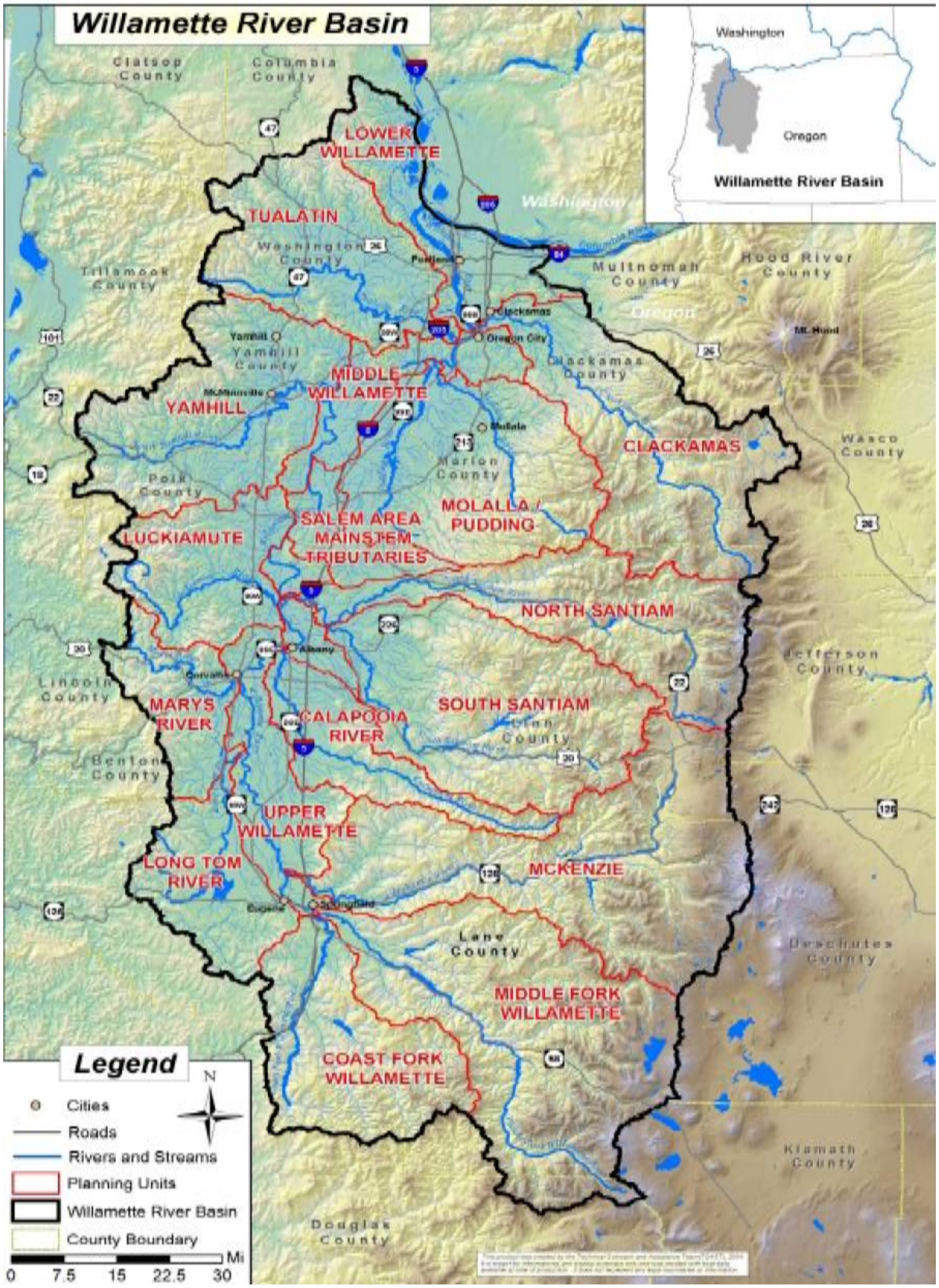

Figure X.1. Willamette Basin. (Source: NPCC Willamette Subbasin Plan, [online] www.nwcouncil.org/fw/subbasinplanning/willamette/plan/App%20H2_BaseMaps-2.pdf.)

The Oregon land use planning approach (embodied in SB100, passed in 1973) was a collaboration between urban and agricultural interests. Two of the major goals required protection of natural resources and land and water resource quality (Goals 5 and 6). The three decades to follow were setting up the land use planning system and dealing with the balance between economic considerations and environmental conditions. In the 1990s, a new set of conflicts around endangered species issues led to a decade of action at the beginning of the 21st century. The OPSW was the main catalyst for these activities (Kitzhaber 1999).

A series of loosely connected efforts dominate the first decade of the 21st century efforts to conserve and restore environmental conditions and maintain economic health. These efforts include the Willamette Restoration Initiative (WRI), Pacific Northwest Ecosystem Research Consortium (PNWERC), Willamette Partnership, Oregon Watershed Enhancement Board (OWEB), NMFS Upper Willamette River Conservation and Recovery Plan for Chinook Salmon and Steelhead (Upper Willamette Plan), and Meyer Memorial Trust's Model Watershed Program (MMT). The results from these efforts are emerging, but no clear and well-measured outcomes with respect to fish and wildlife have demonstrated success of the endangered species efforts.

Led by Oregon State University President, Dr. Paul Riser, "The Willamette Restoration Initiative Board of Directors presented its Willamette Restoration Strategy to Governor John Kitzhaber and State Legislators on February 21, 2001. The WRI report was designed to create a broader vision for the watershed conservation and restoration efforts. This became the Willamette Restoration Strategy and was developed by a group of citizens—the Willamette Restoration Initiative (WRI) Board of Directors. The Board addressed two key questions. The first was whether the Willamette Basin could accommodate more people along with native fish and wildlife. The second was, "Why work on the Willamette?" (www.oregonwri.org/basin_strat.html).

Science for the WRI was provided largely by an Environmental Protection Agency (EPA) sponsored, Pacific Northwest Ecosystem Research Consortium (PNWERC; see Sidebar IV.3) and the related Willamette Alternative Futures project. This PNWERC research project included scientists from the University of Oregon, Oregon State University, and the University of Washington. The project sought to understand the basin's landscape history from the mid 19th century to 1990. PNWERC developed three alternative basin futures to 2050. Coupled with the research was a program to gain input from stakeholders, monthly for 2 years, with emphasis on land-use changes that considered social and economic issues. The research and outreach is an example for gauging preferred approaches to conservation and restoration using a scenario approach to accommodate a doubling of the basin's population.

The three scenarios were—plan trend, conservation, and development. Plan trend "… assumed that existing long-term plans and policies …" would continue (Hulse et al. 2002:86). Conservation assumed "ecological services" would prioritize land and water use patterns. Development assumed "market-oriented approaches" would govern land and water use (Hulse et al. 2002:88). Although, as Hulse says, the stakeholders preferred the "conservation" scenario, the pattern so far has been very much the continuation of "plan trend" (Hulse et al. 2009). Further, a follow-on computer simulation project in which Hulse was also a participant used the same scenarios and showed that the three PNWERC stakeholder scenarios were much narrower in scope than could be conceived using a simulation approach (Guzy et al. 2008).

During the period 2002-2004, the Willamette Partnership was fulfilling a Northwest Power and Conservation Council contract to prepare a subbasin plan for the Willamette. The plan prepared by the Partnership was judged one of the two top subbasin plans that the Council received (ISRP/ISAB 2004-13). Subsequently, in an effort to sustain funding for the Partnership, it became involved in developing an Ecosystem

Credit Accounting System[20] and no longer was involved in subbasin planning. A second effort at trading ecosystem services is by Clean Water Services, a Tualatin watershed utility. With the Oregon DEQ, Clean Water Services started a system of "water quality credit trading for oxygen demanding parameters and for temperature" in 2004.[21]

Building on the Council sponsored subbasin plan, developed by the Willamette Partnership, is the NMFS (2010) Upper Willamette Plan. This landscape approach receives support from NMFS, the Council, Oregon lottery funds, and the Meyer Memorial Trust and Bonneville Environmental Foundation's Model Watershed Program (B-E-F 2009). The final draft of the Upper Willamette River Conservation and Recovery Plan for Chinook Salmon and Steelhead was released in August 2011.

Criteria

Socioeconomic engagement has been fostered by many leaders, who have had a vision for the Willamette Basin and Oregon's future. A landscape perspective is emerging with each vision. The Oregon land use planning process and OPSW provide a flexible, local, and comprehensive governance system that requires collaboration among land users and managers. Adaptive management is an emerging part of all activities associated with the evolving landscape perspective.

Socioeconomic Engagement - In the Willamette Basin socioeconomic engagement has been strong. Understanding and actions have varied considerably with the social, political, economic, and scientific context.

Engagement has been nurtured by civic groups. For example, the City Club of Portland began the mobilization of community concern about the poor water quality of the Willamette River in 1927. The public weighed in very strongly in a 3 to 1 vote to support formation of the Oregon Sanitary Authority via a 1938 ballot initiative. World War II delayed funding to improve water quality. Federal programs and university scientists acted on the public desire for improved water quality in the 1960s, and the Willamette was declared cleaned up in 1972 (Gleeson 1972; Starbird 1972). In the 1980s and 1990s, endangered species concerns were raised. Court cases filed by advocacy groups forced resource managers to plan for species restoration. Species restoration takes considerable time and actual successes are limited.

Socioeconomic engagement comes from a variety of leaders, their visions, and accessing a broad variety of public participation approaches. No one organization has been an enduring vision maker or leader. In general, no one organization mobilized the engagement of Willamette Valley residents, but over the years there has been growing awareness of the need for action. Socioeconomic engagement for the Willamette Restoration Initiative was embodied in CD, newspaper insert, and the networks of opinion leaders who were on the WRI Board. Most socioeconomic engagement activities for land-use planning include use of print, radio, and TV media. Surveys of Oregon residents gauge support. Many debate forums are organized. Public participation in the discussion is welcomed and NGOs are encouraged to participate. The public is encouraged to express itself in letters, discussion forums, and meetings at all levels of government.

The most enduring organization for continuing the socioeconomic understanding and engagement is the Oregon land-use planning process, which brings economic considerations and environmental conditions to bear in most land-use actions. The organization of watershed

[20] See http://willamettepartnership.org/ecosystem-credit-accounting

[21] See www.cleanwaterservices.org/Content/Documents/Projects%20and%20Plans/Temperature%20Management%20Plan%20Annual%20Report%202008.pdf

councils encouraged by OPSW has the objective of educating and working with private landowners on conservation and restoration projects. In an effort to create a web presence for socioeconomic engagement, the Willamette Explorer is a web-based tool designed to provide background to the public (http://willametteexplorer.info/index.php).

Landscape Approach - The diversity of both the life histories and habitat use of Willamette spring Chinook throughout the basin is an excellent example of the importance of a landscape perspective. Juvenile Chinook have a broad diversity of life histories, migratory types, and rearing habitats in the subbasins of the entire Willamette Basin—throughout the year. Some migrate soon after emergence and disperse to the lower reaches of the Basin, often using flood plains and small drainages from agricultural land. Some migrate directly to the ocean (up to 41% of the age 0's PIT tagged upstream of the Santiam River migrated to the estuary at travel rates of 9 to 31 km/d). Some rear until the following spring and migrate as yearlings. Other 0-age fish rear in upper tributaries until the fall before migrating downstream, and going either directly to the ocean or to rear in tributaries of the mid-stem, while others remain in upper tributaries where they hatched and migrate until the following spring. This continuum of life histories (Figure X.2) is a good example of bet hedging or a portfolio effect that spreads the risk against habitat loss and climate change, but also emphasizes the importance of maintenance of good rearing habitats throughout the basin all seasons of the year.

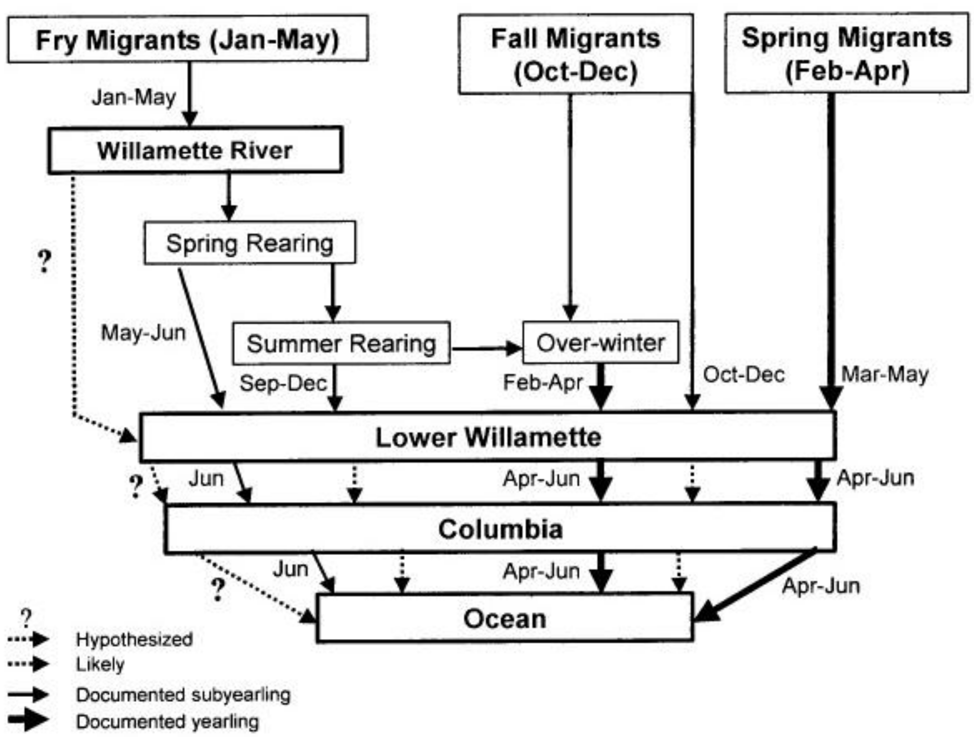

Figure X.2. Schematic representation of the migratory and rearing diversity in upper Willamette River spring Chinook salmon. Starting point at the top of the diagram is based on observed peaks of migration from upper McKenzie River Areas (Schroeder et al. 2007:29).

Several organizations are working to develop a landscape perspective. These include OWEB that requires all watershed councils to make a comprehensive assessment of their watershed. NMFS in its recovery plan and Oregon Department of Environmental Quality (DEQ) with its water quality focus are engaging and providing citizens with data, analyses, and planning to improve landscape and water quality, while being mindful of economic considerations. The joint effort between Freshwater Trust, Meyer Memorial Trust (MMT), and Bonneville Environmental Foundation (B-E-F) is trying to get the adjacent Middle Fork Willamette, Long Tom, Marys River, Calapooia, North and South Santiam, and Luckiamute River Watershed Councils thinking in terms of landscapes and the larger whole. This project is in its early stages. NMFS's Upper Willamette Recovery Plan also includes more specific fish passage projects at three dams, temperature control downstream of another dam, changes in downstream flows, screening of irrigation diversions, improved hatchery practices and facilities, and habitat improvement projects.

Oregon land use planning brings a landscape perspective by forcing consideration to protect farm and forest land and constraining urban, suburban, and exurban expansion. Land-use planning involves inventories of natural and cultural features that are important. Both landscape planning and EPA water quality limits require identifying beneficial uses for humans.

Because of private property values in the United States and Oregon, land and water use decisions are made on a case-by-case basis. Watershed organizations work on specific projects or at best with integrated stream reaches (Flitcroft et al. 2009), although the MMT/B-E-F relationship seeks to change this. As a result of these discussions, more and more citizens know the watershed in which they live, understand the connection between surface and groundwater, and can identify the important ecologies to conserve and protect (Shindler et al. 1995, Wright 2000, Doolittle 2003).

Organize for Integration and Collaboration - Actions in the Willamette Valley do not move forward without joint partnerships and collaborations. Usually, every activity has federal, state, and local government participation; public and private partnerships; engagement by statewide land use, fish, wildlife, and forestry agencies; and local participation of non-governmental groups. These collaborations tend to follow traditional lines and bare traditional economic and environmental divides. More and more businesses are increasing their environmental concerns and environmental NGOs are increasing their economic considerations.

Collaborations of scientists are occurring and science team partnerships are more interdisciplinary. The greater interdisciplinary character of science teams comes from National Science Foundation and other grant requirements. This has resulted in more participation by scientists with socioeconomic backgrounds.

NMFS Upper Willamette Plan brings together water quality (DEQ), state resource agencies (LCDC, ODFW, ODF), the Council, selected university scientists, watershed councils, the Willamette Explorer, and environmental groups. The NMFS response is the closest approach to a landscape perspective with emphasis on the role of the 13 major dams in the basin, but the NMFS plan does not have broadly integrated socioeconomic and biophysical science teams. The plan relies on a web presence and outreach to many local organizations for feedback.

Adaptive Management - Adaptive management is widely emphasized in the OPSW, NMFS Upper Willamette Plan (Anderson et al. 2003; NOAA 2007), the Council's Fish and Wildlife Program, the Northwest Forest Plan, the Oregon Forest Plan, and watershed council projects. Application of adaptive management faces many hurdles that include public unwillingness to test system boundaries and limits, lack of ability by those planning adaptive management to bring the public into the process in its early stages, the complexity of landscape systems make testing hypotheses and developing comparative analyses very difficult, and the time lags for restoration results to occur are often very long. Further, the dynamics of the landscape system makes for complexity that is very difficult to understand. Thus far, adaptation has followed more the direction from continuing public engagement that drives the system toward greater conservation and restoration of ecological processes while economic growth decisions continue many of the past patterns.

Challenges and Lessons Learned

The Oregon land-use planning approach and the OPSW are the backbone of the evolving Willamette Basin landscape perspective. These statewide programs have been supplemented by the Council's subbasin planning process, DEQ/EPA water quality standards and planning, a strong science component and collaboration with state universities and agencies, a broad variety of NGOs that represent a diversity of public interests, and a history of collaboration to work on the environmental conditions taking into account economic considerations.

Overall, socioeconomic engagement has been widespread in the Willamette Basin. The public has been brought in early and a wide range of communication techniques have been used to engage the public and allowed for discussion of socioeconomic issues. An often over used approach to citizen engagement is the public meeting. Willamette Valley citizens have expressed frustration with those hosting these meetings as the only form of citizen engagement because citizens feel their views are often disregarded, their language is not understood, and their local knowledge is not valued. Many citizens prefer to be informed early, have an opportunity to participate, and be active in debate about socioeconomic issues. Citizens, however, have many priorities and getting their engagement is not always easy.

A landscape perspective has been advanced by scientists and the perspective communicated to a substantial segment of the Willamette Valley population. Scientific collaboration has provided a national model in using a comparative scenario approach. Goals and measures for a landscape perspective need more specific development and tracking. Oregon land use planning and the OPSW provide an incentive for collaboration. Land-use planning provides rules for addressing landscape issues and has procedures that promote involvement and collaboration of scientists and managers, diverse groups of citizens, and interdisciplinary science teams. Watershed councils created under the OPSW have the objective of collaborating with local landowners and educating the public.

Adaptive management is mentioned in most resource planning contexts, but its practice still has hurdles to overcome. Much is being learned, but much of that learning is not being archived and used for broader learning. NMFS's Upper Willamette Plan, OPSW, and MMT/BEF model watershed program strongly emphasize adaptive management.

Challenges come from the interaction between economic growth and landscape conservation and restoration. The goal of Oregon land-use planning is to stem the conversion of agricultural and forest lands into development. Land-use planning requires concentrating population in urban areas. This continues to require improved public education and application of development, zoning, and building codes. The continuing population growth and related development decisions appear to be moving the Valley away from large-scale, landscape conservation and restoration. Without more limits to exceptions made by county officials and commissioners, as well as better incentives to landowners for beneficial land uses, conservation goals cannot be reached. For example, the Conservation Reserve Enhancement Program (CREP) only applies to land “in production” and provides no incentive for protecting or keeping other lands along streams out of production. Many landowners who could use CREP do not because they find the application process too bureaucratic, or they do not trust government (Gibson 2003). Another need is for better coordination by regional technical assistance teams to help counties to evaluate land-use policies—many counties lack money and expertise to coordinate with regional technical teams.

Benton County, Oregon is a good example within the Willamette Valley of successfully involving residents, local government, state agencies, non-profits, and scientists in plans to evaluate water use, water quality, and improve the riparian and wetlands of the county. They have had active citizen advisory groups that participate in implementing State requirements for comprehensive planning for land uses, including inventory of riparian, wetlands, ground water, and water quality, and to recommend actions. The problem for Benton County is that this effort has been limited in terms of generating dollars to sustain its goals. This is the same situation faced by other organizations that are unable to generate funds to sustain subbasin social engagement, integrated collaborative science and governance, and adaptive management.

B. Case History: Moreton Bay (Queensland) Australia

Moreton Bay represents a highly innovative and successful application of landscape principles to catchment restoration. The Moreton Bay catchment covers 21,220 km^2, contains 14 major river catchments, and is highly diverse socially, economically and ecologically (see www.healthywaterways.org for more information). A strong body of scientific information was critical for both effective management and for illustrating the value of communicating that information to stakeholders to motivate them to be involved in the work and the decisions. One main driver for change in Moreton Bay was increasing community expectations about improving water quality access and uses and the recognition of the potential loss of industry viability for tourism, fishing, and agriculture. A major coordinated scientific research program highlighted the key assets being endangered and the potential of the Bay to improve the citizen's quality of life. The effective communication of scientific information to all stakeholders and decision makers increased confidence in the information presented to them.

Moreton Bay is home for 270 bird species, 740 fish species, 40 outstanding tropical corals, and several endangered sea turtles. While Moreton Bay represents only 3% of the Queensland coastline, it produces 13% percent of the state's commercial fish catch and supports ~30% of Queensland's recreational income. Several rivers feed directly into the Bay, most notably the Brisbane River (area >13,500 km^2), including >850 km of river and lake bank. Economically, the 1998 - 1999 total trade through the Port of Brisbane was nearly 21 million tons, valued at AUD$13 billion. In 2000, tourism was Queensland's second largest industry behind mining, with visitors contributing AUD$12 billion to the economy. Sound economic management requires that Moreton Bay's natural assets and resources bases be protected and restored in order to support Queensland's second largest industry.

These pressures led government, industry, and community stakeholders to work in close cooperation to develop a Regional Water Quality Management Strategy - a combination of continuing local initiatives and new management actions determined by stakeholders and based on good scientific information. Eventually, the Moreton Bay Waterways and Catchment (Healthy Waterways) Partnership was formalized to facilitate the implementation of the strategy (www.healthy waterways.org).

An innovative regional planning approach for managing the waterways and catchments of Moreton Bay addresses key environmental issues. Based on the need to restore the ecological balance of both land and water, it is crucial for sustaining the waterways and the derived benefits they provide. It adopts a holistic approach focusing attention on all the catchments, from the sources to the sea. The regional plan is implemented by state agencies, local governments, industries and community organizations. Two key elements of the approach are the development of a Regional Water Quality Management Strategy and the establishment of the Moreton Bay Waterways and Catchment (Healthy Waterways) Partnership. During the early stages of the Strategy, development of a common and a coherent vision[22] was agreed upon by all stakeholders and this vision is used as a "rallying" focus to assist resolution of issues relating to the identification, prioritization and scoping of technical investigations and for obtaining agreement on management actions.

[22] The vision: "South-east Queensland's catchments and waterways will, by 2020, be healthy living ecosystems supporting the livelihoods and lifestyles of people in south-east Queensland and will be managed through collaboration between community, government and industry."

Using a mix of regulatory and voluntary measures, the partnership has defined and implemented a set of management actions to resolve catchment – coastal issues, and has been successful in resolving a number of them (details below). The case study demonstrates that linking the management of marine and estuarine areas with the management of catchments require a broad based program including collaboration among government, industry and community, local political leadership, consensus among all stakeholders regarding the objectives and management actions, and decision making based on solid scientific information (see the Healthy Waterways website for scientific details).

Lessons Learned

Socioeconomic Engagement - Much time and effort are spent on technical feasibility and the social, cultural, and economic aspects of environmental choices. Methods used included community consultations, feedback from stakeholders and government officers, decision analysis to determine priority management actions, and cost-benefit analysis of different management actions.

Organize for Integration and Collaboration - Successful development of the Strategy is attributed to strong local political leadership and advocacy. A number of local government leaders provided effective support, and more importantly, these leaders accepted key roles within the Partnership to oversee the delivery of the Strategy.

Stakeholder involvement and collaboration resulted in over 60 organizations undertaking management actions in the Strategy. An Implementation Group, consisting of a range of stakeholders, was established to regularly assess the status of the management actions and report progress to the Regional Coordinating Committee of the Queensland government. This arrangement effectively provided an ongoing audit of stakeholder commitments, a step often overlooked in resource management planning process.

Scientific investigations reveal considerable knowledge of southeast Queensland waterways and highlight serious issues in the catchment. The latest scientific and modeling results are provided to stakeholders on a regular basis enabling them to be fully informed thereby allowing decisions to be made quickly. Communication of information is based, as much as possible, on diagrams and conceptual models. Effective communication methods and communication skills of scientific personnel greatly increase confidence within the community and with the decision makers.

The Strategy fulfills certain priority actions of the Queensland government's Regional Framework for Growth Management and it incorporates and provides information to a variety of local and sub-regional plans and projects and for a variety of legislation. Thus the Strategy provides a common vision, values, and measurable water quality objectives and scientific information to assist the integration of local plans and legislation.

Adaptive Management - The restoration of Moreton Bay is an adaptive management process. However, like any restoration program, there remains important work to be done and measures to be implemented. The results of the 2009 EHMP Report Card, the most recent one available, emphasize the connectivity between the region's catchments, waterways, and Moreton Bay. The significant decline in the ecosystem health of Moreton Bay, declining from B- (in 2008) to D (in 2009) was caused by the discharge of extremely high loads of sediment and nutrients from the catchments as a result of unusually heavy rainfall across the region. Despite this heavy rainfall and the increased nutrient and sediment inputs, there was little change in the overall ecosystem health of freshwater streams, with improvements in biological indicators (macroinvertebrates and fish) resulting from the increased stream flows offset by a slight decline in nutrient cycling. These results highlight the importance of reducing and addressing diffuse source pollution, both rural and urban, to improve waterway health. Results from the most recent devastating floods (December 2010 to January 2011) are currently being analyzed.

The basic tenets and principles used for the Moreton Bay catchment are directly applicable to the Columbia River Basin. The key roles of public education and involvement, inclusion of city and county officials, the role and use of science, and the reliance on the inherent "beliefs" and values of the various cultures in the catchments are foundation ingredients in its success to date.

Contact for Additional Information

- For details on Moreton Bay and the upland rivers see the Healthy Waterways website: www.healthywaterways.org/
- A Brief History of Moreton Bay: www.users.bigpond.net.au/pludlow/bayhistory.htm
- Moreton Bay Catchments Latest Report Card (summary): www.ehmp.org/filelibrary/3d-regionalsummary-moreton-web.pdf
- South East Queensland's Ecosystem Health Monitoring Programme: www.ehmp.org/about_ehmp.html

Learning from Global Examples

In addition to Moreton Bay, recent years have seen a global focus on the restoration of many important catchments and the restoration of numerous rivers. Collectively, these provide a plethora of examples for improving management in the Columbia River Basin. Several hundred case studies from around the world, especially those aimed at Integrated Water Resources Management (IWRM) have been summarized by the Global Water Project (www.gwptoolbox.org; Alcamo et al. 2008).

C. Case History: The Skagit River Basin, Washington

The Skagit River Basin encompasses 8,030 square kilometers of watershed area and includes about 326 hectares of delta connecting the river to estuary and near shore ocean habitats (Figure X.3). The basin represents all freshwater and estuarine habitats for multiple salmonid species, life history types, and stocks. These include spring, summer, and fall Chinook salmon, pink salmon, chum salmon, sockeye salmon, coho salmon, summer and winter run steelhead, sea run cutthroat trout, Dolly Varden and bull trout. The human population is about 200,000 people with stakeholders and governing bodies that include three treaty Indian tribes; two U.S. federal and three state land management agencies; Canadian federal, provincial, and municipal governments; three county governments; various local municipal governments; and private property owners. There has been considerable habitat loss associated with agricultural land conversion, road and highway construction and urbanization in the lower basin and river floodplain areas. This includes an estimated loss of 73% of tidal delta and 98% of non-tidal delta areas, 86% of pocket estuaries, and 37% of the large river floodplain (upstream of the non-tidal delta, Collins and Sheikh 2002). Approximately 17% of the mainstem river channel has been hardened. Five major dams, hydropower development, and logging have been important in the upper basin, but most remaining habitats are still considered to be in relatively good

Figure X.3. The Skagit River Basin in northwestern Washington (from Beamer et al. 2005).

condition, influenced principally by roads and road related erosion.

The Skagit Watershed Council (SWC; www.skagitwatershed.org) a collaborative of 18 member organizations including private industrial and agricultural interests, state and federal agencies, local governments, tribes and environmental and citizen-based groups (Table X.1), has been designated as the Lead Entity to guide salmon habitat restoration planning under Washington State law and the Washington Salmon Recovery Funding Board. Federally recognized Tribes within the Skagit Basin include the Sauk-Suiattle, Swinomish and Upper Skagit tribal communities. Each Tribe, working either through its own natural resources programs or through the consortium known as the Skagit River System Cooperative (SRSC, www.skagitcoop.org) is formally responsible for co-management of the fisheries in the Skagit Basin in collaboration with the Washington Department of Fish and Wildlife (WDFW). The habitat restoration planning, assessment and implementation activities conducted by SWC within the basin have been supported largely by technical staff associated with the SRSC, WDFW, the U.S. Forest Service, and by NOAA Fisheries. The stated intent of the SWC Strategic Approach includes "restoring and protecting landscape processes that will produce the long-term, sustainable recovery of habitat conditions that benefit multiple species" with recognition that "long term watershed health is in part dependent on the community" (Beechie et al. 2010).

Table X.1. Member organizations of the Skagit Watershed Council

Fidalgo Fly Fishers	Long Live the Kings
Mount Baker-Snoqualmie National Forest	North Cascades Institute
North Cascades National Park	Padilla Bay National Estuarine Research Reserve
Public Utility District #1 of Skagit County	Puget Sound Energy
Seattle City Light	Skagit Audubon Society
Skagit Conservation District	Skagit County
Skagit Fisheries Enhancement Group	Skagit Land Trust
Skagit River System Cooperative [1]	The Nature Conservancy
Washington Department of Fish and Wildlife	Western WA Agricultural Association

[1] Composed of the Swinomish Indian Tribal Community and Sauk-Suiattle Indian Tribe

Significant restoration efforts began in the Skagit in the early 1990s, focused on habitat losses influencing coho salmon (Beechie et al. 1994). Efforts to assess habitat losses across the basin and guide more substantial restoration efforts followed ESA listing of Chinook salmon in 1999. Steelhead were listed in 2007. A series of strategy and implementation documents have been developed since 1998 (e.g., SWC 1998; Beamer et al. 2000). A recovery plan for Chinook salmon was completed in 2005 (Beamer et al. 2005) by the SRSC and WDFW in consultation with other groups. A basinwide Strategic Approach was revised most recently in 2010 (Beechie et al. 2010).

Socioeconomic Engagement **-** The SWC expressly acknowledges that a major challenge for species recovery will be achieving community support for the extensive restoration needed on or near private lands. Intensive land conversion for agriculture has occurred in much of the low elevation and floodplain area. One step toward social engagement has been to understand the willingness of Skagit County residents to support actions that benefit salmon and their habitats (ERI 2005). Although land use and development issues represent contentious tradeoffs, many residents valued salmon, supported salmon recovery planning and believed they personally had some responsibility in helping to solve the problems (ERI 2005). Some restoration efforts have intentionally involved volunteers from the public in a form of experiential learning. Evaluation of these efforts suggests that they can influence public understanding and support for restoration and conservation efforts (Breslow 2005). Skagit County has initiated a conservation planning effort known as Envision 2060 engaging a broad representation of natural resource, business, private landowner, government, and conservation interests. This project is supported by the Envision modeling process developed through Oregon State University to help decision makers and the public visualize the effects of a range of policy/land use scenarios on landscapes of the basin.[23]

Landscape Approach **-** Over the last 20 years managers and researchers have focused on habitat change and the causes of that change, building a foundation for conservation and restoration planning with a very strong landscape or basin scale perspective (Beamer et al. 2000). The approach of the SWC has been to target restoration in specific areas guided by three principles: 1) restore processes that form and sustain habitats by focusing on underlying causes of degradation, considering local potential, and matching the scale of restoration to the underlying problem; 2) protect processes and habitats that are currently functioning as sources for long-term recovery and represent the most cost-effective actions; and 3) focus protection and restoration on the most biologically important areas.

Two decades of research and assessment on habitat loss and the implications for salmon and steelhead populations provides a basic understanding of species and life history distributions, status, and key constraints. Focused research and analysis of the physical processes influencing habitat creation and maintenance in key areas (e.g., Beamer et al. 2000; Williams et al. 2004; Yang and Khangaonkar 2006; Beeche et al. in review) provides a foundation for restoration actions. Because life-cycle patterns of habitat use and limitation vary among species and life history types, a spatially explicit evaluation of the patterns in, and magnitude of habitat loss and the processes driving habitat impairment provide an important perspective (Figure X.4). The integrated analyses support a tiered restoration strategy that prioritizes basinwide restoration efforts and targets the fundamental causes of habitat loss, degradation, or constraint (Figure X.5). Coho, for example, appear most strongly limited by the loss of floodplain delta and pond habitats. Chinook salmon populations that make extensive use of mainstem and floodplain habitats throughout the life cycle are constrained most by losses in these areas. Steelhead are believed to be most limited by mainstem floodplain and some tributary habitats. Because the greatest impairments have occurred in the estuary, river delta, and river floodplain areas used by Chinook salmon (the current target species for federal funding), these are considered the most limiting and important conditions to address in the near term. Tier 1 targets these conditions for restoration. Tier 2 targets areas nearshore and floodplain rearing habitats used by important, individual populations. Tier 3 targets tributary watersheds that are generally less impaired overall but have localized problems with elevated erosion or hydrologic conditions that influence incubation survival of Chinook salmon.

[23] www.skagitcounty.net/Common/Asp/Default.asp?d=EnvisionSkagit&c=General&p=modeling.htm

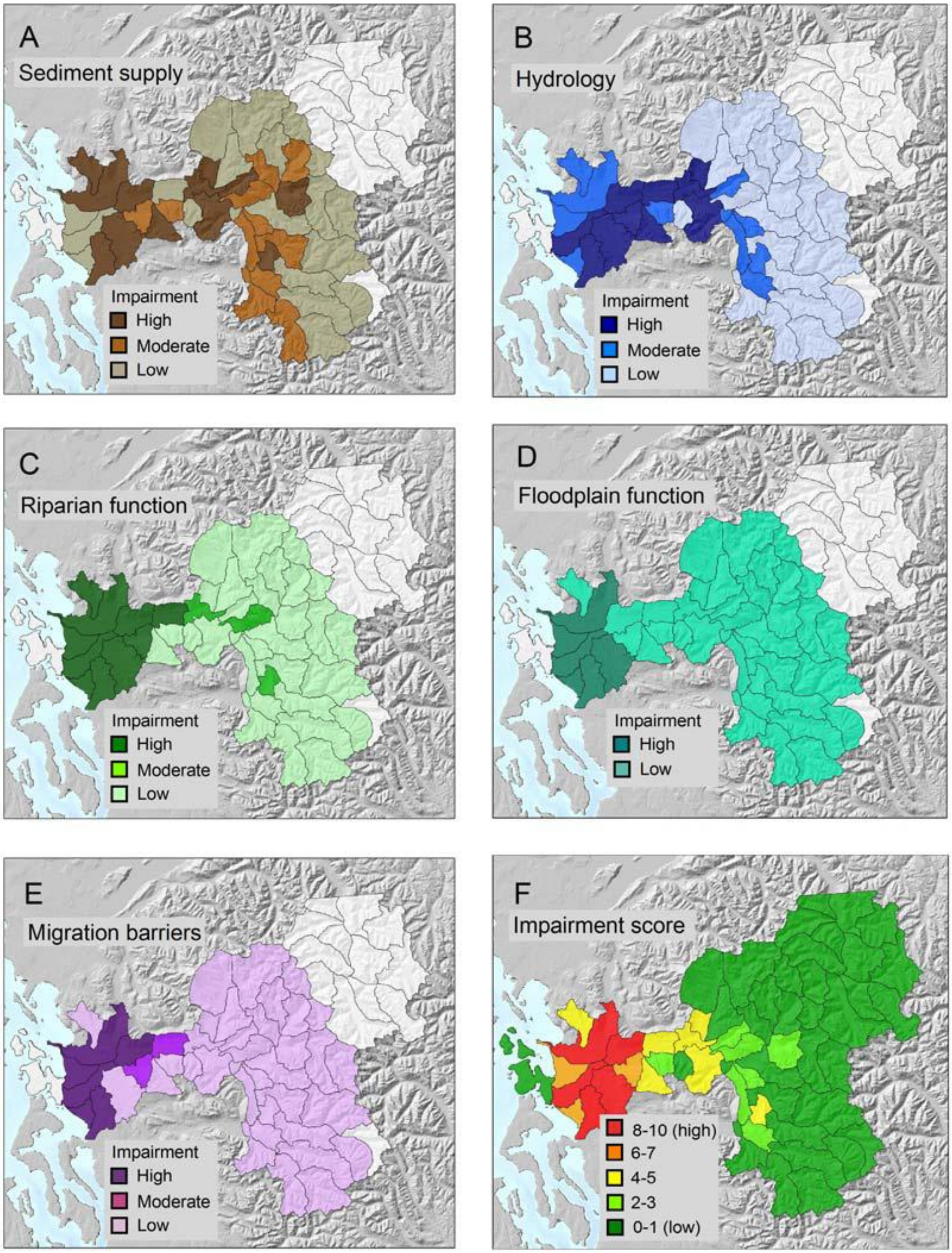

Figure X.4. Habitat impairment maps for the Skagit River Basin watersheds (from Beechie et al. 2011).

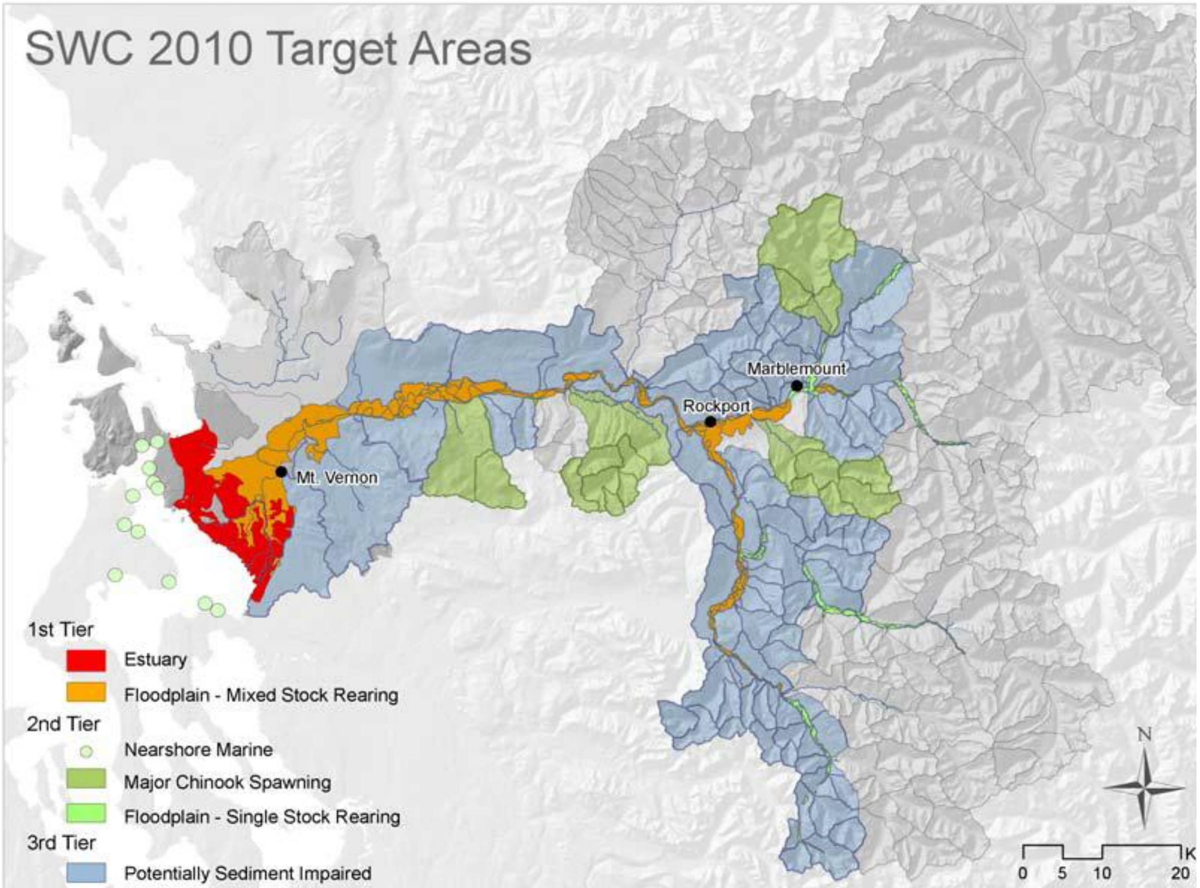

Figure X.5. Three Restoration Tiers from the Skagit River Strategic Approach (from Beechie et al. 2011).

Organize for Integration and Collaboration - The Skagit Watershed Council provides a potential framework for coordination of diverse interests focused on or interacting with habitat restoration across the basin. The science efforts have been multi-disciplinary in the sense that they have relied on the expertise of hydrologists, riparian ecologists, geomorphologists, and fishery biologists. Land-use planning initiated by Skagit County has engaged broader diversity of technical capacities for both public and private interests that could conceivably integrate with watershed restoration efforts.[24] Recognition of the SWC as the lead entity for salmon recovery planning within the State and technical support provided through state, tribal, and federal authorities should provide scientific credibility in that broader forum. The planning and guidance provided by the SWC provides a framework for restoration, but implementation will depend on opportunities that emerge with willing landowners, diverse funding sources, and the capacities represented by collaborating groups. Although restoration may still progress in piecemeal and opportunistic fashion clear

[24] www.skagitcounty.net/Common/Asp/Default.asp?d=EnvisionSkagit&c=General&p=techmembers.htm

articulation of priorities and focus on critical process could make these efforts more efficient and effective. In our view, the opportunity to leverage additional and larger resources for restoration and conservation should be strengthened by the implied consensus of the diverse partners in the SWC and the strong technical foundation in restoration planning.

Adaptive Management - Monitoring and adaptive management are mentioned repeatedly in the planning and implementation documents. The Skagit is part of the larger Puget Sound Partnership (www.psp.wa.gov) that is currently developing a monitoring and adaptive management plan for the Puget Sound Chinook Salmon Recovery Plan (Shared Strategy for the Puget Sound 2007). The draft plan received generally high marks in an independent technical review (RIST 2009) and appeared to be particularly strong in guidance and infrastructure for governance, and coordination. Implementation is still in the early stages, however, and there is little information to judge how effective actual implementation can be.

Challenges and Lessons Learned

The broad base of scientific assessment with a focus on underlying process and the most limiting habitats critical to the expression of complete and diverse life histories provides a strong landscape perspective. Although current restoration efforts are focused on recovery of Chinook salmon, the prioritization of massively altered habitats important to multiple species and life history types should contribute to abundance and diversity for other fishes as well.

A strategy for prioritization of restoration actions has been forged through a process of inclusion, collaboration, and governance (through the SWC and its member organizations) for over 15 years. Fisheries and watershed science and research have been effectively engaged with this collaboration to create a landscape- science perspective. That experience is relatively unique and may serve as a useful example for others struggling with integration, collaboration, and effective governance. Despite the strong foundation, resolution of social and economic issues remains a critical challenge. Land conversion has been extensive, and the general trend toward development and growth continues. Although the public has been generally supportive of salmon restoration in concept (e.g. ERI 2005) the hard decisions and tradeoffs needed to conserve existing systems and restore those damaged by excesses of the past are still strongly debated. Strong support from local non-tribal agricultural and urban landowners is lacking, and “NMFS acknowledged existing disagreements among various parties in the Skagit Basin about certain aspects of the local watershed plan” (NOAA 2006:28). Resolution of conflicts between agriculture and watershed/riparian restoration and conservation has proven to be a particularly difficult issue. Whether landscape restoration important to the maintenance of resilient native fishes and fisheries in the Skagit can be truly effective over the long term remains an open question, but the technical capacities and collaboration here are strong and those elements should provide important lessons for others.

D. Case History: The Snohomish River Basin, Washington

A major challenge associated with recovering imperiled species is identifying a set of actions needed to ensure the species' persistence. Often the myriad causes of a species decline make it difficult to choose strategically among potential recovery actions. In the Snohomish River Basin, a 4,780 km^2 watershed in northwestern Washington, a group of scientists and stakeholders (41 member forum) developed a quantitative and transparent modeling approach for identifying key actions across the broad landscape for recovering Chinook salmon, which are listed as threatened under the Endangered Species Act. This approach to salmon recovery planning is unique because it encompasses actions across the entire watershed, including 62 subbasins, and throughout the life cycle of Chinook salmon, e.g., habitat, harvests, hatchery interactions, and hydropower (Snohomish Basin Salmon Recovery Forum 2005, Bartz et al. 2006, Scheuerell et al. 2006). The approach is data intensive, but the modeling framework has been developed and published along with functional relationships that can be readily modified for adaptation to unique characteristics of each watershed.

An initial step was identifying salmon habitat conditions and river processes that could be linked to land use activities in the watershed (Figure X.6). The approach used statistical rather than mechanistic relationships when linking habitat quality (e.g., prespawning temperature, incubation temperature, peak flow, and fine sediment) to land use activities and geomorphic attributes. A limitation of this approach was that some land-use activities were not linked to salmon habitat quality, so that the model probably underestimated the overall benefit of habitat restoration activities. Potential juvenile and adult habitat capacity characteristics were based on detailed GIS mapping and literature estimates of mean density in each habitat type (e.g., pool, riffle, glide, backwater, etc. for juveniles).

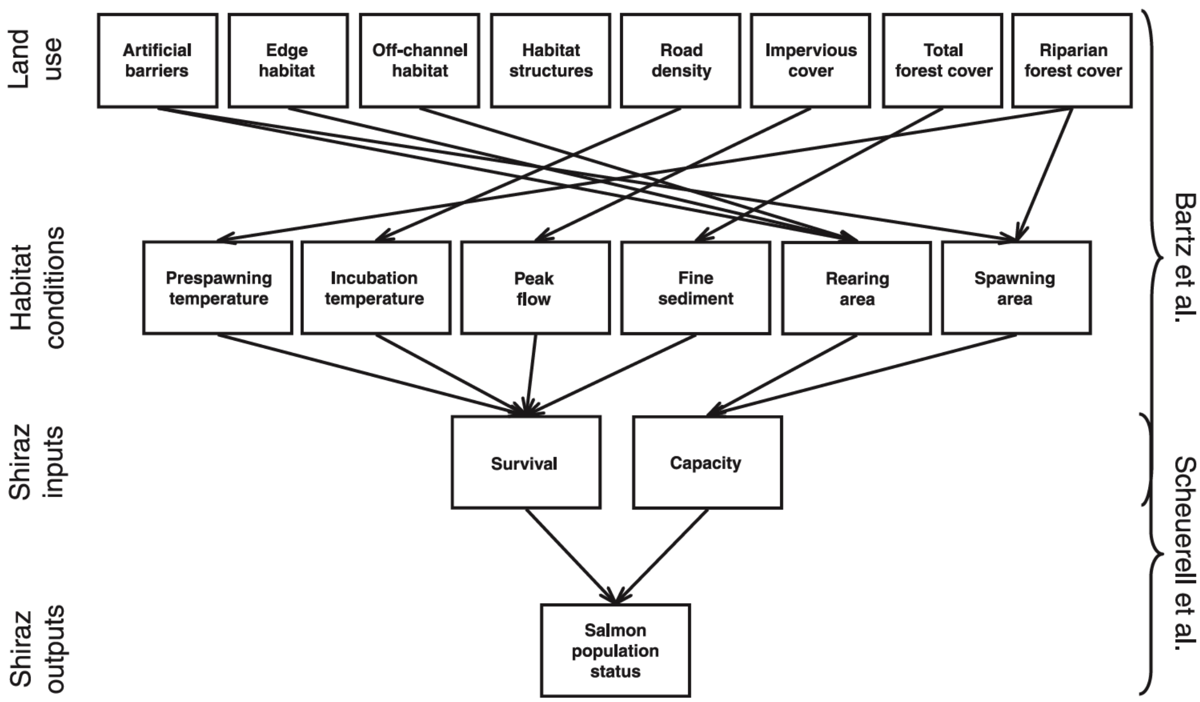

Figure X.6. Diagram of the linkages between land use activities, salmon habitat, and salmon population status (estimated by Bartz et al. 2006 and Scheuerell et al. 2006).

The Shiraz life history model (Scheuerell et al. 2006) was used to integrate key factors affecting Chinook salmon across the entire life cycle (six life stages considered), and in specific watersheds occupied by freshwater life stages. For this, the model uses a series of Beverton-Holt recruitment curves representing each life stage so that density-dependence, habitat capacity, hatchery releases and harvest scenarios can be incorporated into the model findings. The model considered only ocean-type Chinook salmon that go to sea after only a few months of rearing in freshwater. Abundances of fish at each life stage can be estimated.

Using the Shiraz model, the scientists compared three scenarios: current conditions, a test case where specific habitat conditions were improved, and historical conditions. These scenarios were evaluated in terms of key salmon population attributes: abundance, productivity, spatial structure, and life-history diversity. The modeling effort, along with information provided by Ecosystem Diagnosis and Treatment evaluations, provided the Snohomish Basin Recovery Planning Group with clear choices for strategies to recover Chinook salmon. Robust salmon populations during historical conditions provided evidence that habitat protection was key. Sensitivity analyses suggested that restoration actions aimed at improving juvenile rearing habitat in the estuary and lower mainstem reaches would have the best chance of improving overall population performance. This finding was consistent with independent observations that these habitats were highly degraded. Furthermore, the model findings indicated that the test case scenario for habitat restoration would only achieve 50% of the goal for Chinook salmon recovery that was adopted by the planning group (Figure X.7). Additional use of the Shiraz modeling approach is described in the 10-year Snohomish River Basin Salmon Conservation Plan (2005). This use includes adaptive management and incorporation of climate change scenarios. It was also used along with the Ecosystem Diagnosis and Treatment approach. The Shiraz modeling approach has rarely been applied to other large watersheds, as it was in the Snohomish Basin, because the approach requires considerable data (M. Scheuerell, NMFS, pers. communication).

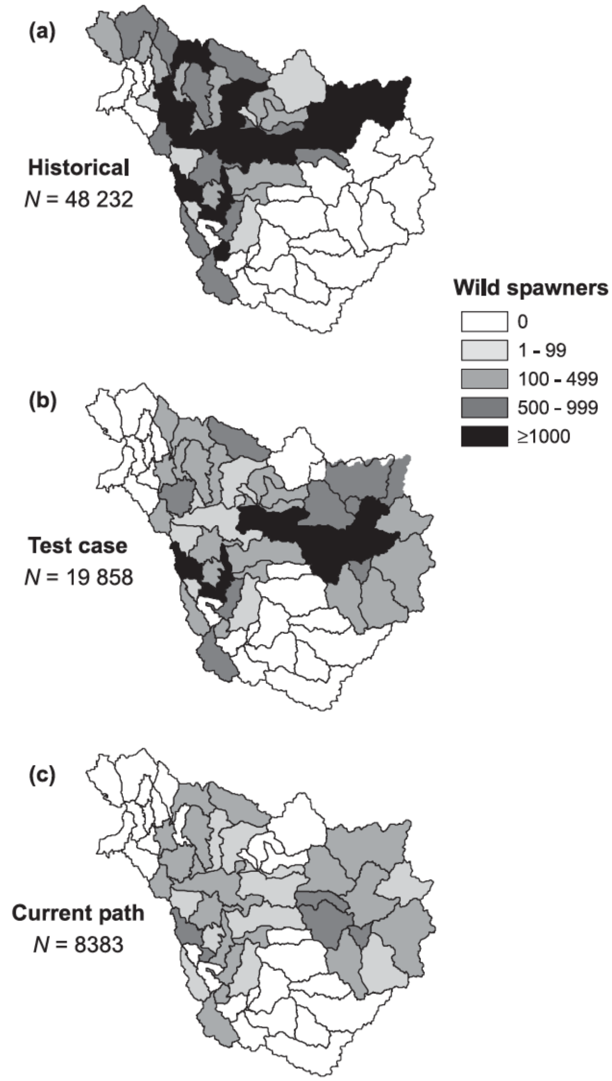

Figure X.7. Maps of the spatial distribution of the predicted number of Chinook spawners under a) historical, b) test case, and c) current path scenarios. The estimate of equilibrium spawner abundance (R/S = 1) is listed under each name. The predictions were based on the Shiraz model (Scheuerell et al. 2006).

Challenges and Lessons Learned

Socioeconomic Engagement - The planning effort initially identified a basinwide funding goal of $15 million per year over the 10-year planning period to meet specific habitat and fish goals, but the 3-year review concluded that the annual need is $21 million per year (SBSRF 2010) or approximately $210 million over the 10-year planning period. Although the recent overall funding level is $15 million (including mitigation funds), the habitat proportion of the plan has only received 34% of what is needed and the current backlog of project work is $40 million. The severe funding shortfall places a much greater need on accurate prioritization of projects. The SBSRF (2010) concluded that project grant periods should be scaled to the size and complexity of the project rather than the typical 18-month grant period. Key factors affecting implementation of restoration activities include conflicts with agriculture and recreational boat use (large wood placement). In particular, quasi-governmental diking districts can impede restoration projects even when the land owners support restoration. Creative approaches, such as land trades, are being considered as a means to restore key habitat while also preserving agriculture.

Landscape approach - The Snohomish Basin restoration effort provides an example of how a salmon life cycle model can be used to evaluate and prioritize habitat protection and restoration activities across a large watershed while also integrating harvests, hatcheries, and hydropower. Although habitat protection was identified as the top priority, the conservation plan did not establish a detailed protection strategy (SBSRF 2010) and there is concern that key habitat is not being protected (PSP/RITT 2010). A recent four-year grant from EPA will enable the watershed group to develop habitat protection strategies in response to development and climate change (PSP/RITT 2010). Key regulatory mechanisms for protecting habitat include shoreline master programs and critical area ordinances, FEMA's National Flood Insurance Program, and reversal of the Army Corps of Engineers Levee Vegetation Management Policy (PSP/RITT 2010).

Organize for Integration and Collaboration - Practical and political issues were considered when targeting habitat restoration, but targets were primarily based on science (e.g., 80% of basinwide capital project resources should target nearshore, estuary, and mainstem strategy groups). The conservation plan developed land-use recommendations, but local governments such as diking districts retain the authority to implement policies and projects. A three-year work plan (updated annually), produced by the Forum and maintained by the Puget Sound Partnership, is used to inform stakeholders about specific progress relative to benchmarks and funding issues. The plan and projects are integrated with a variety of other activities in the Puget Sound region, as well as hatchery and harvests.

Adaptive Management - One of the biggest challenges for implementing recovery plans in the Puget Sound is the development of a realistic, useful, and applicable adaptive management plan at the watershed level. A monitoring and adaptive management framework was developed, and a detailed plan is now under development in the Snohomish Basin. The three-year work plan describes linkages between plan strategies, benchmarks, and implementation progress in order to re-evaluate priority actions. The workgroup recognizes the need for monitoring restoration projects and evaluating basinwide responses of fishes. The work plan is critiqued by the Puget Sound Partnership and Recovery Implementation Technical Team (PSP/RITT 2010), who also oversee implementation of conservation plans throughout the Puget Sound.

E. Case History: Oregon Coastal Coho Conservation Plan

The State of Oregon's Coastal Coho Conservation Plan (hereafter Coho Plan; ODFW et al. 2007) is an example of a well-articulated landscape-level plan for meeting a desired status for a non-ESA listed ESU salmon resource. Oregon's mission for fish and wildlife is to "restore the watersheds of Oregon and to recover the fish and wildlife populations of those watersheds to productive and sustainable levels in a manner that provides substantial environmental, cultural and economic benefits" (P. 11). Oregon's Coho Plan is a specific extension and application of that mission dealing with the coastal coho ESU and its 57 constituent populations. The plan has "a science-based, socially established desired status goal" (P. 3-4) encompassing ecological, social, economic, and other considerations. The Coho Plan is viewed as a living, evolving process, with a 50-year time frame to improve the status of the species.

Although the word landscape is nearly absent in the 63-page plan and its appendices, this collaborative effort takes a landscape approach and effectively uses adaptive management. However, it does not give much evidence of collaboration beyond agencies and does not indicate feedback from adaptive management to stakeholders.

Socioeconomic engagement - A key element of this plan is to provide a "higher and more effective level of support to local conservation groups and private landowners (e.g., Soil Conservation Districts, watershed councils, industrial forestland owners, Salmon and Trout Enhancement Program (STEP) volunteers, and other individuals and groups). These community-based groups have demonstrated an impressive record of planning, prioritizing, and implementing habitat improvement projects …" (P. 3).

Landscape Approach - The Coho Plan is designed to "address the potential effects of human activities, or threats, across the full life cycle of the coastal coho ESU including management activities upstream from the distribution of coho salmon, downstream through tributaries, mainstems, estuaries where coho reside, and/or migrate to the ocean." (P. 6). The plan is concerned with salmon productivity, distribution, stock diversity and habitat across the ESU. They are interested in implementing restoration activities within populations, so they "will continue to support local watershed entities as they implement population-specific actions at scales appropriate for conservation." (P. 6). The plan is not, however, intended to prescribe habitat actions at local scales, "but instead, establish direction and sideboards to help local conservation entities custom-tailor restoration activities to address specific limiting factors within their watersheds" (P. 6).

Overall, they identify stream complexity, specifically high-quality overwinter rearing habitat, as the predominant limiting factor for populations in the Oregon coast coho ESU. High flows, which can commonly occur in winter in Coast Range rivers, can flush juvenile coho out of streams and into the salt water where pre-smoltification mortality would ensue. Complex overwinter habitat provides critical refuge for fish during these periods. They identified high quality over-wintering habitat for juvenile coho by one or more of the following features: "large wood, a lot of wood, pools, connected off-channel alcoves, beaver ponds, lakes, connected floodplains and wetlands, and other conditions…. High quality over-wintering habitat is almost always present *only* in areas where the stream is fairly low gradient and there are broad valley areas alongside the stream" (P. 24). Although overwintering habitat was considered the most common limiting factor overall across the ESU, exotic species may be limiting in some instances, and water quality is a secondary limiting factor in numerous cases. Since most of this limiting habitat is on private lands, they conclude that "the best strategy for protection and restoration of high-quality over-winter rearing habitat in these privately-owned, lowland areas … is to seek the voluntary participation of the landowners" (P. 29).

Several of the participating agencies are addressing landscape-level and watershed-level planning, research, and monitoring and evaluation as part of the plan. For example, the Interagency Mapping and Assessment Project (IMAP) by the Oregon Department of Forestry is designed to "produce consistent, landscape-wide vegetation mapping…" (P. 36).

Organize for Integration and Collaboration - The plan notes that all historical salmon plans for coastal coho salmon in Oregon have failed because "all of the salmon restoration plans created prior to the Oregon Plan noted the adverse effects of traditional land and water uses, but none offered any substantive means of protecting or restoring habitat. These historical salmon management plans were created solely by an Oregon fisheries agency, independently, and without support from the various state and federal management agencies that directly affected the watersheds that support salmon throughout their life cycle" (P. 12). In the Coho Plan, a large number and diversity of agencies acting directly and through cooperation with private landowners and other publics are integral parts of the plan. The agencies include Oregon Department of Fish and Wildlife, Oregon Watershed Enhancement Board, Oregon Department of Forestry, Oregon Department of Agriculture, Oregon Water Resources Department, Oregon Department of Environmental Quality, Oregon Department of State Lands, Oregon Department of Land Conservation and Development, Oregon Department of Geology and Mineral Resources, Oregon Department of Transportation, Oregon Parks and Recreation Department, U. S. Environmental Protection Agency, U.S. Forest Service and Bureau of Land Management.

There is significant involvement by Oregon Department of Forestry, the Oregon Watershed Enhancement Board, the Oregon Department of Agriculture and others to enlist funding for groups such as watershed councils and soil and water conservation districts. The Coho Plan noted that these groups are critical for developing relationships in local communities that will allow projects to be implemented on private lands. Private landowner involvement is critical because a premise of the plan is that habitat management and improvement is the key to protecting and enhancing coastal coho, and much of the most important coho habitat, especially the limiting over-wintering habitat, is on private land. The Coho Plan concludes that "habitat improvement on private land is most likely to occur through incentive-based cooperative partnerships with landowners; and the [plan] provides the best vehicle for securing these partnerships and implementing habitat improvements" (p. 6).

Adaptive Management - Adaptive management is prominent in the Coho Plan, which has a separate section entitled "Application of Adaptive Management" (Page 54 *et seq*.). They call the Coho Plan "… a dynamic strategy that will adapt and be modified over time in response to learning from monitoring data and implementation experience" (P. 4). Adaptive management in Oregon is identified as having four steps:

1. Natural resources are managed under existing statute, rule, or policy guidance.
2. Monitoring provides data for future analysis.
3. Periodically, monitoring data are assessed.
4. Results of data analysis are considered by a responsible agency, board, or commission regarding the need or appropriateness of changes to statutes, rules, or management policies. Occasionally, the deliberation may involve a broader legislative and public policy discussion. (P. 54)

Under this adaptive management, the state of Oregon commits to "reassess the status of coastal coho populations and their supporting habitat on a periodic basis, providing information that may be considered in an adaptive management process… these commitments include the following:" (p. 54-55)

- A succinct six-year status report "regarding implementation of commitments by agencies, restoration work accomplished, and summarizing coho and habitat data available by population, strata, and for the ESU" (p. 55).

- A twelve-year ESU assessment including "performance of the coho, trends in habitat, and implementation and effectiveness of restoration and management commitments" (P. 55). Appendix 2 of the Coho Plan contains a detailed list of measurable criteria for evaluating whether progress is being made toward the desirable state of the coastal coho ESU. The criteria include adult fish abundance, persistence, productivity (recruits per spawner), within-population distribution, genetic diversity, and habitat conditions. Criteria are also established for dependent populations, i.e., those dependent on nearby independent populations for long-term persistence.

- Annual status reports **–** brief reports serving as an early warning system of changing factors. Proposed content of these brief reports is also identified, including adult fish counts, juvenile monitoring data, habitat data, harvest impact data, hatchery survival data, natural fish survival rates, information from local entities and landowners and conservation project implementation data.

The role of adaptive management is spelled out clearly: "The …Coho…Plan is intended to describe key elements for immediate implementation and also provide a strategic means of improving management decisions in the future – in essence, to be a living document. This will be done through an adaptive management process that will allow for the continual assessment of the effectiveness of management strategies and actions to improve the status of coho in the ESU" (P. 56). A key aspect in RM&E is *evaluation* to support adaptive management (P. 8): "Through the analysis of research, monitoring, and evaluation (RM&E) data, the Oregon Plan Core Team will be able to determine if the premise of the plan - that the management strategy will be able to help the ESU achieve desired status – is accurate. If not, the adaptive management process will allow for the state to consider a different premise" (P. 56). They also note that the adaptive management process will occur at different levels. The adaptive management process can lead to changes in all aspects of the plan, not just strategies and actions.

A recent status review required by the ESU recovery process outlined above suggests the effort to use adaptive management is working. The recovery effort has well-defined habitat and population criteria for recovery, and it has a mechanism for evaluating progress toward those goals.[25] In the 2010 status review, the Biological Review Team (BRT) determined that the ESU was still "threatened" despite substantial increases in abundance. Monitoring showed limited habitat improvements, supporting the conclusion that the upswing was related to cyclic ocean conditions. By taking a larger perspective and integrating monitoring and restoration, the BRT showed that more effective habitat restoration is needed to sustain coho during downturns in ocean conditions.

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[25] www.nwr.noaa.gov/ESA-Salmon-Listings/Salmon-Populations/Alsea-Response/OCC-ESA.cfm

F. Case History: Upper Columbia Salmon Recovery Board (UCSRB)

The UCSRB is one of eight salmon recovery boards in Washington. The UCSRB grows out of the listing of spring Chinook salmon in 1997, failed state and federal efforts to address endangered species issues in the Upper Columbia, and recognition by local leaders that they had to become part of the solution. Notable about the salmon recovery boards in Washington is their effectiveness improving collaboration and governance. The UCSRB recovery plan was published in the Federal Register in 2007 (FR Doc. E7–19812 Filed 10–5–07). In December 2010, the UCSRB received the Partners in Conservation Award from the U.S. Department of Interior (USDOI), "…recognizing excellence in achieving natural resource conservation goals in collaboration with others" (UCSRB 2010a).

Washington and Oregon pursue two different approaches to salmon recovery attempting to solve the listing of salmon populations in different ways. Oregon relies on over 100 watershed councils to work with local citizens, and the effort is coordinated by the Oregon Watershed Enhancement Board. Washington takes a more regional approach using 62 Water Resource Inventory Areas (WRIAs) that are integrated into salmon recovery boards who evaluate proposals, allocate funding, implement and monitor projects, and evaluate the effectiveness of actions. The goal of salmon recovery boards is to use a more holistic, coordinated, and landscape-based approach.

The UCSRB (2007) is comprised of representatives from Chelan, Douglas, and Okanogan counties, the Colville Confederated Tribes and the Yakama Nation in the north-central part of Washington State (Figure X.8). Their mission is, "To restore viable and sustainable populations of salmon, steelhead, and other at-risk species through collaborative, economically sensitive efforts, combined resources, and wise resource management of the Upper Columbia region." Recovery boards emerged from the listing of salmon throughout Washington in the 1990s. Early efforts to conserve and restore salmon populations led to contentious exchanges between locals and government officials. Recovery boards are designed to bridge this gap and most effectively allocate recovery resources in a way that accommodates both salmon conservation and local economic needs.

Figure X.8. Salmon Recovery Board areas in Washington State (source: Washington State Recreation and Conservation Office, www.rco.wa.gov/salmon_recovery/regions/regional_orgs_map.shtml).

The 2007 recovery plan (UCSRB 2007) includes five watersheds, each with an associated Watershed Action Team (WAT)—Okanogan, Methow, Entiat, Wenatchee, Foster Creek and Moses Coulee. WATs are citizen groups that are interested in conservation and restoration activities in each of the five watershed areas. Members of each WAT are also opinion leaders in the watershed. Scientific guidance and restoration priority setting comes from the Upper Columbia Regional Technical Teams. The recovery plan was built from the NW Council's subbasin plans, and actions are governed by the UCSRB with oversight from NMFS, the Council, and Bonneville. Funding has amounted to $22.5 million, and this funding is having a significant local economic impact, particularly for construction jobs in bioengineered restoration actions.

Implementation of the plan has just begun and data on achieving the goals are yet to be consistently measured. The governance and collaboration structure is designed to engage willing participants in salmon conservation and restoration, to have a local voice, to boost the local economy, and to provide water for "people, farms, and fish." The Entiat subbasin is also an "intensively monitored watershed" – one of the watersheds studied as part of the Integrated Status and Effectiveness Monitoring Program (ISEMP) in which restoration actions are being monitored to determine project effectiveness.

Evaluation of the UCSRB plan is preliminary. The plan is new, actions are just beginning, and few projects have been completely implemented. Thus, currently not enough has been accomplished to know whether the major goals are being met. The UCSRB and the Willamette plans are two that take the most holistic landscape perspective in the Columbia Basin. They have distinct collaboration and governance structures, the evolution of which would be useful to follow.

Socioeconomic Engagement - UCSRB activities have allowed diverse interests to better understand one another. The recovery board is directly linked to county and tribal government, local citizens, and selected special interests through a variety of organizational entities (see governance and collaboration). Socioeconomic engagement, in the recovery plan is described as, "Implementation of specific recovery actions will be coordinated with local stakeholders and jurisdictions that determine the feasibility of recommend actions, including socio-economic interests, benefits, and costs" (UCSRB 2007:xix). The UCSRP plan specifies tribal, local government, interest group, and citizen participation in the process. The plan has limited guidance on citizen engagement.

The socioeconomic section of the plan is mainly concerned with the costs of completing actions (UCSRB 2007:250-260). Public involvement (UCSRB 2007:263-264) is handled through Watershed Action Teams. The plan encourages, "Local watershed citizen groups (e.g., Watershed Action Teams) engage in planning processes before project development resulting in project concepts that have a high probability of public support" (UCSRB 2007:264).

The main social engagement concepts are that actions are voluntary, locally based, bottom-up, and economically viable. Locals point out an agency "… can create any document they want, but it won't happen without buy-in by local people."

Landscape Approach - The plans of the UCSRB are focused on conserving and restoring habitat for spring Chinook, steelhead, and bull trout to remove these fish species from the Endangered Species List. The UCSRB closely aligns itself with National Marine Fisheries Service, Interior Columbia River Basin Technical Recovery Team (TRT).

Review of the UCSRB (2007) recovery plan by the Council's Independent Scientific Review Panel (ISRP 2010-28) asked that careful attention be paid to monitoring and evaluation to capture lessons learned from project implementation. The ISRP said, "Careful re-examination of limiting factor assumptions at regular intervals can help ensure that restoration efforts are focused where they can do the most good and help avoid situations that require expensive, frequent maintenance" (ISRP 2010-28:3). Since the UCSRP and the Willamette are the two areas "…to consolidate multiple habitat restoration actions under an overarching umbrella that potentially offers administrative efficiency and a landscape-based strategy …" the ISRP recommended comparisons of these two approaches on three and six-year intervals (ISRP 2010-28:4)

As the ISRP has noted in its reviews of both the Upper Columbia and Willamette plans, project proponents have abandoned a project-by-project focus in favor of a more regionally based approach to identifying and implementing conservation and restoration activities. Overall, this strategy does have the potential to address a major shortcoming in many habitat restoration proposals—the lack of a landscape-based context that provides justification for proposed actions. Under the Upper Columbia and Willamette plans, restoration funds can more effectively go toward those places most in need of habitat improvement. However, whether the approach will be effective depends on the availability of sound (and current) environmental data from the watershed in question, the accuracy of assumptions about what factors most likely limit the species of concern, and the ability of restoration actions to address these factors. This will require the technical review teams in each area to keep up with restoration science and to be familiar with the latest habitat and fish population data from their watershed.

Organize for Integration and Collaboration - The strength of the UCSRB is in governance that brings together county and tribal governments, citizens, and special interests in a collaborative, governance process. The five-member UCSRB is composed of one county official from each of the three counties and a Yakama Nation and Colville Confederated Tribe representative. The Implementation Team is the key to projects.

Actions stem from the Implementation Team that gives its plan to the UCSRB for approval and coordination with funders and outside groups. The Implementation Team is made up of Washington Department of Fish and Wildlife Upper Columbia Regional Technical Team (UCRTT) representatives, interested stakeholders, key agencies, tribal and county representatives, and a Watershed Action Team (WAT) representative. The Implementation Team is responsible for habitat projects and programs in the region, monitoring the status of actions, assessing trends in outcomes, and reporting results. The Implementation Team will also promote public involvement activities, assist monitoring programs, host and maintain Recovery Plan web site, and sponsor workshops the public can attend.

The organizational structure is an alphabet soup that does not always connect. For example, what is the relation between WATs and WIRAs, NMFS and ISRP? How are TRTs and RTTs composed and coordinated? Is EMAP or CHaMP a better monitoring framework? The names of structures listed in the UCSRB (2007) plan are not always the same names for organizations used by the counties. Further, the three counties differ significantly in their web presence on salmon conservation and restoration.

The UCSRB approach, like that in the Willamette subbasin, substantially removes project-specific scientific oversight from the ISRP. Where in the past the ISRP reviewed individual restoration projects for scientific adequacy and monitoring effectiveness, the new organization places project-specific scientific oversight and monitoring design largely in the hands of regional technical groups. This may be beneficial in terms of local familiarity with the projects in question, but under the new governance structure some of the reviewers may have a direct interest in the project itself. The UCSRB has assured the Council and Bonneville that steps are being taken to avoid conflict of interest situations, but it is too early to tell if the quality of scientific oversight will remain high and restoration priority setting will maintain the needed level of objectivity.

Adaptive Management - Monitoring and adaptive management are central features of the plan (UCSRB 2007:265-2). Monitoring is coordinated with the Council's MERR program. No mention is made of local involvement in monitoring, although WATs are involved in the monitoring process. Mention is made of "U.S. Environmental Protection Agency's Environmental Monitoring and Assessment Program (EMAP) design, which is a spatially balanced, site-selection process developed for aquatic systems and recommended within the Upper Columbia Monitoring Strategy" (UCSRB:267). In addition, the UCSRB has indicated that it will implement CHaMP protocols (see ISRP 2011-10), which call for detailed habitat measurements at a minimum of 25 sites within each watershed. The details of who will carry out the CHaMP monitoring effort and how it will be fully funded over time remain to be determined.

Challenges and Lessons Learned

Government, tribal, technical, scientific, agricultural, fishing, and local participants in the UCSRB have come to better understand one another. The process has shifted from one of conflict and lack of participation to greater local engagement and better understanding of the issues and actions to conserve and restore key areas. A governance and collaboration process has been created that can set goals, plan projects, implement actions, and monitor results. A video, *The Power of Partnerships* (UCSRB 2010b), shows how hostility has been turned into partnerships and project achievements. Actual results in terms of the conservation and restoration of salmon populations are incipient.

The biggest achievement has been the governance and collaboration structure to get local entities working together with basin partners to understand the issues and options. The UCSRB plan provides a vision for working together to delist salmon and improve environmental conditions, while also taking into account economic considerations.

G. Case History: Fraser River Estuary Management Program (FREMP)

Located in southwestern British Columbia, Canada, the Fraser River watershed (238,000 km^2) has a mean annual discharge of $3,972 m^3 s^{-1}$, and is 1,375 km long. All five species of salmon as well as steelhead and cutthroat trout are found in the estuary, and the Fraser River is one of the largest salmon producers in the world. The estuary is also a critical habitat for shorebirds and migratory waterfowl of international significance. It is the only major river on the west coast of North America that does not have mainstem dams. Unlike the Columbia River estuary, the Fraser River estuary is not subjected to an unnatural hydrograph because of dam and irrigation operations upstream. As a result seasonal water level changes in the estuary are similar to those of the Columbia River before development and flow regulation. The inner estuary is extensively diked and channelized, more so than the Columbia River estuary, where loss of tidal marsh and swamps has been about 25% (ISAB, 2000-5). Between 70-90% of the original wetlands in the Fraser River estuary have been converted to other uses but intact extensive sand banks and eelgrass beds are still found in the lower estuary.

For operational purposes, most authorities define the estuary as the lower 42 km of the river – this includes about 16 km of salt wedge influenced habitat and 26 km of fresh water tidal habitat. However, the river has tidal influence about 100 km from the mouth. Linkages of wetland habitat to juvenile salmonids via habitat residency and feeding habits are well established in existing research, but limiting factors are still not well understood (Levings 2004). Food webs in the Fraser River estuary have been studied extensively and are known to be supported by detritus, which is thought to originate mainly from the ribbon marshes in the tidal portions of the estuary and riparian zones in the lower river. A description of the ecosystem and food webs of the estuary was given in ISAB 2011-1.

The estuary delta at the river's mouth is the largest in western Canada (about 1000 km^2) and the urbanized area is growing rapidly. The human population in the immediate area is currently about two million. The estuary region includes part of Port Metro Vancouver – the estuary is also important for local water transport especially logs and wood products.

Socioeconomic Engagement - The direct involvement of partners not directly concerned with conservation has required FREMP to take a broad perspective on conservation, development, and economic drivers. There are six action programs in addition to fish and wildlife habitat: Integration/Sustainability; Water and Sediment Quality; Dredging and Navigation; Log Management; Industrial and Urban Development; and Recreation. Habitat restoration, creation, and improvement can be conducted under Fisheries and Oceans Canada's (DFO) "no net loss" policy. DFO's Salmonid Enhancement Program[26] also has an active role in habitat restoration in the FREMP area, frequently in partnership with provincial and local governments and NGOs.

Direct engagement is primarily through the partner agencies. FREMP mapping, reach overviews, the overall estuary plan and other projects are open to public participation. Four factors were considered important to improve engagement of FREMP stakeholders and citizens at large: 1) complete the area designations with the municipalities within the FREMP area, with the aim of making the area designations and municipal zoning and Official Community Plan designations complementary in terms of supporting sustainable development; 2) Improve the understanding that FREMP is strictly a forum for regulatory agencies to provide coordinated management;

[26] www.pac.dfo-mpo.gc.ca/sep-pmvs/about-sujet-eng.htm

3) refine the habitat shoreline classification to make it more consistent but retain flexibility based on site-specific conditions; 4) obtain sufficient professional expertise and financial support from partner agencies to operate effectively (Williams and Langer, 2002). A 1999 survey of FREMP stakeholders concluded that, while environment/conservation groups supported a more interventionist role, industry did not, and government representatives did not support changes that might have reduced their agency's power (Hanna 1999).

FREMP provides one model of how consensus and a more cooperative spirit can be approached in the context of sustainable development and also as a "working model of an environment-economy partnership", as espoused by The World Commission on Environment Development (McPhee 1989 cited in Calbick et al. 2004). The Program is therefore predicated on the acceptance of the principles of sustainable development.

Landscape Approach - By the mid-1970s there were mounting concerns about the cumulative impacts of development on the Fraser River estuarine ecosystem, in particular water pollution, habitat loss, and pressures on fish and wildlife. A proposal to expand Vancouver International Airport onto Sturgeon Banks, an important juvenile salmon habitat in the estuary, brought the issue to a head and resulted in the federal, provincial, and local governments beginning joint studies. These eventually evolved into FREMP, which was established in 1985 (Dorcey, 1996). FREMP activities encompass 155 km^2 on the wet side of the dike of the Fraser River downstream from Kanaka Creek and Pitt Lake to the Strait of Georgia (Figure X.9). FREMP also includes Sturgeon Bank, Roberts Bank, and Boundary Bay which are major intertidal areas on the Strait of Georgia, characterized by sand flats and eelgrass beds. There is about 74 km of tidal freshwater habitat above the FREMP boundary. The FREMP area is considered to include 60% of all the wetlands in the delta outside the dikes (Ward 1989).

Figure X.9. Map of the Fraser River Estuary and adjacent Metro Vancouver region, showing the area (light blue) under the jurisdiction of the Fraser River Estuary Management Program (from www.bieapfremp.org/pdf/bieap-fremp-ar-2009-10.pdf).

FREMP established one of the earliest estuarine classification systems for managing fish and wildlife habitat on the northeast Pacific coast. It is based on ground-truthed inventories of habitats and vegetation (includes detailed GIS mapping of vegetation units and on aerial photography.[27] The possible de-emphasis on non-vegetated areas may be problematic as the ecosystem functions of this habitat are poorly understood. FREMP area designations and municipal zoning and Official Community Plan designations are not always complementary.

There are thirteen cities or municipalities that have shorelines in the estuary (Figure X.9). Opportunities for wetland restoration by dike breaching in the inner estuary are limited because the flood protection structures have enabled urban and industrial development, but are pursued wherever feasible. Restoration techniques have tended to emphasize vegetation planting to create marsh benches and sand platforms (Adams and Williams 2004), but several recent large scale projects have involved reopening channels (Johannes et al. 2011). Early efforts also included construction of an intertidal island from dredged material (Levings 2004).

[27] See http://cmnbc.ca/atlas_gallery/bieap-fremp-habitat-atlas

Organize for Integration and Collaboration - FREMP operates under a Memorandum of Understanding between six partners – three Federal agencies (Environment, Fisheries and Oceans, Transport), one Provincial agency (Environment), Metro Vancouver (13 cities or municipalities in Metro Vancouver are in the estuary), and Port Metro Vancouver. FREMP exists solely as a coordination and facilitation organization – the six partners hold the decision-making power in their legislative mandates. Industrial and urban expansion into sensitive fish and wildlife habitat brought about the need for FREMP. An overall estuary management plan, developed with input from the partners, the general public, and the five First Nations in the area, also provides guidance.[28] FREMP "provides …a framework to protect and improve environmental quality, to provide economic development opportunities and to sustain the quality of life in and around the Fraser River Estuary".

FREMP's coordinated Project review process and registry are strong points (2180 projects between 1985 and 2004). Available on line, a central database is open to the public and enables developers and conservation agencies to determine if an estuarine area is classified for possible industrial use subject to compensation or mitigation. As described below, the partners collectively review proposals before a federal, provincial or municipal authority makes a decision that would allow the project to proceed. All project decisions, however, are the responsibilities of partner agencies with their specific mandates. Restoration may be funded through habitat compensation ratios applied to developers, as permitted under Fisheries and Oceans Canada habitat policy[29] as well as government fish and wildlife enhancement programs.

A description of the review process is extracted from the FREMP 2009-2010 Annual Report:[30]

> FREMP uses a two-track process to review projects in the Fraser River Estuary. 'Track 1 projects are generally of a predictable nature, frequently maintenance or repair type activities with little public interest and a low risk of environmental impact. Track 1 applications are dealt with by the Lead Agencies (e.g., Port Metro Vancouver), those agencies with the permitting responsibility and are made available for comment by the other Environmental Review Committee agencies. Track 2 projects constitute proposals of a more complex nature and generally have a greater potential for environmental impacts. In 2009, examples were new development projects (e.g., a new marina), maintenance projects (e.g., dredging) and renewal projects aimed specifically at improving the environmental integrity of a site (e.g., decommissioning or demolition of facilities). These projects are reviewed by the FREMP environmental review committee. The coordinated review process allows FREMP partners to collectively review proposals before a federal, provincial or municipal authority makes any decision that would allow the project to proceed. It is important to note that the coordinated project review process does not issue project approvals. Instead, it provides the responsible authorities with recommendations and conditions to ensure that projects remain compliant with the legislation administered by the agencies of the review committees. Review of Track 2 projects is the main function of the Environmental Review Committees. Once the Environmental Review Committees (ERCs) are satisfied that a project will not cause environmental harm and that the project does not trigger the need for further permitting by one of the partner agencies, the ERCs will issue a Letter of

[28] www.bieapfremp.org/fremp/pdf_files/Revised%20EMP%202003%20August%20.pdf
[29] www.dfo-mpo.gc.ca/habitat/role/141/1415/14155/fhm-policy/index-eng.asp
[30] www.bieapfremp.org/pdf/bieap-fremp-ar-2009-10.pdf

Recommendations or Project Review letter. The letter describes a list of mitigation measures designed to prevent adverse environmental effects caused by the project and ensure the compliance of the project within the legislative mandates of the partner agencies. The ERC's always aim to have completed project reviews within a 30-business day timeframe, depending on the complexity of the project.

Adaptive Management –The overall estuary management plan was written in 2004, and its vision "A Living Working River"[31] has not changed. Reach overviews, most recently addressing the extensive sand and mud flats in the lower estuary, are a mechanism for updating information. While a modest net gain in fish and wildlife habitat has been measured, it is not clear if all ecological functions have recovered since the persistence of wetland restoration projects is undocumented (Kistritz, 1996; Levings, 2004) and focused monitoring and research is still needed on this topic to inform decision making. Sixteen indicators, using a mixture of ecological and economic metrics, were used in a monitoring program.[32] Some of the indicators (e.g., waterbird abundance) were inconclusive because of lack of data.

FREMP has had to adapt to changes in partner agencies legislation over the past 26 years. An example is the increasing emphasis on biodiversity conservation, in parallel to an original goal of wetland conservation and food webs, which tend to relate to salmonid production. A recent biodiversity forum for the area concluded that adaptive management was not being fully implemented.[33] Participants recommended building organizational capacity and develop champions within organizations to assist with the task.

Adaptive management at the regional scale has been influenced by the relative success of the FREMP model for coordination. In 1991, a similar mechanism was created for Burrard Inlet (Figure X.9), the nearby marine embayment where most of the shipping and industrial activity in Port Metro Vancouver occurs. The Burrard Inlet Environmental Action Plan[34] was linked in 1996 with FREMP. The FREMP model also influenced the design of Fraser Basin Council[35] that was introduced in 1992 to facilitate coordination among all organizations concerned with the economic, environmental and social sustainability of the entire Fraser basin (Dorcey, 2010).

[31] www.bieapfremp.org/fremp/pdf_files/Revised%20EMP%202003%20August%20.pdf
[32] www.bieapfremp.org/fremp/pdf_files/Revised%20EMP%202003%20August%20.pdf
[33] www.bieapfremp.org/pdf/Biodiversity_Oct4_Email_Small.pdf
[34] www.bieapfremp.org
[35] www.fraserbasin.bc.ca

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