Fish and Wildlife Program Scientific Foundation

I. Introduction to the Scientific Foundation

In their review of the Council's program in 1996 and again in 2000, the Independent Scientific Group[1] introduced the region to the notion of a conceptual foundation (Independent Scientific Group 2000). They defined a conceptual foundation to be "a set of scientific principles and assumptions that can give direction to management activities…" They stressed that the importance of the conceptual foundation lies in its ability to provide a consistent and clearly defined approach to restoration. An explicit conceptual foundation would provide the program with clear assumptions and hypotheses that could be scientifically tested and refined over time.

The Scientific Foundation described here responds to the need for a conceptual foundation identified by the Independent Scientific Group. It provides a set of general scientific principles, an organizational framework, a procedure for developing biological objectives and a geographic structure for the program. Respectively, these describe the Council's overall scientific assumptions, how the program elements logically fit together, how to measure progress and how we have organized the program based on ecological patterns across the landscape. Attached to the foundation are detailed working hypotheses that are the basis for development of biological objectives and for measuring progress of the region's efforts.

The Scientific Foundation is the basis for the policies, guidelines and measures described in the Council's fish and wildlife program. The Council intends that the elements developed at the provincial and subbasin levels are also based on this foundation. The Council has directed that the scientific review of projects funded under its program be based on the principles and concepts in this foundation.

This Scientific Foundation is based on the premise that species are inexorably tied to their biological communities and habitats. Achieving goals for individual species,

[1] The Independent Scientific Group was created in the Council's 1994-95 program. The Council and the National Marine Fisheries Service agreed to form a joint scientific group, the Independent Scientific Advisory Board, to replace the ISG. The ISAB provides scientific advice on both the Council's program and the federal actions under the Endangered Species Act.

such as salmon, will require developing ecological condition consistent with the needs of those species. While intuitively appealing, this is a departure from the belief that guided the region for much of the twentieth century. We have tended to separate species of interest from their natural environment to protect them from the changes and loss of habitat resulting from development. The region has viewed the Columbia River and its natural resources as components of a regional economic machine (White 1995). Increasingly, the science is telling us that species and their habitats form an integral system that is responsible for the abundance, productivity and diversity of the individual species such as salmon that may be of particular economic or cultural interest (Independent Scientific Group 2000). The conceptual foundation embodied in this Scientific Foundation suggests that restoring fish and wildlife in the Columbia River will require restoration of the ecological functions and habitats that form a system conducive to species of concern. It recognizes that many of the ecological goods and services provided by the Columbia River that are of intrinsic and economic value to humans also depend on the restoration and maintenance of the ecological system.

The Scientific Foundation is not based on values or policy judgements. It describes how the pieces fit together and operate regardless of how we value the system. Some may value wild salmon and wilderness within the Columbia Basin while others value the river's contribution to agriculture and the regional economy. Regardless, the system still works a certain way. The Scientific Foundation is an attempt to capture how the system works in a way that is useful to fish and wildlife management in the Columbia River Basin. The scientific and political challenge is to determine how human economies can operate within the constraints imposed by the natural system.

Development of the Scientific Foundation.

The Scientific Foundation brings an understanding of the ecosystem to bear on the problem of fish and wildlife restoration in the Council's program. No part of this scientific foundation is without uncertainty or controversy. To every principle there will be exceptions and controversy. The complexity and variability of natural systems defy attempts to develop universal laws or incontrovertible statements. However, we should not allow the complexity, variability and uncertainty of the natural world to prevent us

from identifying problems and suggesting solutions based on scientific evidence and knowledge. Our intent is to develop a set of broad principles and organizational tools that can be usefully applied to the restoration of fish and wildlife in the Columbia River Basin, recognizing that they may change as our knowledge improves.

To this end, we expect scientific research and evaluation to continually test and refine this knowledge, to establish new conclusion and perhaps suggest new directions. The Scientific Foundation captures information at a point in time while providing a stable scientific basis for the region's fish and wildlife recovery efforts. It describes scientific understanding at a broad level that is designed to be a relatively stable portion of the program. It should change only after deliberative scientific review and not in response to short-term observations or to shifts in the political climate. The Council has directed the Independent Scientific Advisory Board (ISAB) to review the foundation whenever this program is open for major amendment, a process that occurs about every five years. The ISAB should suggest changes and updates if their review indicates the need for a significant shift in the scientific direction of the program.

Attached to this Scientific Foundation is a set of detailed working hypotheses concerning a host of biological and physical factors in the Columbia River. These are based on the foundation and represent detailed pointing of the foundation at important biological and physical relationships. In contrast to the foundation, the working hypotheses are more dynamic and are often the subject of scientific controversy. They are <u>working</u> hypotheses in the sense that the Council intends to use them as the basis for setting biological objectives and for analyzing the projected effectiveness of measures and programs. The working hypotheses should be refined and tested through the regional research program and are expected to change much more rapidly than will the more general foundational elements.

Components of the Scientific Foundation.

The Council's Scientific Foundation consists of the following elements that will be described in detail in the sections below:

1. A set of eight overarching scientific principles
2. A description of the framework used in the Council's program

3. A description of the derivation of biological objectives
4. The geographic description of the ecological provinces.

The working hypotheses are included as a provisional appendix to this foundation pending further review and development.

II. Scientific Principles for Ecological Management

The Scientific Principles are a set of broad scientifically based statements that describe how the biological and physical features of the Columbia River form a functional ecosystem, and, in turn, how this ecosystem affects the biological performance of species of interest for commercial, cultural or other reasons. The principles are based on concepts highlighted by the Council's Independent Scientific Group (2000). They are similar to the ecological principles for land management developed by the Ecological Society of America (Dale and others 2000) and those of Quigley and others (1996) for federal land management.

The eight principles describe the relationship between species and their ecosystems (Principle 1), the characteristics of ecosystems (principles 2 and 3), development and maintenance of habitats (principle 4), the role of species ecological functions and biological diversity (principles 5 and 6) and human roles and management of ecosystems (principles 7 and 8). The principles are not independent and, in fact, overlap in important areas as a result of the integral coupling of ecosystem components, characteristics and performance. They apply equally to aquatic and terrestrial species and are intended to foster a common approach to management of all species and habitats in the Columbia Basin. While based on general ecological knowledge, they focus on the restoration of fish and wildlife in the Columbia River Basin and do not necessarily apply equally to all ecosystems.

Each principle is stated followed by a discussion and implications section. The discussion provides an expansion of the principle with references to the primary, peer-reviewed scientific literature that is the basis for the principle. The implications section focuses on how the principle would affect natural resource management, especially with regard to the Council's fish and wildlife program.

Principle 1: The abundance, productivity and diversity of organisms are integrally linked to the characteristics of their ecosystems.

Discussion**:** An ecosystem is the organized complex of physical and biological components that make up the world we observe every day (Tansley 1935). Physical and biological elements self-organize into a system that captures and processes energy to produce the observed diversity, abundance and productivity of plant and animal species including humans (Kauffman 1993, Odum 1993). The characteristics and abundance of individual species reflect co-evolution with other species and the species response to its environment. Because of the pervasive impact of human actions on ecological systems (Vitousek and others 1997), achieving goals for individual species of commercial, cultural or other human interest will require managing human activities to support appropriate ecological processes (Christensen and others 1996).

Although we may have an intuitive feel for what constitutes an ecosystem, management goals are frequently couched in terms of individual species. Management actions typically focus on developing individual species rather than the physical and biological system to which they contribute. As environments have been altered by human action, we have attempted to prop-up species of commercial and cultural concern. These efforts have met with sporadic success. There is increasing recognition of the need for multiple species management and the integration of land management with fish and wildlife management (Christensen and others 1996, Dale and others 2000). This means recognizing the processes that form the habitats necessary for species and the functions that species provide to the ecosystem. The combination of suitable habitats and needed ecological functions combine to form the ecosystems needed to provide the desired abundance and productivity of specific species.

Local climate, hydrology and geomorphologic factors as well as species interactions strongly affect ecological processes and the abundance and distribution of species at any one place (Dale and others 2000). Life histories, physical features and diversity of individual species are shaped by climate, physical structure of their habitat and by biological interactions. Change in physical or biological features of the ecosystem, either natural or human-induced, will affect the capacity, productivity and diversity of fish and wildlife species.

Implications: Management of species in isolation from each other and from their habitats at best provides an incomplete picture, and at worst misleads by not accounting for the context and mechanisms that control species abundance, capacity and diversity. This principle notes the integral relationship between species and their environment and the role that species themselves play in maintaining that environment. It couples ecological conditions to the productivity and abundance of species including those of management interest.

Natural resource management, especially fisheries management, often isolates species from their environment to protect them from habitat loss or other impacts of human actions (Bottom 1997). In the Columbia River we have constructed a protected environment of hatcheries, dam bypass systems and juvenile fish transportation while allowing the ecological support system to be dramatically altered. This neglects the role of biological and physical factors of the ecosystem in shaping individuals, populations and species through natural selection. These efforts also do not replace the habitats themselves or the ecological function that species provide. For salmon, the reality has been that, although hatcheries have released large numbers of individuals into the system that have been protected through much of their freshwater phase, fewer and fewer fish return to spawn.

Principle 2. Ecosystems are dynamic, resilient and develop over time.

Discussion**:** Although ecosystems have definable structures and characteristics, their behavior is highly dynamic, changing in response to internal and external factors (Dale and others 2000). The system we see today is the product of its geological, climatological, biological, and human legacy. Natural cycles of change structure biological communities and affect species abundance and distribution (Beamish and others 1999). Disturbance and change are normal ecological processes and are essential to the structure and maintenance of habitats (Bisson and others 1997).

Disturbance can be the result of natural processes such as fire, flood or insect outbreaks, or human activities such as timber harvest or agriculture. Natural disturbance patterns create a mosaic of habitats across the landscape and through time (Reeves and

others 1995). At the same time, ecosystems maintain characteristic features and support definable communities of organisms. Habitat-forming processes resulting from the underlying geology, climate and hydrology and species ecological functions of the individual species impart a degree of resilience to the system allowing it to accommodate change and maintain essential characteristics (Holling 1973). Depending on the degree of perturbation and the resilience of the system, the ecosystem may eventually resemble its previous condition once the disturbance dissipates.

There are, however, limits to the ability of an ecosystem to absorb change and retain its original characteristics (Holling 1973, Reice and others 1990). Human actions and natural events can catastrophically alter ecological systems. The system is not destroyed but instead shifts into a new configuration. Different species will be favored and new biological and physical interactions will develop.

A natural ecosystem will show describable, if not generally predictable, patterns of change over time (Odum 1969). Forests, for example, have successional patterns characterized by the change from pioneer to mature species. A forest, like other ecosystems, may appear stable when we observe it at one point in time, but it changes over broader time frames (Odum 1969). Similarly, lakes and streams mature with dramatically different ecological character at various points in time (Cummins and others 1984). Natural disturbances can interrupt succession locally leading to a mosaic of habitats across the landscape (Reeves and others 1995). More widespread and pervasive disturbance including many human activities can stop or reset ecological succession patterns and prevent formation of habitats and processes that may be essential to continuation and abundance of some species.

<u>Implications</u>: Many natural resource management actions are designed to control the environment, reduce variability and achieve a stable and predictable yield from a highly dynamic system (Holling and Meffe 1996). For example, hatcheries were conceived, in part, to smooth out natural variation in fish populations and to sustain harvest over time (Bottom 1997). Dams and other structures dampen seasonal variation in water flow, while banks are stabilized and diked. Hatchery production and fish passage measures are timed and engineered to provide a predictable fish migration with minimal conflict with

human uses of the river. Fires are suppressed altering forest succession and species composition as well as insect outbreaks (Quigley and others 1996).

This principle encourages a departure from attempts to freeze the system in a certain constant state and manage for constant yields. Natural resource management programs should anticipate and accommodate change. Expectations of constant abundance or yield from natural resources are unrealistic and ignore fundamental features of ecological systems. Natural patterns of disturbance should be recognized as events that develop and maintain a diversity of habitats. Efforts to stabilize the environment and reduce disturbance will fundamentally alter habitats to the detriment of capacity, productivity and diversity of species.

Principle 3. Biological systems operate on various spatial and time scales that can be organized hierarchically.

Discussion: Ecosystems, landscapes, communities and populations are usefully described as hierarchies of nested levels (Allen and Hoekstra 1992). These levels are distinguished in regard to their spatial and time scales. Biological processes and function at higher levels fluctuate over long time intervals relative to the frequency of change in lower levels. Expansive ecological patterns and processes constrain, and in turn reflect, localized patterns and processes (Wiens 1989). Across this hierarchy we can recognize discontinuous points in space and time that form natural organizational units.

The definition of the hierarchy and scale is dependent on the question asked (Levin 1992). There is no single, intrinsically correct description, only one that usefully addresses the problem at hand. Performance at any given level reflects both the synergistic effect of actions at lower levels and the constraints imposed by higher level factors (Allen and Hoekstra 1992). Observations at a single level should clarify the higher-level constraints (the context) as well as the lower-level mechanisms that affect performance (Weins 1989). This suggests neither a top-down nor a bottom-up approach, but an integration of both.

Viewing ecosystems as hierarchies is useful for depicting the underlying structure of many ecological components. Regional climates vary through time on scales ranging from millennial to inter annual (Greenland 1998). Disturbance regimes within

ecosystems can be described at a variety of spatial and temporal levels (Delcourt and others 1983) that can affect life history patterns and genetic structure (Wissmar and Simenstad 1998). Similarly, Frissell and others (1986) describe a hierarchical classification system for aquatic habitats based on underlying geomorphic hierarchies.

Implications: If ecosystems are viewed as nested hierarchies, it is necessary to define appropriate scales for their management and study (Holling and Meffe 1996). To solve problems regarding the entire Columbia River Basin, we may need to filter out more localized data. On the other hand, questions concerning localized components (e.g. subbasins) cannot be addressed by looking at the entire basin. Understanding basin-level problems requires knowledge of actions and processes that take place in subbasins, while the success of subbasin level actions may depend on factors operating at basin and regional levels.

This principle provides an ecologically based way to structure fish and wildlife recovery (Quigley and others 1996). Such a structure should reflect ecological pattern within the system while providing a useful organizational device for recovery efforts. A necessary first step is to define the ecosystem at the point in the ecological continuum appropriate to the question being asked. The ecosystem at that point reflects the characteristics of the features nested within and higher level constraints on performance.

Principle 4. Habitats develop, and are maintained, by physical and biological processes.

Discussion: Habitat refers to the resources and conditions present in an area that allow a species or a group of species to exist and thrive (Hall and others 1997). From a species perspective, habitat is the string of conditions encountered over its life cycle that contribute to survival and reproduction (Independent Scientific Group 2000). Structuring and forming habitats is an important ecological function of many species that operate in addition to physical processes. Physical habitat forming processes include runoff patterns, heating/cooling, forest succession, and erosion/deposition (Imhof and others 1996). These act over a range of spatial and time scales to create, alter and maintain habitats (Allen and Hoekstra 1992). At the local scale, habitats are created and

maintained by processes related to larger scale hydrology and geology that encompass aquatic and terrestrial factors throughout the watershed. Regional scale climatic conditions in turn control temperatures and precipitation that are important in the development of habitats. Locally observed conditions often reflect more expansive or non-local processes and influences, including human actions. The habitat features created by these processes interacting with the biological capabilities of the organisms determine the abundance, productivity and diversity of species and communities (Morrison and others 1998).

The active agent of many aquatic habitat-forming processes is water interacting with the underlying geology, topography and climate. The hydrologic linking of habitat processes means that the impacts of actions can radiate and accumulate downstream. Habitat conditions such as water temperature or sediment can be the result of actions and conditions that occur upstream. Aquatic habitat conditions are affected by terrestrial conditions and actions that accumulate as water moves downslope.

Terrestrial habitats are often described in terms of food, water and cover. Formation of these features is related to vegetational patterns that result from environmental needs of individual plant species, succession and patterns of human-caused and natural disturbance (Whittaker 1975). In turn, vegetation pattern is related to local geology, topography, climate and biological processes in the context of regional climatic and other factors.

Organisms themselves are also key factors in structuring and maintaining habitats. In terrestrial ecosystems, trees and other vegetation are obvious habitat features playing essential roles in the distribution of other plant and animal species. Similarly, in aquatic ecosystems wood and riparian vegetation form key habitats for many species. Beavers structure many riparian and aquatic habitats (Cederholm and others 2000) while the spawning activities of salmon can alter and maintain riverine conditions (Peterson and Foote 2000).

<u>Implications</u>: Understanding the physical and biological processes that create and maintain aquatic and terrestrial habitats are key to the management of human impacts on those habitats (Imhof and others 1996, Beechie and Bolton 1999). Even though problems

are often perceived at the local level, the underlying causes and solutions may be best understood at larger watershed or subbasin scales. Our efforts to correct habitat problems often focus on correcting symptoms of habitat degradation and loss rather than on causes. We try to "fix" the problem by engineering localized solutions. These efforts often prove futile because the processes and conditions creating the problem are still active (Kauffman and others 1997). For example, logging practices in the upper parts of watersheds may affect water temperatures and sediment levels and negate efforts to correct problems lower in the system. Livestock grazing may preclude development of normal vegetational succession in riparian areas with local impacts to wildlife and downstream impacts on flow, temperature and sediments. Management to achieve goals for specific species implies allowing normal habitat forming processes to operate and develop an appropriate environment. Loss of key species such as beaver and salmon has likely altered many aquatic habitats with impacts on other species and ecological processes.

This principle stresses the need to understand and address habitat forming processes in order to restore and maintain aquatic and terrestrial habitats (Beechie and Bolton 1999). Habitat restoration actions undertaken without understanding the underlying habitat-forming processes will not be effective in the long term (Reeves and others 1995). Land use practices affect habitats through processes similar to those structuring natural habitats. Relating practices to process is key to ensuring that habitats are available to support biological communities and species of interest.

Principle 5. Species play key roles in developing and maintaining ecological conditions.

Discussion: Organisms are not passive occupants of their habitats. Instead, species have ecological functions that are key to the development and maintenance of ecological conditions (Walker 1995). Species, in effect, have a distinct job or occupation that is essential to the diversity, sustainability and productivity of the ecosystem over time (Morrison and others 1998). For example, plant, animal and bacterial species structure habitats, capture and transport energy and control species abundance and diversity. The existence, productivity and abundance of organisms depend on these functions. To

varying degrees, similar ecological functions may be performed by groups of species. Groups with similar roles can enhance the resilience of the ecosystem in the face of disturbance or environmental variation (Walker 1995, Schlapfer and Schmid 1999).

Some ecological functions are performed by a limited number of species. Removal or declines of these species can have significant impacts on their associated ecological function, the ecosystem and other species. In Pacific Northwest ecosystems, for example, salmon often have a key role in transporting nutrients and energy from the marine environment to freshwater and terrestrial habitats for which there are few ecological alternatives (Cederholm and others 1999). Removal of salmon results in ecological changes that can have far reaching impacts on a variety of aquatic and terrestrial plant and animal species (Willson and Halupka 1995, Cederholm and others 1999).

Implications: This principle points to the important role of species composition in ecosystem function and persistence. Many species have key ecological functions; loss of these species can shift ecosystem structure with impacts on all species. New species introduced from outside the natural biological community may not perform the same function and may compete with native species potentially leading to the loss of ecological functions.

The principle also affirms the integral relationship between species and their ecosystems and the need to consider species in the context of their ecological functions. Actions to enhance species of cultural or economic concern often isolate and protect species such as salmon even as the surrounding environment is altered in fundamental ways. Salmon hatcheries, for example, may provide harvest benefits to some human users when habitats have been altered or destroyed, but generally do not replace the ecological role that salmon play in the ecosystem (habitat structure and nutrient cycling, for example). The result can be significant ecological change affecting the presence and abundance of other aquatic and terrestrial species (Cederholm and others 2000). Actions such as the use of hatcheries may have a role in natural resource management, but need to be used in a way that not only bolsters survival of salmon and the capacity of the

environment, but also restores or replaces the function that salmon play in their ecosystem.

Principle 6. Biological diversity helps ecosystems persist in the face of environmental variation.

Discussion: Biological diversity is the variety of life forms across the landscape and their ecological roles and the genetic diversity (Odum 1993). It develops as a result of natural selection in response to variability in the physical and biological template of the environment (Southwood 1977). Variation in biological characteristics among species, populations and individuals is the fuel that fires adaptation in response to environmental variation.

Biological diversity can contribute to ecological stability and resilience (Walker and others 1999). In many systems, the presence of functionally similar species contributes to the resilience of the ecosystem as species wax and wane over time (Morrison and others 1998, Peterson and others 1998, Walker and others 1999). Species that are abundant contribute to ecological function and performance at a particular time, whereas rarer species can contribute to ecological resilience over time (Walker and others 1999). Loss of species, particularly those for which there are few ecological equivalents, can jeopardize ecological structure and stability (Walker 1995).

Within a species, diversity can contribute to the stability of the species over time by providing a wider range of solutions to the challenges posed by variation and changes in the environment. Over the spectrum of populations that comprises a species (chinook salmon in the Columbia River, for example) there is a variation in survival as the environment shifts over time. As some populations suffer under an environmental extreme such as an El Niño condition, others may fare better. However, the species survives, bolstered by its ability to respond to the shifting environment (Bisbal and McConnaha 1998).

Implications: Human actions often constrain or reduce biological variation (Urban and others 1987, Policansky and Magnuson 1998). As we simplify and decrease variability in

the environment, biological variation is reduced as well. This leads to the potential loss of species as they become less capable of responding adaptively to environmental change. In turn, the loss of ecological functions they provide can decrease stability and resilience of their ecosystems.

If we accept that biological diversity can contribute to ecosystem resilience and to the ability of organisms to better sustain themselves and adapt to changing environments, then we should manage our activities to encourage natural expression of biological diversity. While diversity can be quantified, determination of the "proper" level of biological diversity is likely not possible, partly because it shifts and varies over time in response to natural selection. We cannot predict future environments or situations and therefore cannot pretend to know what level of diversity is needed. It is not simply that more diversity is always good; introduction of non-native species, for example, can increase diversity but disrupt ecological functions as the community adjusts and new patterns of species richness and abundance are established. Some ecosystems are naturally lower in diversity than others yet persist through time. Maintaining the ability of the ecosystem to express its own species composition and diversity allows the system to remain productive in the face of environmental variation. The challenge is to manage human activities to encourage development of compatible biological communities and minimize our impacts on selection so that diversity can develop accordingly.

Principle 7. Ecosystem management is adaptive and experimental.

Discussion: Many of the features of ecological systems described in these principles counsel against the notion of command and control of the environment (Holling and Meffe 1996). Instead, the complexity and variability of ecosystems argues for management that is experimental (McConnaha and Paquet 1996) and admits and accounts for the range of natural dynamics at all levels of biological organization. Our knowledge of ecological systems is incomplete. We can describe the structure and nature of ecosystems in some ways, but important details elude us. More importantly, we have only recently begun to appreciate the Columbia River as an ecosystem. For most of the last century we thought of the Columbia River as a machine that can be adapted to meet

our needs (White 1995). Ready solutions to management of fish and wildlife within a highly developed system like the Columbia River have not been developed. Finally, as emphasized in these principles, ecosystems vary over time. What is key to recovery of species may change as the system shifts in some largely unpredictable fashion.

Adaptive management – the use of management experiments to investigate biological problems and to test the efficacy of management directions – provides a model for experimental management of ecosystems (Holling 1978). However, ecological management presents special challenges to adaptive management (Walters 1997). Ecosystem experiments may be impractical, infeasible or pose equity questions (Volkman and McConnaha 1993). We may be unwilling to experiment with beleaguered fish and wildlife populations. Under these circumstances, there may be less opportunity for large-scale management experiments, and more need for directed experimentation and research. Nevertheless, an explicit, directed approach to learning should be used whenever possible. Adaptive management does not mean passive 'learning by doing'. Instead, it requires a directed program aimed at understanding key ecosystem dynamics and the impacts of human actions using established methods of scientific experimentation and inquiry (Platt 1964).

Implications: This principle argues for management that conscientiously experiments and probes to better understand the ecosystem. Natural resource management that conscientiously applies ecological principles anticipates change and variability and includes mechanisms to probe and learn about the system. What is critical to fish and wildlife restoration in one decade may not be critical in the next as the ecosystem shifts in response to internal or external factors and as human values shift. Ecosystem management requires new measuring indices and tools (Done and Reichelt 1990). To the standard measures of abundance of important fish and wildlife species, ecosystem management calls for new indicators of success such as development of habitat characteristics, normal trophic structure, biological diversity and species conservation status.

Principle 8. Ecosystem function, habitat structure and biological performance are affected by human actions.

Discussion: Humans are integral parts of ecosystems and are key to the characteristics and performance of many ecosystems. Our actions have a pervasive impact on the structure and function of ecosystems, while, at the same time, our own health and well being are tied to these conditions (Vitousek and others 1997). Like many other organisms, we structure and control ecosystems for our own needs. In some ecosystems, human impacts are major factors controlling the environment. However, unlike other organisms, we can consciously control our actions to permit and encourage needed ecological conditions to develop. While our actions may be unique in regard to the scale of impact on ecological systems, our method of interaction with the ecosystem is not; ecological principles apply to human interactions with ecosystems as much as they do to the interactions of fish and wildlife species and the ecosystem.

It is a reasonable assumption that for most species, the ecological conditions that are most conducive to their long-term survival and productivity are those under which they evolved. Human actions in the Columbia River have shifted the environment away from these conditions with negative impacts for many native species, especially fish. Some changes are irreversible. New species such as smallmouth bass, walleye and many plant and terrestrial animals have been introduced and permanent changes have been made to the landscape. Even with complete cessation of human activities, the system would not return to its previous condition. However, human impacts on ecosystems can be managed to move the system to a state that is more compatible with the needs of other species.

Implications: As humans, we often view ourselves as separate and distinct from the natural world. We see ourselves as observers and users rather than active participants. This principle stresses our integral role in the ecosystem and our ability to shape our ecological future. Humans have significantly altered the natural landscape in the Columbia River Basin for millennia with significant effects on the abundance and distribution of plants and animals (Martin and Szuter 1999). In highly developed ecosystems like the Columbia River, human actions and technology will continue to

dominate the system. However, those actions can be managed in a manner consistent with the needs of other species. The issue is to what extent we are willing and able to control our impacts to balance the various services potentially provided by the Columbia River ecosystem. It is a question of the type of environment in which we choose to live and how much we are willing to limit our actions to encourage it to develop.

III. A Framework for Ecosystem Management.

The Framework is a way to organize the Council's program to efficiently focus our efforts, to facilitate learning and to provide accountability for actions. Taken with the scientific principles, it is a way to implement an ecologically based conceptual foundation and to avoid conflicting purposes. The framework is structured to reflect ecological organization of the basin. In this way, it can help us think about the Columbia River as an ecological system rather than a set of disparate parts to be managed in isolation.

The concept of the framework is simple: figure out what we really want to do with the Columbia River, describe the conditions we need based on current science and then determine what we need to do to achieve it. One of its aims is to encourage development of a consistent approach throughout the basin that recognizes local differences and values. To do this, it starts with a very broad focus of the Columbia River Basin and then progressively narrows to eventually consider individual subbasins. The Scientific Principles provide the scientific basis for linking the framework to provide a scientific basis for the Council's program.

Overview of the Framework

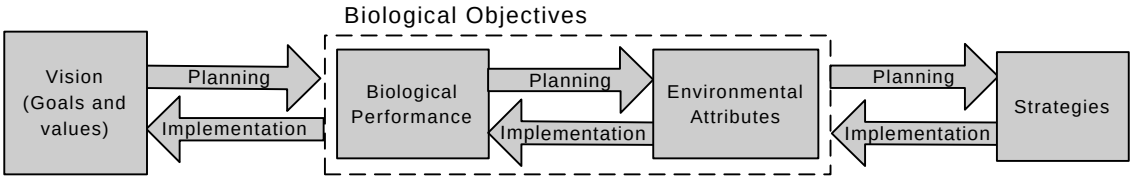
There are three major components of the framework. The Vision describes the values attached to the ecosystem, Biological Objectives[2] describe the needed condition of the ecosystem, and Strategies are the human interventions that affect Biological Objectives to achieve the Vision. As will be discussed further, Biological Objectives are conceived of as addressing both the expected biological performance of fish and wildlife populations as well as attributes of their environment. The framework components are linked by a rationale based on the Scientific Principles and the working hypotheses. Each component has significance only in the context of the ecosystem framework. A Vision for the region that does not consider the needed change in Biological Objectives and

[2] In other descriptions of the framework, the conditions needed to achieve the vision have been called Ecological Objectives. While probably less descriptive, Biological Objectives have particular significance to the Council's program because they are called for in the Northwest Power Act.

actions is little more than wishful thinking. Similarly, Strategies that are not tied to specific changes in the environment (Biological Objectives) and ultimately to some purpose (Vision) are disjointed and unlikely to satisfy regional needs.

The framework elements stress development of a program of human actions focused on a human-centered vision for the basin. However, the program is implemented within the context of natural factors operating at all scales and largely outside the control of the Council's program. These include larger scale climatic conditions that constrain the entire ecosystem as well as smaller scale physical and biological factors affecting local habitat conditions and biological performance. The effect of the external factors is accounted for in the analytical process of development of the biological objectives.

To emphasize the linkage between the framework components, we will use the following recurring icon:



The arrows represent the rationale linking the components and emphasize the continuity of the framework. During planning (development of the Council's program), the flow is from left to right. Planning begins by developing a vision of a desired end state for the Columbia River and ultimately develops a set of strategies to achieve this condition. However, implementation and evaluation of the program reverses this flow and the addresses how the Strategies achieve the Objectives, and how this changed ecosystem achieves the Vision.

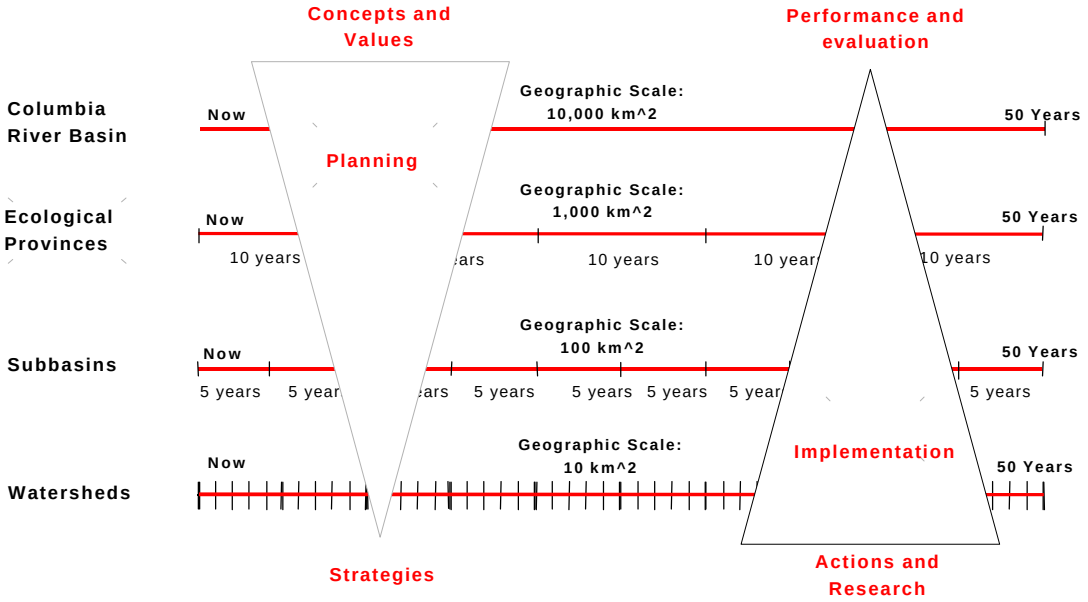
Although the arrows in the icons imply a unidirectional flow during planning and implementation, in actuality there is likely to be considerable iteration between framework elements. For example, a Vision may be proposed that requires biological and environmental change that the regions deems unacceptable for economic or social reasons. In this case, the Vision would have to be modified to result in a socially affordable program. Importantly, this iteration cycles through a consistent Scientific

Foundation that is independent of the values and policies embodied in the Vision and the eventual choice of acceptable Strategies.

Scaling within the Framework.

The Columbia River ecosystem can be described over a range of spatial and time scales. In a like manner, the Framework is applied at different scales ranging from the entire Columbia River ecosystem to individual subbasins. A large-scale level such as the Columbia River Basin might encompass 100,000's of square miles with decadal biological and physical cycles, whereas smaller scale levels such as an individual subbasin might encompass 100's of square miles and vary over shorter time frames (Figure 1). The different levels form a nested hierarchy such that small scale elements (e.g. subbasins) are nested within larger scale elements (ecological provinces and the basin). The geographic structure for the Council's program is described in Section V, below.

Figure 1. Framework spatial and time scales

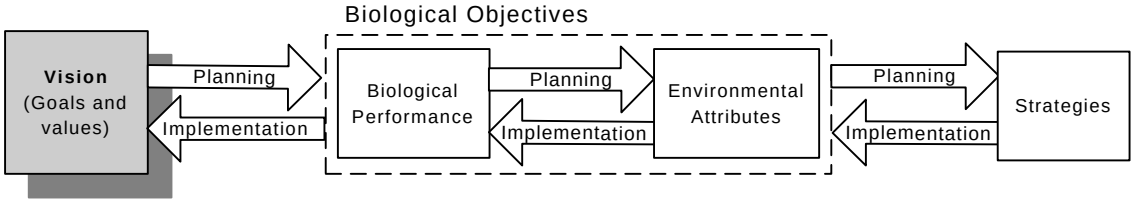


Programmatic planning applies the framework elements at the broad level of the Columbia River Ecosystem and sequentially focuses them down to finer scales such as individual subbasins (Figure 1). For example, a Vision can apply to the Columbia River Basin, a regional aggregation of subbasins (termed an Ecological Province) and to a

specific subbasin. At the same time, actions implemented at the finer scales aggregate to produce larger scale performance. Information is typically collected at fine scales and then used to make larger scale inferences and to evaluate the program. This is not strictly a top-down or a bottom-up approach. There will be considerable iteration between levels as broad visions and concepts meet finer scale practicalities. The region needs to develop overall directions and objectives, but local concerns and fine scale environmental variation will, to a large degree, determine the set of actions implemented and their effectiveness.

Components of the Framework

A. Vision.



The Vision identifies the ecological/biological, economic, social, cultural, aesthetic and other values we associate with the Columbia River. This includes aspects or qualities of the river that are valued by the region. Examples include: goals for harvest of fish, persistence, abundance and distribution of native fish and wildlife, recreational opportunities, preservation of cultural and ceremonial traditions related to fish and wildlife, etc. Values can also include things other than fish and wildlife goals and can describe commercial or spiritual values as well. Values and goals are defined at all geographic levels.

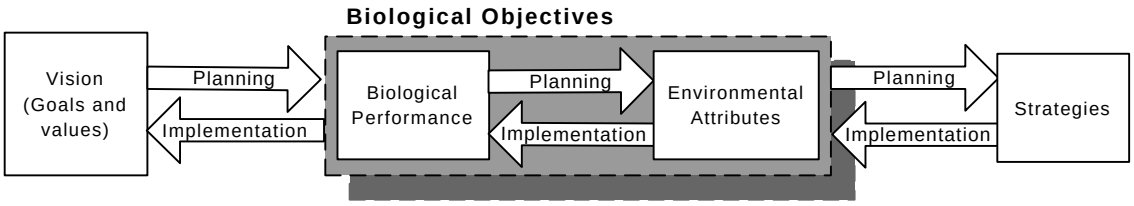
The Vision defines a set of ecological/biological, economic, social, cultural and other values we expect the Columbia River to provide in the future. The Vision captures not only those values to be gained, but should also reflect values we expect to forgo. The Vision is intended to drive the program in a particular direction to result in a set of

actions focused on a common end. It should determine the Biological Objectives and thereby the choice of Strategies.

Traditional goals for harvest, abundance or persistence of species can be part of a Vision. However, the Vision is actually a larger concept that tries to paint a picture for the future of the river. It addresses broad themes for the basin and can include intrinsic values in addition to more narrowly focused goals for specific species or populations.

A Vision should include values that we associate with the ecosystem. This does not refer to dollar amounts but rather to intrinsic qualities of the basin and specific goods and services. A Vision should address terrestrial as well as aquatic values of the system and the needs of many species. While focusing on values for natural resources, a Vision could also address values for industry, agriculture or commerce and specifically should contemplate the balance and trade-offs in values. “Wild and scenic,” “harvestable spring chinook” and “adequate, efficient, economical and reliable power supply” are examples of values that could be derived from the Columbia River ecosystem.

B. Biological Objectives.



Biological Objectives describe how the Columbia Basin should be configured to achieve the Vision. They have two components. Biological Performance describes characteristics for specific populations of fish and wildlife such as abundance, productivity and life history diversity. Environmental Attributes describe habitat conditions consistent with the Biological Performance. These two components are linked by working hypotheses based on the Scientific Principles.

Biological Objectives are a scientifically based description of the ecosystem implied by the Vision. They describe how the present ecosystem should change to achieve the qualities and values described in the Vision. The need for Biological Objectives in the Council's program is specified in the Northwest Power Act and has been reinforced in judicial review of the Council's program. Because of their importance to the Council's program, Biological Objectives and their derivation are described more fully in Section IV of the Scientific Foundation.

We have defined Biological Objectives to consist of two components. Biological Performance describes aspects of specific populations of fish and wildlife. For example, they can describe the abundance, productivity and life history diversity of chinook salmon needed to achieve the aesthetic, harvest and sustainable qualities of chinook described in the Vision. Environmental Attributes describe the physical environment needed to achieve the Biological Performance. This might include water flow and temperature, aquatic sediment characteristics or terrestrial vegetation types.

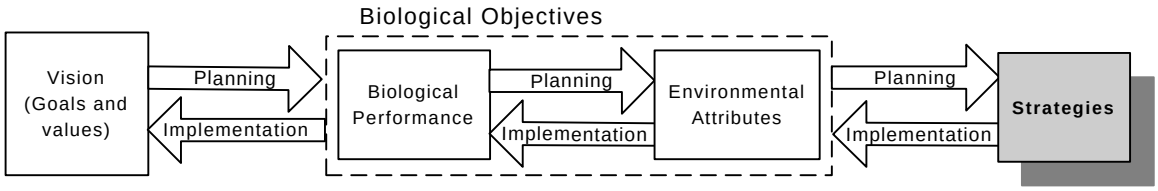
There is an obvious and important connection between the two components of Biological Objectives. The logic of the objectives is that if we change the habitat in ways described by the Environmental Attributes, we would expect to see the changes in fish and wildlife populations described by Biological Performance. This belief is based on the working hypotheses. These are consistent with the Scientific Principles and reflect current scientific understanding of the habitat-performance relationship. These hypotheses should be refined and tested through research and will likely change. As a result, although the Vision should endure through time, the Biological Objectives may change as our knowledge improves.

Biological Objectives are not immutable standards but rather guidelines for planning, implementation and evaluation. The measures of Biological Performance, such as abundance of specific chinook salmon populations, and the Environmental Attributes, such as late summer water temperatures in tributaries, should be the target of the region's monitoring efforts to determine if expected changes occurred. The working hypotheses

linking the two components should be investigated through scientific research to refine our understanding of the relationship between habitat and biological performance. Finally, various strategies designed to change the environment and biological performance can be evaluated to determine their effectiveness.

C. Strategies.

Strategies are categories of human actions designed to change the environment and affect biological performance. They include passive actions to relax human constraints on the environment such as a change in land use practices. They also include actions to directly modify the environment such as changing water flow from a storage project or constructing a fish hatchery.



Strategies are the point where the Council's program moves from the conceptual and planning aspects to directly reconfigure the basin and achieve the end described in the Vision. All other aspects of the Framework are designed to achieve a set of strategies that is biologically effective and economically and socially feasible. Within the Framework, the strategies are directly linked to needed biological change and a desired overall outcome (the Vision). Without this logic, strategies become ends in themselves and desired end-state becomes lost in the details.

Strategies are broad categories of actions that can include a number of specific measures. For example, a Strategy might be to reduce soil erosion to achieve an Environmental Attribute describing sediment levels in a stream. This strategy could include a number of actions such as to changing land use practices and stabilizing stream banks by planting trees. The belief that this set of actions will affect one or more

Environmental Attributes is based on a hypothesis or a set of evidence. This provides direction for evaluation of the effectiveness of the strategy and refinement of strategies over time.

IV. Biological Objectives.

The Northwest Power Act directed the Council to adopt measures that are the most cost effective means to achieve "sound biological objectives." The Act does not further define biological objectives. Federal courts have criticized the Council's program partly based on the lack of biological objectives (the Tang decision). Scientific reviewers have also criticized the Council's program for its lack of clear direction and objectives (Independent Scientific Group 2000). Based on these and the language of the Northwest Power Act, biological objectives represent a key element of the Council's program that explains the Council's intent and guides selection of measures. Because of their importance to the Council's program, this component of the Framework is expanded in this section to describe a procedure for development of Biological Objectives.

In the framework, the Biological Objectives represent an explicit, scientifically based description of the type of biological system required to achieve the Vision. They provide a more rigorous exposition of the Vision. They are used to direct the Strategies (types of measures in the sense of the Council's program) that result in movement toward the Vision of the program.

Like all of the framework elements, Biological Objectives can be developed at any level within the geographic hierarchy that we use to describe the Columbia River ecosystem. Because smaller scale features like subbasins are nested within larger scale features such as the ecological provinces, the Biological Objectives at the subbasin level are constrained and directed by the Biological Objectives at the province and basin scales. At the province scale, for example, the Biological Objectives indicate the amount of change needed to achieve the province vision and contribute to the basin scale vision. These would guide and constrain the Biological Objectives at the subbasin scale. In this way, they serve as an important means to structure subbasin plans as contributions to the overall regional plan.

Derivation of Biological Objectives.

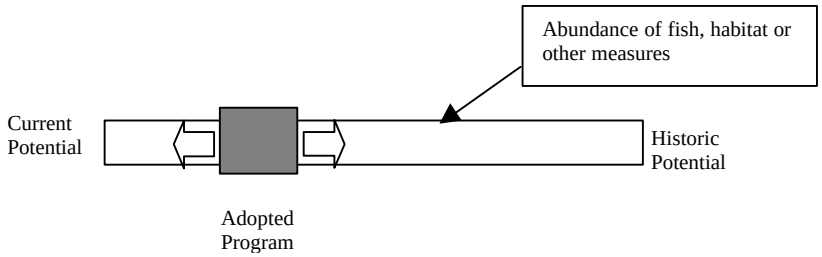
The Biological Objectives are based on an explicit set of working hypotheses attached to this Scientific Foundation and consistent with the Scientific Principles. These working hypotheses would be contained within the Ecosystem Diagnosis and Treatment (EDT) model (Mobrand Biometrics 1999). The hypotheses are derived from the scientific literature, research studies and regional statistical analysis and models. The hypotheses capture the state of our knowledge at one point in time about how biological and physical components interact to form the Columbia River ecosystem. Because our knowledge is imperfect and because the ecosystem will vary and shift through time, the working hypotheses will be refined and changed in response to monitoring, evaluation and research. The Council intends to use EDT to evaluate subbasin plans for their contribution to the larger scale (province and basin) Vision and Biological Objectives. To develop biological objectives, EDT describe the amount of environmental change needed within a province to meet the overall Vision. Subbasin plans detail the strategies and actions needed to make this amount of change across the province.

Biological Objectives are planning guidelines that apply to development of the program at any geographic scale and serve as a basis for monitoring, research and evaluation. They are not prescriptive regulatory standards. Objectives at a particular level guide development of objectives at finer scales. The Biological Objectives concept is based on a belief that it is possible given existing scientific understandings to describe the type, direction and magnitude of environmental change needed to achieve a desired end-state (the Vision). It recognizes that scientific information is refined and changes over time; consequently, our objectives may change even if our Vision remains the same.

The Biological Objectives are measurable attributes that provide a way to define progress, provide accountability and track change through time. In this way, they also provide the basis for a regional monitoring and research and evaluation effort. When adopted, the Biological Objectives will be based on a set of working hypotheses contained within EDT. These would be tested and refined through research and evaluation that could lead to revision of the objectives at some future point.

EDT characterizes habitat in the basin in regard to some 40 physical attributes that are described at the HUC-6 level (Seaber and others 1987)[3]. These attributes are related through the working hypotheses to estimate life-stage survival. Integration of these life stage survivals across the life history trajectory of the target species (e.g. chinook salmon) provides an estimate of the biological performance measured as the abundance, productivity and life history diversity of the species as a result of the habitat conditions

Biological Objectives are based on three characterizations of the environment derived from the EDT hypotheses: 1) the current potential, 2) the adopted program and 3) the historic potential:



These are developed at the basin and ecological province scales based on information gathered at the HUC-6 level.

The <u>current potential</u> describes the current habitat condition (environmental attributes) and the biological potential of that habitat in regard to the abundance, productivity and life history diversity of specific fish and wildlife populations. The actual abundance of a population at any point in time rarely equals the potential of the habitat because of a variety of environmental and biological factors. Thus the biological potential of the current habitat is generally higher than the actual abundance. The simulation of the current situation incorporates observational data on temperature, flow, sediments, and so on.

The historic potential is roughly equivalent to the historical condition and is a depiction of the basin and province based on regional climate, geology and other parameters without the influence of large-scale human activities and the biological potential of that habitat. This can be thought of as a depiction of the basin in, say, 1800, prior to most European settlement of the basin. It is an attempt to describe the best possible (but not necessarily perfect) condition and biological potential, and is used as a reference point to describe change.

The characterization of the adopted program (the gray slider on the figure above) shows how the environment in the current situation would move toward that of the potential based on a set of strategies (measures) contained in the Council's program. These calculated changes in the environment and in biological performance would be the Biological Objectives for the adopted program. The working hypotheses provide the rationale for believing that a strategy would have some desired effect on the current situation and move the system toward the potential.

The Biological Objectives characterize the projected movement of the environment from the current condition to that of the adopted program in the direction of the potential. The Biological Objectives describe specific levels within the geographic hierarchy. Those at the basin scale guide those at the province scale that, in turn, guide those at the subbasin scale.

There are a variety of physical and biological attributes that could be used to characterize the desired system at any level. While the desire is to have quantitative objectives for the program wherever possible, those at the broadest scale, such as the basin, are more qualitative relative to those at the finer scales such as the province or subbasin. However, in all cases, Biological Objectives are based on explicit criteria such as the following:

- Readily measurable (or at least clearly definable for those of a more qualitative nature)
- Strongly affected by actions in the Council's program

[3] HUCs (hydrologic unit codes) are a standard hydrological classification system. There are some 7,500 HUC-6s within the U.S. portion of the Columbia River basin.

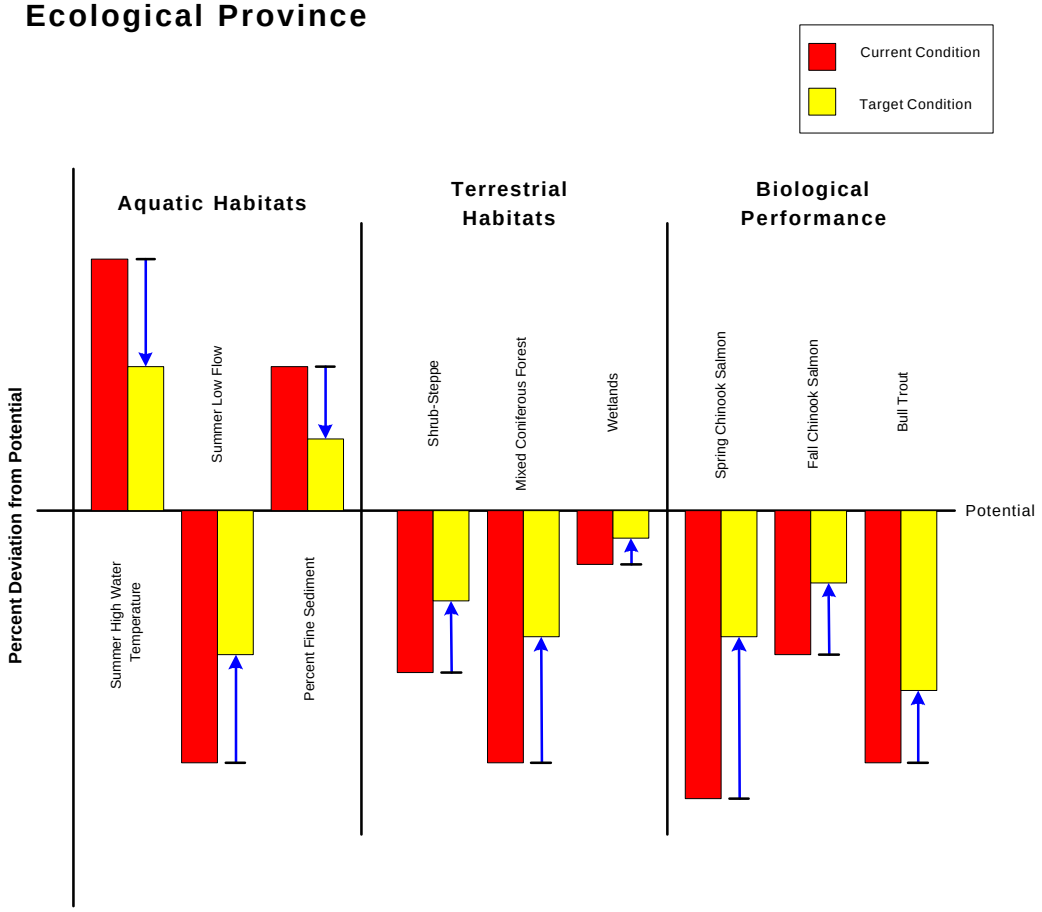
- Based on the working hypotheses (quantitative objectives)
- Intuitive
- Capable of providing clear direction to smaller scale planning
- Effective in capturing needed conditions
- Integrative across many human activities.

Scaling of the Biological Objectives.

Basin Scale. Basin scale Biological Objectives will guide development of objectives at the province scale. They refer to conditions that transcend provinces or affect two or more provinces. They are system parameters that apply at all lower levels. Examples are objectives for performance of hatchery fish relative to associated natural populations. Other basin scale objectives could provide objectives for processes that transcend provinces such as the hydroelectric system. Objectives could describe spill, bypass or transportation as well as quantity and timing of desired river flow levels.

Many of the objectives at the basin scale are qualitative. They describe the type of system contained in the basin-wide vision and provide guidance to development of the vision, biological objectives and strategies at the province scale. However, the basin scale also provides some extremely important quantitative objectives as well. There could be objectives for configuration of the dams (presence or absence), spill levels, bypass systems and flow levels. These would be based on the logic of EDT and include rules based on more detailed analysis such as that done by PATH. These system variables constrain performance at other levels and guide development of objectives at the province and subbasin levels.

Figure 2. Bioloical Objectives for a Particular Ecological Province



Ecological province scale. Biological objectives for the eleven ecological provinces guide development of objectives at the subbasin level. They will be used to judge the merits of proposed subbasin plans in regard to province and basin level vision and objectives. For example, if the Biological Objective for a province is to reduce average water temperatures in late summer by some amount, the job at the subbasin level is to devise a set of strategies to achieve this in the most biologically effective manner at the lowest cost while keeping with local values and so on. The concept of biological effectiveness is key because it might be possible, for example, to change average water temperature across a province in a manner that has relatively little biological benefit. Biological effectiveness is based on the vision and other qualitative characteristics of the environment and determines the pattern of change as well as the quantity of change. The Council would approve subbasin plans and direct funding of actions that are consistent

with the goal of changing conditions within a province as described by the Biological Objectives.

Figure 2 illustrates the concept of Biological Objectives at the province scale. The set of bars to the left are attributes describing aquatic habitats, the middle set contains terrestrial habitat types and those on the right describe biological performance using the abundance of three fish species as indicators. In each case, EDT would describe the current state of the parameter based on the hypotheses within the model, the potential for the parameter and the target value associated with the adopted program. The Biological Objectives describe the amount of change needed in the attribute within a province. Change is measured relative to the current state and in the direction of the potential in four categories:

1. Aquatic habitats. While all of the attributes used within EDT are potentially important, it is likely that a smaller subset capture many other attributes as well as the effect of most management actions. The figure shows three candidate attributes: summer low flow, summer high temperature and the percent fine sediment. The figure summarizes the results for a single ecological province. The bars show the deviation of the province for two situations in regard to each attribute relative to the potential for the province. Those on the left of each group show the current deviation of the province while those on the right show the target situation for an alternative or for the adopted program. The arrows refer to the *Biological Objectives: the amount of change in an attribute within a province needed to meet the program vision based on the set of hypotheses within the EDT model*.

2. Terrestrial Habitats. Terrestrial habitats are often described in different terms than aquatic habitats reflecting different scientific traditions and perspectives. While the two sides are converging, differences remain that should be reflected in the Biological Objectives. Terrestrial biologists generally refer to habitat types that are described on the basis of vegetational coverages rather than on the habitat attributes that are used for aquatic habitats. The figure demonstrates how terrestrial habitat types can be handled in much the same way as the aquatic habitat attributes. Again, the potential, current and

target habitats are displayed to derive a Biological Objective as the change in a habitat type (e.g. shrub-steppe) within a province in the direction of the potential.

3. Biological Performance. This refers to measures of abundance, productivity and diversity of specific species. These are calculated within EDT on the basis of the rules and habitat conditions. For many, these are the "bottom line" for performance of the program and are often directly translatable into the values and qualities referred to in the vision for the basin. EDT can be used to set Biological Objectives for the program in terms of biological performance that could be expected if the other objectives are met and if the hypotheses within the model effectively capture the behavior of the Columbia River ecosystem. In many ways, these are the final check on how accurately we can depict the behavior of the system. They are meaningful only over relatively long time frames and are the result of complex and imperfectly understood ecological processes, only a subset of which are affected by the Council's program. Hence, while important, they may be less revealing about program effectiveness in the short term relative to other parameters such as the habitat attributes.

Some measures of biological performance may be derived using other methods, for example, the federal agencies may define criteria for delisting species listed under the Endangered Species Act. These could be incorporated and used as objectives. It is likely that the same procedure for monitoring and evaluation using EDT as the analytical framework could be used to track progress toward ESA recovery goals.

4. Artificial production. Artificial production is somewhat difficult to fit into this scheme reflecting the difficult and often undefined ecological role of hatcheries. At the basin level, objectives could describe performance objectives of hatchery fish relative to wild fish, the preferred relationship to natural populations and other measures that would apply at all levels. Biological objectives for hatcheries can be the difference between the biological potential of the habitat under the program and that desired under the Vision. For example, if we set objectives for summer low flow, summer high temperature and percent fine sediment that, in EDT, did not appear to meet the vision for a province or

subbasin in regard to abundance or productivity of a specific species, such as salmon, artificial production could be used to fill in the gap to replace the capacity of lost habitat. The artificial production guidelines in this program note the relationship between habitat quality and effectiveness of hatcheries. Hence, the habitat attributes do not in any way preclude the use of hatcheries and, in fact, would be key to their success.

Relationship to Research, Monitoring and Evaluation.

Biological Objectives and their underlying rationale should be the basis for research, monitoring and evaluation conducted under the Council's program. They provide the basis for defining progress and accountability of the region's efforts. The objectives themselves are observable properties of the ecosystem that should be the subject of a regional monitoring program. Ecological processes and functions that are the underlying mechanisms determining observable properties (such as the working hypotheses) would be investigated through scientific research. Many of the hypotheses are measurable only under controlled circumstances such as those in a research program. Once understood they would lead to better hypotheses but would not need to be routinely monitored (there may be exceptions to this such as some survival rates).

Monitoring of the objectives and research into the underlying hypotheses should lead to an assessment of the progress and a formal updating of the objectives. The five-year life of the Council's fish and wildlife program stipulated in the Northwest Power Act provides a natural point to assess progress and to refine the Biological Objectives if necessary.

V. Geographic Structure.

The Columbia River is part of an immense bio-physical system that encompasses a vast array of physical, biological and human elements. Because of its size and complexity, the river is usually managed as a collection of individual components. Different countries, states, and agencies are each concerned with separate parts of the ecosystem. Terrestrial areas are managed separate from aquatic areas, wildlife separate from fish and commercial species separate from non-commercial species. The result is a hodgepodge of loosely coordinated programs with sometimes conflicting mandates and actions.

A unique feature of the Northwest Power Act is its direction to consider the Columbia River as a system. This was recognition of the need to form a regional vision of the river that transcends parochial interests. Managing the river as a system means recognizing its structure and how the parts work together. These are a primary motivation for the Scientific Foundation in general and the Geographic Structure in particular.

Consideration of scale within the framework.

While stressing the need to consider the Columbia River as a bio-physical system, the basin is too large and complex for us to understand or manage as a single entity. We must break it down into smaller pieces on which we can focus our efforts. At the same time, managing each piece as an independent entity risks losing appreciation for the interaction between components and their collective performance as a system. For this reason, we propose an ecologically based structure that stresses the inter-relationships of the many parts. Reflecting Scientific Principle 3, it is based on an hierarchical description of the system at different spatial and time scales. Each level is nested within a larger scale level that provides the context for the level and constrains its characteristics.

This is like viewing the ecosystem from different heights. At a very high elevation we can see the entire system, but our resolution is poor. We cannot see all of

the detail but we can discern large-scale features and appreciate the system as a whole. We can set long-term directions and policies that guide and constrain the smaller scale details. As we descend, we see additional features. We can see how the smaller scale systems interact to affect the whole. We can manage and change smaller scale features to affect performance of the larger system. At the same time, all of the detail is set in the context of the larger system. Importantly, the shift from large to small scale helps us understand that biological performance is more than the sum of individual components but instead results from the synergy of the components acting as a system.

The geographic structure of the Council's program is based on the following considerations:

1) The structure is defined with respect to native fish and wildlife and their associated biological communities and habitats.

2) Within the basin, it is based on river hydrology that links many of the biological and physical features of the Columbia River. The Columbia River Basin is divided into Ecological Provinces that are ecologically related sets of subbasins consisting of one or more watersheds.

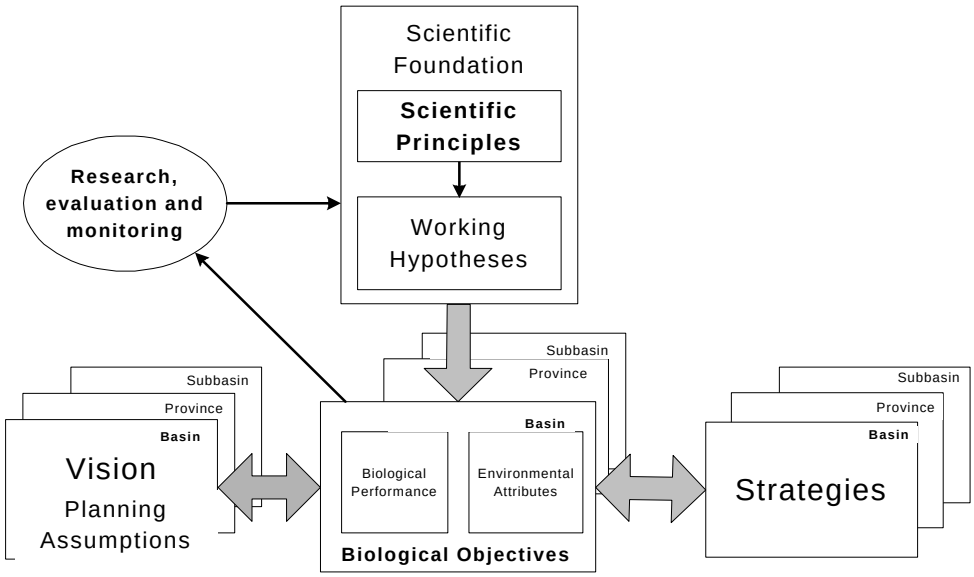
3) The structure is devised to facilitate management of natural resources in the Columbia River basin. While based largely on patterns in ecological organization, it also contains features intended to facilitate planning and management.

The geographic structure is designed to benefit planning and implementation of the Council's program and to encourage a systems view of the Columbia River Basin. Other entities have organized the basin along different lines for different purposes (e.g. Quigley and others 1996). It is not necessary or possible to have a single organizational scheme that will satisfy all needs. Available technologies, such as Geographic Information Systems, allow ready transformation between different schemes to enhance communication and coordination between management efforts.

The geographic structure is coupled with the program elements described above to complete the Framework for the Council's Fish and Wildlife Program (Figure 3). Framework elements described at one level constrain elements described at smaller scale

levels. For example, the Vision at the basin level constrains the Vision for each ecological province. These in turn constrain the visions for each subbasin. At the same time, Biological Performance at the higher levels reflects performance of populations and communities at smaller scales.

Figure 3. Fish and Wildlife Program Framework



We define at least five nested levels within the structure of the Columbia River Bio-Physical Region that can be distinguished by their spatial and time scale as well as function within management of the Columbia River. At each level, we can discern a different scale of feature. This is the “pixel” of the picture we can see at each level. These pixels are the management units that can be manipulated to change biological performance. The levels that we propose to use for purposes of regional planning are show in Table 1 (typical areas and frequency of change are approximations for illustration).

Table 1. Hierarchical levels and features of the Columbia River Ecosystem.

Ecological feature	Typical area	Expected frequency of change	Management Unit	Management considerations
Columbia River Bio-physical region	100,000s of square miles	Centuries to millenia	Regions	Global climate change
Region (NE Pacific Ocean /Columbia River Basin	1,000s of square miles	Decades	Ecological Provinces	Regional vision; information, research management
Ecological Provinces	100s of square miles	5-10 years	Subbasins	Coordinated regional planning
Subbasins	10s of square miles	5 years	HUC-6	Local planning and action
HUC-6	1-10 square miles	1 years	Specific sites	Local actions

At the broadest scale, we define the Columbia River Bio-Physical Region (Figure 3) based on the biological and physical elements associated with the focal species that represent the native ecological system. This encompasses to major areas, the watershed of the Columbia River and that portion of the northeast Pacific Ocean inhabited by anadromous salmonids of Columbia River origin. The ocean range of chinook salmon, the most abundant anadromous salmonid in the Columbia, extends from Oregon into Southeast Alaska and a considerable, but inexactly known, distance offshore (Healey 1991).

Within these landscapes we recognize areas with distinct ecological character that we term Ecological Provinces (Figure 4). Ecological Provinces are areas with distinct physical and biological features containing ecologically related subbasins. They are distinguished primarily on patterns related to climate and regional geology and population distributions of native fish and wildlife. Each Ecological Province is hydrologically contained, that is, a province consists of a set of ecologically related subbasins that are connected to larger hydrologic units. The provinces will be the basis for regional planning of actions that occur at smaller scales (i.e. subbasins). Our classification of provinces is similar, but not identical, to ecological areas defined by

others, usually based on vegetational patters (e.g.Franklin and Dyrness 1973, Quigley and others 1996).

Subbasins within the Ecological Provinces are major watersheds that are tributaries to the mainstem Columbia and Snake rivers. Examples are the Yakima, Salmon, Methow and Willamette river subbasins. These subbasins will be the subject of individual subbasin plans, designed to be consistent with the Vision and Biological Objectives at the province level. It may be reasonable to group smaller tributaries with larger tributaries for purposes of developing subbasin plans.

While ecologically based, the provinces also reflect the need to organize recovery and management actions. For example, dams are often used to indicate hydrologic boundaries. For our purposes, a subbasin can only be in one province; boundaries do not cut across subbasins[4]. Based on patterns of terrestrial vegetation, the headwaters of subbasin are often distinct from the lower reaches and have been put into separate areas in other schemes (e.g. Franklin and Dyrness 1973). However, for purposes of planning, especially with respect to anadromous salmonids, it makes little sense to split subbasins. Instead, we treat each subbasin as an integral component of a set of related subbasins forming a province (Table 2).

[4] One exception to this rule was made for the Spokane River where we split the river at Lake Coeur d'Alene. The portion below the lake is in the Intermountain Province while the lake and the upper portion of the river are in the Mountain Columbia Province.

Figure 4. Ecological Provinces of the Columbia River Ecosystem.

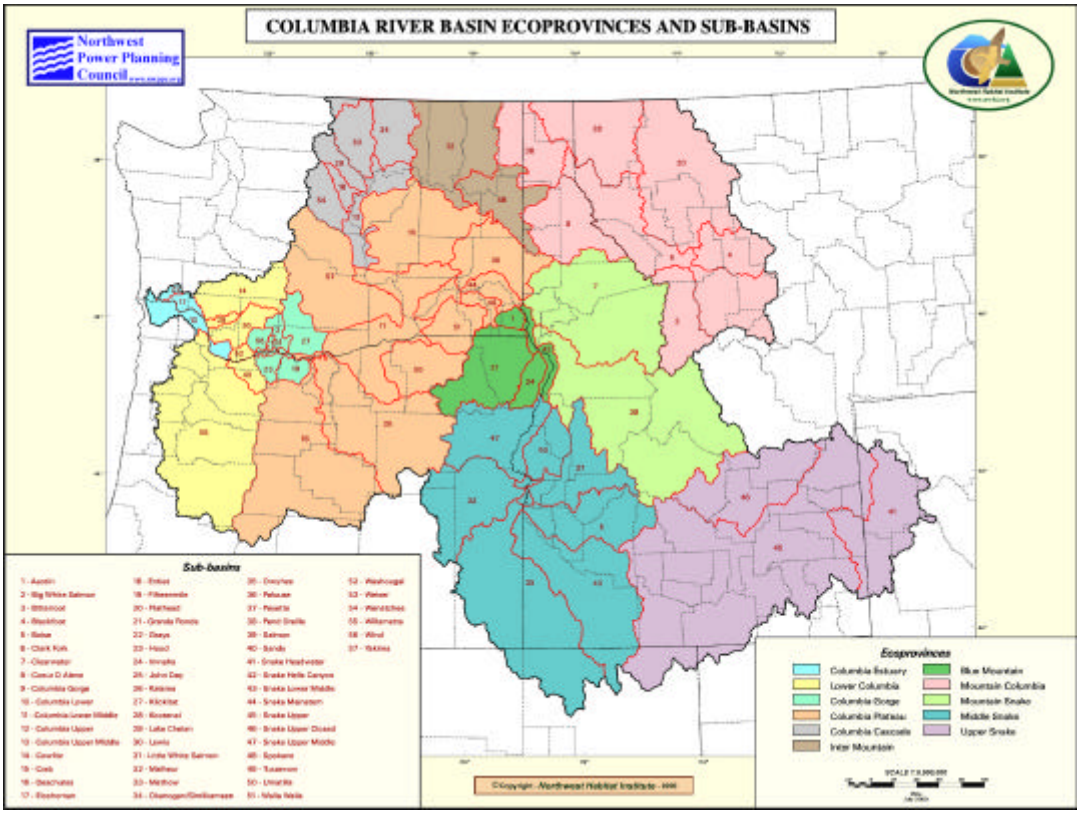


Table 2. Geographic Structure of the Columbia River Bio-Physical Region excluding the Marine areas.

Landscape	**Province**	Subbasin
Columbia River Basin	Columbia Estuary	• Youngs • Grays • Elochoman • Baker Bay • Cathlamet Bay • Columbia River downstream of mile 47
	Lower Columbia	• Cowlitz • Kalama • Lewis • Willamette • Washougal • Sandy • The Columbia R and all tributaries downstream of, but not including, Bonneville Dam to river mile 47.

Columbia Gorge	• Wind • White Salmon • Little White Salmon • Klickitat • Hood • Fifteenmile Cr • The Columbia and all tributaries between, and including, Bonneville and The Dalles dam*s*
Columbia Plateau	• Deschutes • John Day • Yakima • Umatilla • Walla Walla • Crab Cr. • Tucannon • The Columbia and all tributaries upstream of The Dalles up to and including Wanapum Dam • The Snake River and all tributaries from Lewiston, ID to the confluence with the Columbia R.
Cascade Columbia	• Wenatchee • Entiat • Lake Chelan • Methow • Okanogan • The Columbia R and all tributaries downstream from, but not including, Chief Joseph Dam to Wanapum Dam.
Intermountain	• Powder • San Poil • Spokane downstream of Lake Couer d'Alene • The Columbia and all tributaries between and including Chief Joseph Dam and the US/Canada border
Mountain Columbia	• Pend Oreille • Spokane above and including Lake Couer d'Alene • Preist • Kootenai • Clark Fork • Flathead • Blackfoot • Bitteroot
Blue Mountain	• Grande Ronde • Asotin • Imnaha • The Snake R and all tributaries from Lewiston to Hells Canyon Dam.
Mountain Snake	• Clearwater • Salmon

	Middle Snake	• Burnt • Powder • Weiser • Boise • Owyhee • Bruneau • The Snake R and all tributaries from Hells Canyon Dam to Shoshone Falls.
	Upper Snake	• Big Wood • Little Wood • Little Lost • Henry's Fork • The Snake R and all tributaries from Shoshone Falls to headwaters, all closed basins within the Columbia Basin east of Shoshone Falls.

The finest level we have defined in the geographic structure is the HUC-6. This is based on a generally adopted hydrologic categorization of watersheds (Seaber and others 1987). Briefly, the system is based on how freshwater systems are organized as they dissipate energy from upper catchment areas to the ocean. The Columbia River, for example, is classed as a HUC-2, the Willamette River, a tributary to this, is classed as a HUC-3, a tributary to the Willamette a HUC-4 and so on. Unfortunately, the Canadian portion of the basin has not yet been classified by this system. For the U.S. portion of the basin, there is approximately 7200 HUC-6 units.

Description of the Columbia River Ecosystem at the basin and ecological province scales.

A. The Columbia River Basin

The Columbia River Basin covers an area of 259,000 square miles. The lands in the Basin are highly diverse and encompass a large range of biological, geological and climatic zones. Environments within the basin range from the Pacific Ocean on the west to the continental divide in the Rocky Mountains on the east. Elevations extend from sea level to over 13,000 feet. The topography has been shaped by dramatic regional geological forces ranging from continental edge folding in the Rocky Mountains, flood basalts and glacial flooding on the Columbia River Plateau and volcanism, folding and

glaciation in the Cascade Mountains (Orr and Orr 1996). This has resulted in a large range of biological zones ranging from alpine, to high desert to coastal rainforests (Franklin and Dyrness 1973).

Within this vast area, climate patterns are determined by regional processes interacting with topographic features. Moist air from the Pacific Ocean moves east until it encounters the Cascade Mountains. Much of the moisture is dropped on the west side of the Cascades producing a temperate rain forest, while the area east of the Cascades is arid. Within these extremes, the type and distribution of vegetation varies with elevation, soils, long-term precipitation patterns and climate. Forested vegetation ranges from the spruce-hemlock dominated coastal rainforest to the dry interior Douglas fir and Ponderosa pine zones. Grasslands, shrublands and woodlands dominate the basalt plateaus. The Basin is, for the most part, sparsely populated with the majority of the population concentrated in urban areas west of the Cascade Mountains.

The area is drained by the Columbia River and its tributaries. The river falls some 2,600 feet over a 1,210 mile course from Columbia Lake in British Columbia to its mouth at Astoria, Oregon (Neal 1972). The Columbia is the __ largest river in North America with an average annual discharge of ___thousand cubic feet per second.

Over 43,000 species of macro-organisms are estimated to occur in the Basin and over 17,000 species are known (Quigley and others 1996). Microorganisms, critical to ecosystem health and function, probably number at least several hundred thousand species. This diversity of species results from the extensive habitat types, topography and geologic and climatic events that have shaped the region.

Within the aquatic areas, salmonids (anadromous and resident) and other species structure habitats and form ecological linkages between major ecological provinces. Biological species link marine and freshwater environments and aquatic and terrestrial environments. They interact with the physical habitat to maintain ecosystem integrity. Juvenile salmonids move within watersheds to take advantage of diverse food sources that change with the seasons. When they migrate to the ocean, anadromous salmon (e.g. chinook, *Oncorhynchus tshawytscha*) feed on marine organisms for several years and grow to mature size (Healey 1991). In a similar manner, adfluvial resident salmonids (e.g. bull trout, *Salvalinus confluensus*) move between stream and lake habitats over the

course of their life cycles. When anadromous and adfluvial fish return to their natal streams as adults, they move nutrients from marine to freshwater systems and within freshwater habitats. They are consumed by a variety of terrestrial animals (e.g. black bear, *Ursus americanus* and eagles, *Haliaeetus leucocephalus*) forming a linkage between marine, freshwater and terrestrial environments (Willson and Halupka 1995). Nutrients from spawned-out carcasses foster growth of aquatic plants, bacteria, fungi, stream insects, and other fish in environments that otherwise have low natural productivity (Cederholm and others 1999). Thus, salmonids play a key role in nutrient cycling and ecosystem productivity (National Research Council 1996). Salmon and other species (e.g. beaver,*Castor canadensis*) can also be important agents in shaping and forming aquatic, riparian and terrestrial habitats (Peterson and Foote 2000).

B. Ecological Provinces

1. Columbia Estuary Province

The Columbia River Estuary/Plume Province includes brackish and nearshore environments defined by the interface between riverine and marine waters. The Columbia River Plume influences the distribution of nutrients, salinity, and the upwelling front off coastal Washington and Oregon. Discharge from the Columbia River is the dominant source of freshwater runoff to the local coastal and oceanic waters. The horizontal and vertical extent of this plume can be defined by the contour of 32 parts-per-thousand in salinity. The low salinity surface water of the plume represents an offshore extension of the estuary that varies seasonally in its location along the coast. During late spring and early summer, the plume extends 300-400 km seaward and 500 km or more southwest. During the winter, the region of lower salinity extends seaward about 50-100 km and along the coast from about 100 km south of the river mouth northward to the Strait of Juan de Fuca. The oceanographic structure and dynamics of the plume varies markedly from one area to the other, because of variations in runoff, winds, tides, mixing, etc. Upwelling may also occur in many localities with suitable winds. It has been postulated that the turbulent plume waters provide a low visibility environment where outmigrating juvenile salmon find protection from potential predators (Pearcy 1992).

Also, the nutrient content and mixing processes may define productive conditions that provide abundant food sources.

The Columbia River Estuary extends over more than 85,000 hectares of tidal and non-tidal wetlands. It includes the lower 47 miles of the Columbia River, from the borders of Wahkiakum/Cowlitz Counties in Washington and Clatsop/Columbia counties in Oregon, and can be divided into three sections along the salinity gradient. The lower estuary, from the mouth to about river mile 7, is basically marine; the middle estuary, from river mile 7 to river mile 23, is transitional (mixing), and the upper estuary, above river mile 23, is fluvial (fresh water). This province includes tidally-influenced subbasins such as the Youngs Bay, Cathlamet Bay, Elochoman River, Grays Bay, and Baker Bay.

Surveys of fish species and invertebrate ecology in the estuary documented significant differences in the habitat characteristics and biological assemblages of the three proposed sections. This information suggests that these sections are of relevance for the production of key fish species, in particular migratory salmonids. Currently, 13 populations of salmon and steelhead, pass in and out of the Columbia River estuary each year.

2. LOWER COLUMBIA PROVINCE

The Lower Columbia Province is the portion of the Columbia River watershed downstream of Bonneville Dam not including the Columbia Estuary. It consists of the west-side temparate rainforest west of the Cascade Mountains except for the area of the Columbia River Gorge.

This area was shaped by development of the Cascade and Coast mountain ranges. On the eastern edge the uplift of the Cascade Range and formation of the Cascade volcanic peaks such as Mt. Hood began about 4 million year ago and produced peaks over 11,000 feet in elevation (Orr and others 1976). On their western side, the Cascades form the watershed of the Sandy River, the upper tributaries of the Willamette River, Elochoman, Cowlitz, Kalama Lewis and Washougal rivers.

The western part of the province is dominated by the older Coast Range with peaks averaging 1,500 feet in elevation. The Coast Range contains the watersheds of the

Grays, Lewis, and John Day rivers and the upper Willamette River. In between these mountain ranges is the trough of the Willamette River Valley. The valley bottom contains extensive deposits of material that originated much further up the Columbia River (McDowell 1991). These were transported by a series of massive glacial floods (the Missoula Flood) at the end of the last glaciation about 15,000 years ago (Baker and Bunker 1985). The Willamette River drains both the Cascade and Coast ranges and forms the second largest tributary to the Columbia River.

The upward tilting that formed the base of the Cascades about 5 million years ago had a dramatic effect on regional climates (Orr and Orr 1996). Winds from the Pacific Ocean are forced upward by the Cascades where they drop most of their moisture on the west side within the Lower Columbia Province. This produces a temparate rainforest with annual precipitation of over 100 inches. The result is an historical condition of dense forests, mature soils and highly variable seasonal stream flows.

Human development in the province over the last century has resulted in the largest urban region in the Columbia River basin. Much of the lowland forests have been replaced with agriculture or urban lands. Mid-elevation forests are heavily logged while major portions of the upper elevation forests in the Cascades are protected.

3. COLUMBIA GORGE PROVINCE:

The Columbia Gorge Province is the smallest of the ecological provinces but is recognized because of its unique transitional environment linking the temparate rainforest of the Lower Columbia Province and the arid Columbia Plateau Province. For our purposes, we define Gorge Province as the Columbia River between Bonneville and The Dalles dams and the associated watersheds.

The gorge marks the path of the Columbia River through the Cascade Mountains. As the Cascades were uplifted and formed, the river kept pace cutting a relatively narrow gorge through the mountains. At the end of the last regional glacial period, about 15,000 years ago, glacial floods rushed through the gorge scouring the sides clean (Baker and Bunker 1985). On the south side of the gorge especially, the floods produced the steep

gorge wall with hanging valleys that form numerous waterfalls such as Multnomah Falls.(Tolan and others 1984). The route of the river through the Gorge was most recently altered by the Bonneville landslide about 400 years ago. In this immense slide, the south side of Table Mountain broke loose and slid into the river. This has resulted in the constricted course of the river at Bonneville Dam and Bridge of the Gods.

The steep gorge and the climatic effect of the Cascades results in the unique environment of the Columbia River Gorge. There is a dramatic transition in precipitation from the heavy rainfall of the western edge around Bonneville Dam to the relatively arid area of The Dalles Dam only 45 miles upstream. In the western end of the Gorge, major watersheds are present only on the more gently sloping north side. This includes the Klickitat, Wind, White Salmon and Little White Salmon drainages. Various small creeks drain from the south side of the gorge, most plunging over the shear cliffs to form dramatic waterfalls while others go through the cliffs in their own steep gorges like Eagle and Oneata creeks. Most of the drainage from Mt. Hood goes east into Hood River and Fifteen Mile Creek that open out onto the more arid east end of the Gorge.

Human development in the Gorge has been relatively slight with the exception of the Columbia River itself. Its cut through the Cascades has resulted in a pronounced constriction at the Bridge of the Gods and cataracts above this point. Both the relatively large drop in elevation and the navigational hazards made the Gorge an early target of development, first in the form of locks at Cascade Locks and later with construction of Bonneville Dam in 1936. The rapids at the upper end of the Gorge resulted in construction of The Dalles Dam in 1960. Urban development has been relatively small with the city of The Dalles being the largest city in the Gorge. Watersheds are typically forested with logging being important, especially on the relatively more modest slopes of the north side.

4. COLUMBIA PLATEAU PROVINCE

The Columbia Plateau Province in the largest of the ecological provinces. It is defined by the Columbia River drainage downsteam of Lower Granite Dam on the Snake

River and Wanapum Dam on the Columbia River, down to The Dalles Dam on the Columbia River. The Plateau includes several major subbasins including the Deschutes, John Day, Umatilla and Yakima rivers. It encompasses the area of eastern Washington known as the "channelled scablands"(Bretz 1932) drained by Crab Creek that enters the Columbia below Wanapum Dam.

The Plateau is generally defined by the major extent of Columbia River basalt formation that forms an area of low topography. The basalt resulted from a series of extensive lava flows during the Miocene period some 50 million years ago (Orr and others 1976). Flows moved down the course of the river eventually reaching the Pacific Ocean over 700 miles away from the source of the flow (Tolan and others 1989). The flow spread north across much of eastern Washington. Simultaneous subsidence in the area around Pasco, Washington resulted in pooling of the flow and accumulation of basalt to a depth of over three kilometers.(Reidel and others 1982).

The basalts determined the course of the Columbia River in eastern Washington. As they spread across the surface, the river was pushed to the periphery of the flow. The present river course, pinched between the edge of the flow and Cascade Mountains that were forming to the west, was firmly established some 50 million years ago (Reidel and others 1989). Subsequent folding of the basalts formed the Yakima Hills and set the lower courses of the Yakima drainage (Reidel and others 1989).

The basalt also determined the course of the lower Snake River. Later in the Miocene, the source of the basalts moved eastward into Idaho. Flows moved down the Snake River filling the river valleys and moving it several times to its present location (Reidel and others 1989).

The second formative event for the Plateau was the development of continental glaciation to the north. During the last glaciation that ended some 15,000 years, glacial ice extended approximately to the northern edge of the Plateau (Richmond and others 1965). The Plateau itself remained free of glaciation (except the mountainous upper

portions of some subbasins). However, dry, cold arctic conditions created by the glaciers and their outwash resulted in deposition of hundreds of feet of very fine-grained sediment. This material is thought to have been deposited from the south by wind moving glacial material back toward the glacial front (Baker and others 1991). These deposits now form the Palouse hills on the eastern portion of the Plateau.

The final character of the Plateau was shaped by the Missoula Flood. During various glacial advances, lobes of ice dammed the Columbia, Spokane and Clark Fork rivers forming immense lakes on the northern edge of the Plateau (Baker and Bunker 1985). As the lakes filled, the ice dams tended to float eventually producing catastrophic draining of the lakes. The result was a series of immense floods that shaped the surface of the Plateau and much of the valley downstream (Waitt 1980, Reidel and others 1989). The floods spilled across the northern edge of the Plateau and stripped off much of the western Palouse sediments to form the channeled scablands. The drainage pattern across the scablands remains as Crab Creek. The floods also set in place many of the present river bars and gravels of the Columbia River including those in the Hanford Reach (Hall 1988).

The result of all these events is a surface of relatively low topography, thin soils and deeply entrenched river courses. The Cascade rain shadow produces an arid climate with an average rainfall of around 15 inches. Much of the native vegetation is classed as shrub-steppe composed of sage and grasses (Franklin and Dyrness 1973). Much of the native vegetation has been converted to irrigated agriculture. The exception to this is the Hanford Reservation and associated areas along the Hanford Reach where agriculture has been excluded and where the only the only extensive area of native vegetation remains.

Many of the tributaries included in this province arise in mountain ranges that are ecologically distinct from the Plateau. The Yakima arises from the Cascades, the Deschutes from Mt. Hood, the John Day and Umatilla from the Blue Mountains. The lower courses of these rivers flow across the Plateau, often in valleys incised in the basalt. Historically, these tributaries, especially the Yakima, were major producers of

chinook salmon (Howell and others 1985). The slope of the Columbia River decreases over the Plateau relative to upriver areas. Although firmly constrained by the surrounding geology, the Plateau is one of the few areas where the Columbia takes on a more alluvial character forming a series of gravel bars, backwaters and islands. This resulted in historically important mainstem spawning areas for chinook salmon (Fulton 1968, Battelle Pacific Northwest Division 2000) including the Hanford Reach, the only remaining area of extensive chinook spawning in the mainstem Columbia River.

5. COLUMBIA CASCADE PROVINCE

This province consists of subbasins that arise in the Cascade Mountains in Washington State and enter on the west side of the Columbia River. The downstream limit of the province is marked by the hydrologic drop between Wanapum and Priest Rapids dams but is set for convenience at Wanapum Dam. The upstream terminus is the limit of anadromous fish passage at Chief Joseph Dam. The province includes four major hydroelectric projects, Wanapum, Rock Island, Rocky Reach and Wells dams.

Much of the province is formed by the northern Cascade Mountains. The northern Cascades consist of tightly folded and metamorphosed sedimentary rock that was uplifted during the Pliocene (Alt and Hyndman 1995). Subsequent volcanic intrusions occurred, including the volcanic peaks of Mount Baker and Glacier Peak. The Cascades were heavily glaciated producing characteristic valley shapes and features, most notably the fjord-like Lake Chelan formed by a terminal moraine at the end of a steep-walled glacial valley.

The province includes the Wenatchee, Entiat Lake Chelan, Methow and Okanogan subbasins. These rivers are relatively short, high gradient systems. As a result, these aquatic systems have a relatively low productivity (Mullen and others 1992). Spring chinook and steelhead are the predominant anadromous salmonid throughout most of the area open to anadromous passage with summer chinook in the lower mainstem areas (Mullen and others 1992). Fall chinook historically spawned in the mainstem Columbia River (Battelle Pacific Northwest Division 2000). However, most mainstem populations were eliminated by construction of the four mainstem dams within the

province. Vegetation over much of the watersheds is subalpine and montane mixed conifer forest (*Abies spp*., *Tsuga mertensiana*. and *Pseudotsuga menziesii* assemblages Franklin and Dyrness 1973). Much of the upper watersheds are in National Parks and Forests. The province is within the Cascade rainshadow and the climate with hot dry summers and harsh winters. Most precipitation occurs in the upper parts of the subbasin as winter snow. Lower portions of the subbasins are generally arid.

The lower valley bottoms support orchards and other irrigated agriculture. The area is relatively sparsely populated. The major urban center within the province is Wenatchee, Washington.

DESCRIPTIONS FOR THE FOLLOWING PROVINCES ARE STILL BEING DEVELOPED:

6. INTER-MOUNTAIN PROVINCE

The Columbia R and all it's direct tributaries between Chief Joseph Dam and the United States / Canada Border.

7. MOUNTAIN COLUMBIA PROVINCE

The Pend Oreille R, Preist R, Kootenai R, Clark Fork R, Flathead R, Blackfoot R, and Bitteroot R subbasins.

8. Blue Mountains Province

The Blue Mountains Province includes the Grande Ronde and Imnaha rivers arising in the Blue Mountains and draining to the Snake River. The province also includes the Snake River from Hells Canyon Dam to the upper end of Lower Granite Pool at Lewiston, Idaho. This is the only remaining free flowing stretch of the Snake River accessible to anadromous fish.

The Blues are a geologically distinct region that includes the oldest geological formations in Oregon (Orr and others 1976). Most of the Blues consist of Paleozoic terrenes that accreted to the leading edge of the continental craton as it moved relative to the Pacific Plate as a result of sea floor spreading (Alt and Hyndman 1995). The climate at mid and lower elevations is arid characterized by hot and dry summers and harsh

winters. Upper watershed areas are forested with areas protected within National Wilderness designations.

9. Mountain Snake Province

The Mountain Snake Province consists of the Clearwater and Salmon River subbasins that drain into the Snake River. The Snake River portion of the province has been allocated to the Blue Mountains Province. The Clearwater and Salmon rivers are extensive systems draining the Idaho Rocky Mountains. The subbasins arise on the Idaho Batholith, a large granitic intrusion. This results in steep terrain and relatively low productivity. Major portions of the Clearwater and Salmon drainages are protected in wilderness or other designations.

10. MIDDLE SNAKE PROVINCE:

The Burnt R, Powder R, Weiser R, Boise R, Owyhee R, Bruneau R subbasins, and the Snake R and it's direct tributaries from Hells Canyon Dam to Shoshone Falls.

11. UPPER SNAKE PROVINCE

The Big Wood R, Little Wood R, Little Lost R, Henry's Fork R subbasins, the Snake R and all it's direct tributaries from Shoshone Falls to headwaters, all closed basins within the Columbia Basin east of Shoshone Falls.

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