Proceedings of the Klamath Basin Science Conference, Medford, Oregon, February 1–5, 2010

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Chapter 1. An Overview of the Klamath Basin Science Conference

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"An ecosystem view…involves a different framework of ideas derived from other scientific tradition's natural histories, evolutionary biology and ecology. In these traditions, environmental variation is an essential organizing property of living organisms. The purpose of conservation is not to "improve" nature by eliminating variability; it is to protect the interrelationships that allow populations and communities to sustain themselves in a changing world". Dan Bottom (1995)[4]

Introduction

This report presents the proceedings of the Klamath Basin Science Conference (February 2010). A primary purpose of the meeting was to inform and update Klamath Basin stakeholders about areas of scientific progress and accomplishment during the last 5 years. Secondary conference objectives focused on the identification of outstanding information needs and science priorities as they relate to whole watershed management, restoration ecology, and possible reintroduction of Pacific salmon associated with the Klamath Basin Restoration Agreement (KBRA). Information presented in plenary, technical, breakout, and poster sessions has been assembled into chapters that reflect the organization, major themes, and content of the conference. Chapter 1 reviews the major environmental issues and resource management and other stakeholder needs of the basin. Importantly, this assessment of information needs included the possibility of large-scale restoration projects in the future and lessons learned from a case study in South Florida.

Other chapters (2–6) summarize information about key components of the Klamath Basin, support conceptual modeling of the aquatic ecosystem (Chapter 7), and synthesize our impressions of the most pressing science priorities for management and restoration. A wealth of information was presented at the conference and this has been captured in chapters addressing environmental setting and human development of the basin, hydrology, watershed processes, fishery resources, and potential effects from climate change. The final chapter (8) culminates in a discussion of many specific research priorities that relate to and bookend the broader management needs and restoration goals identified in Chapter 1. In many instances, the conferees emphasized long-term and process-oriented approaches to watershed science in the basin as planning moves forward.

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[3] U.S. Geological Survey, California Cooperative Fish and Wildlife Unit, Humboldt State University.
[4] From "Restoring salmon ecosystems: myth and reality."

This proceedings document is intended for a broad readership, not all of whom may possess strong technical backgrounds but nonetheless are interested in our findings. For this reason, the authors deliberately avoided providing extensive citations but have listed key scientific references as recommended reading at the conclusion of each chapter (see Chapter 1, section, “About this Report”).

Background

The Klamath Basin Science Conference was convened in Medford, Oregon, February 1–5, 2010. This timing preceded the signing of the historic Klamath Basin Restoration Agreement (KBRA) and Klamath Hydropower Settlement Agreement (KHSA) and, as such, these impending agreements provided a timely backdrop for the conference. The agreements and scientific needs assessment associated with the Secretarial Determination Process, while important, were not the sole criteria for holding this meeting. The last major Klamath Basin science conferences had occurred in 2004[5] and there was widespread consensus within the user communities about the need for updating and sharing of scientific information. Therefore, the primary purpose was to review the current understanding of the Klamath Basin ecosystem with respect to the most relevant issues for natural resource conservation, ecological restoration, and possible reintroduction of salmon associated with possible dam removals. A watershed approach, couched in an ecological risk assessment framework, was planned by meeting organizers to focus attention of conference presentations on (1) linkages between upper and lower subbasins; (2) ecosystem processes and interactions; (3) drivers, stressors, and high-level indicators of change; and (4) identification of priority needs as they relate to the management of valued resources or environmental conditions. A related goal was to increase basinwide collaboration by building trust and relationships across science and management entities representing the diverse group of stakeholders in the Basin. The geographic scope was the Klamath Basin, although it generally was recognized that environmental factors occurring at much larger scales (e.g., Northeast Pacific Ocean) would need to be acknowledged in light of their influences on salmon and other resources and ecosystem processes. It was anticipated that the ecological information presented at the conference, including our understanding of human activities and land use change, would support the development of a conceptual foundation from which science needs could be appropriately assessed. For now, the emphasis of this conceptualization would be identification of key processes and interactions rather than the quantification of these relations across a unique geography that includes the headwaters of the Klamath River, its major tributaries, estuarine and coastal areas, and adjacent marine waters.

Water is a limited resource with respect to its availability and uses in the Basin. This makes it an extremely valuable commodity and issues surrounding competing needs, resource allocations, and effects of dams have been contentious. The greatest controversies surround competing uses of water for agriculture, such as for irrigation, and ecological needs, or for conservation of endangered fish species. Water quality, quantity, and availability issues have been at the epicenter of resource conflicts that have intensified during recent drought years (2001–2005 and 2010). To illustrate, in 2001, irrigation water was shut off to approximately 1,200 farms in the Klamath Irrigation Project and civil unrest characterized the upper subbasin. The following summer, restored flows in the Klamath River resulted in suboptimal habitat conditions and high levels of mortality in adult Chinook salmon (*Oncorhynchus tshawytscha)*. Large numbers of fish (> 30,000) died prior to spawning, triggering cultural unrest and a renewed sense of urgency among many for dam removals.

[5] Upper Klamath Basin Science Workshop, February 3–6, 2004, Klamath Falls, OR; and Lower Klamath Basin Science Conference, July 7–10, 2004, Arcata, CA. No proceedings reports were produced.

In 2006, the combined effects of consecutive drought years and above-average water removals impacted salmon production in the Klamath Basin leading to the closure of the West Coast salmon fishery by the Secretary of Commerce. The declaration of a commercial fishery failure by the Federal Government authorized $60.4 million in economic relief to eligible fishery related stakeholders.

Given the history, legalities, and political intensity of the conflicts, the National Academy of Sciences was commissioned to independently evaluate the status of knowledge regarding the hydrology, ecology, and fishes of the Klamath Basin. Two books, one published in 2004 and another in 2008, synthesize existing scientific information, examine available models, and broadly describe science needs. Importantly, in 2008, the National Research Council reported "that the most important characteristics of research for complex river-basin management were missing for the Klamath River: the need for a 'big picture' perspective based on a conceptual model encompassing the entire basin and its many components."

As mentioned, the Department of the Interior (DOI) and its partners also convened two major science conferences in 2004. Their respective purposes were to update scientific information and resource management needs in the upper and lower subbasins. The potential effects of land-use practices on water conditions and ecology of endangered suckers was a focus of the upper subbasin meeting. The emergence of fish health issues associated with an endemic parasite and Klamath Basin salmon provided an impetus for the second conference. An important socio-environmental result of these meetings was how well they demonstrated the basin-level differences in biological and physical settings, communities, and resource management concerns. It was evident from these meetings that more communication and a basinwide approach were needed for integration of science. Simply stated, upstream actions have downstream consequences and these ecosystem relationships needed to be better understood.

Concerns about effects of hydroelectric power generation and other uses of dams on Pacific salmon are signature issues in California and the Pacific Northwest. The effort to forge a basinwide settlement agreement, including the possible removal of four PacifiCorp dams on the Klamath River as early as 2020, has created a more cooperative environment among members of the stakeholder community than existed in 2004. This has involved communication and legitimate efforts for shared understanding about respective water resource needs and economic and environmental concerns. It is not just about endangered fishes or water for agriculture anymore; it is more about the comprehensive needs of the entire Klamath Basin including its human constituents. Solutions are being sought outside the courtroom and, at the time of the conference, there seemed to be recognition of the potential merits of ecosystem-based and adaptive management approaches to restoration that include human economies, cultural needs, species conservation, and watershed health. The loosely-knit partnerships that have formed provide an environment where listening can occur and will be crucial for finding local solutions to Klamath Basin water issues. Moving forward, these partnerships will be important in decisions about water quantity, water quality, ecological needs, land-use planning, and other factors. Once divided by legal interpretations or water dependencies, tribal and other user groups are now attempting to find common ground through information sharing and negotiation. The information shared in these proceedings is meant to assist in these conversations, and to help stakeholders resolve historic conflicts and eventually guide the restoration to more natural conditions.

Secretarial Determination Process

On January 7, 2010, negotiations on KBRA concluded. Public Review Drafts of both the KBRA and the KHSA were made available to more than 30 negotiating partners for review and signatory decision making. Both agreements were signed on February 18, 2010. If fully implemented, the KBRA and KHSA would remove four dams on the Klamath River starting in 2020 (fig. 1-1). In 2012, the DOI Secretary will make a final determination regarding dam removal. Thus, as noted previously, this conference was timely because the science presentations and interdisciplinary discussions would help set a framework for final decision making by the DOI Secretary. The framework will be based on scientific predictions about the environmental consequences of dam removal, and improving science is at the center of the Secretarial decision.

The KBRA is intended to result in effective and durable solutions which will: (1) restore and sustain natural fish production and provide for full participation in ocean and river harvest opportunities of fish species throughout the Klamath Basin; (2) establish reliable water and power supplies that sustain agricultural uses, communities, and National Wildlife Refuges; and (3) contribute to the public welfare and the sustainability of all Klamath Basin communities. The KHSA establishes a process for the potential removal of four PacifiCorp dams on the middle Klamath River, thus allowing volitional fish passage.

The KHSA requires that the DOI Secretary, in consultation with the Departments of Commerce and Agriculture, must make a determination by March 31, 2012, as to whether the Federal Government supports dam removal and the concepts embodied in the KBRA[6]. This requirement is known as the Secretarial Determination (SD) Process. The DOI has identified November 30, 2011, as the date by which its environmental review for the determination must be completed. During the ensuing period, the Federal Government (in consultation with its non-Federal partners) is gathering new information and analyzing existing data and reports to inform this decision.

A Technical Management Team (TMT) has been created to coordinate the process of collecting and analyzing information for the SD. The TMT is comprised of members of participating Federal agencies and includes technical experts from the U.S. Fish and Wildlife Service (FWS), National Marine Fisheries Service (NMFS), Bureau of Indian Affairs (BIA), Bureau of Land Management (BLM), Bureau of Reclamation (Reclamation), and U.S. Geological Survey (USGS). Senior managers from DOI and the member agencies are providing high-level guidance on the SD Process. The TMT has legal, policy, and budgetary support from the respective offices of its constituent agencies.

The TMT is charged with developing and implementing a Project Management Plan (PMP) to assure the broad informational needs of the SD are met. The TMT is led by a Program Manager (USGS) with responsibilities for overseeing planning and conduct of studies and data collection required by the PMP. In addition, a Project Manager (BOR) is responsible for the coordination of the technical and operational activities funded by the BOR in support of the SD. The Program Manager regularly provides status reports to an Executive Management Group comprised of Regional Executives from member agencies to keep them informed.

In addition to the management positions described above, the TMT is led by chairs (or co-chairs) from nine sub-teams that have been tasked with identifying and addressing information needs in specific disciplinary areas: Economics; Environmental Compliance (NEPA/CEQA); Engineering, Geomorphology, Sediment and Hydrology; Biology; Water Quality; Cultural/Tribal; Recreation; Real Estate; and Public Involvement. The nine sub-teams include 45 Federal experts (e.g., economists, engineers, and resource scientists and managers) from eight Federal agencies. The Program Manager,

[6] Updated information about SD activities is available at http://klamathrestoration.gov/home.

Project Manager, and sub-team chairs (i.e., the TMT) are addressing PMP objectives and needs of the SD by ensuring that: (1) information sharing and coordination among sub-teams; (2) resources are properly allocated among tasks; (3) critical timelines are met; (4) studies reflect objective science; (5) reports of data and findings are accurate, comprehensive, and peer reviewed; and (6) collaboration and information exchange with stakeholders and the public is open, timely, and substantive.

The overall purpose of the PMP is to provide a broad framework for organizing and managing a large interagency Federal team tasked with gathering and analyzing the environmental and economic information needed for the SD. Specifically, the PMP is written to address the following four questions: (1) Will implementation of the two agreements advance fish restoration? (2) Is implementing these agreements in the public interest? (3) Can dam removal and site restoration be achieved at or under the estimated project cost of $450 million (in 2020 dollars)? and (4) What liabilities and risks might a Dam Removal Entity face before, during, and after dam removal?

The implementation of the PMP includes extensive reviews of existing information and models and new efforts to address outstanding gaps. Following these reviews of existing models and after consultation with other experts and stakeholders, each sub-team identified priority needs that must be met in each disciplinary area to fully inform the SD. These questions have led, or are leading to new data collection, analysis, and modeling efforts. Examples with respect to dam removal include:

- To what degree (if any), and in what timeframe, would dam removal and implementation of KBRA affect salmonid and resident fish populations in the Klamath Basin?
- How much sediment is stored behind the dams, how quickly would the sediment and associated contaminants be moved downstream if the dams are removed, and what impact might the sediment and any associated contaminants have on fish habitats and human health?
- What is the most economical and effective way to stabilize newly exposed reservoir sediments to minimize adverse effects (short- and long-term) on aquatic biota?
- How would dam removal and KBRA impact water temperatures, seasonal flows, and fish populations in the Klamath River?
- If fish populations respond to dam removal, what are the potential effects of this change on commercial, subsistence, and recreational fisheries (in-river and ocean fishing), local economies, and Tribal culture?
- What are the most probable adverse effects of removing reservoirs on recreation, tax bases, and lakeside real estate?

The TMT is addressing these questions using quantitative approaches whenever possible. For example, quantitative information is needed regarding the volume of sediment in the reservoirs and their associated contaminant concentrations. Predictive capability is needed to determine how reservoir sediments would be transported downstream using available sediment-transport models. In contrast, when a quantitative approach is not possible, because of the lack of models or data, expert panels will be used to review best available information to provide expert opinions (and probabilities) about associated effects or outcomes. The TMT anticipates using expert panels to estimate the likely population responses of at least four fish species if the PacifiCorp dams are removed and the KBRA is implemented.

NMFS[7] is conducting an economic analysis to ensure that the wide-ranging socio-economic effects of dam removal are accurately reflected in the SD. The cost-benefit analysis is considering dam removal costs; benefits to fish populations and fisheries; foregone hydropower; foregone reservoir and whitewater recreation; agricultural, real estate and Tribal/cultural effects; non-use value to the public; and effects on county-level income, employment and tax revenue. Within the cost benefit analysis, NMFS is developing a model to predict the response of Chinook salmon.

Because the SD will have a large environmental impact on the Klamath Basin, a joint National Environmental Policy Act/California Environmental Quality Act (NEPA/CEQA) analysis will be performed. An Environmental Impact Statement/Environmental Impact Restoration (EIS/EIR) document will be prepared in collaboration with the State of California. The NEPA/CEQA analysis will focus narrowly on a comparison of impacts associated with removing all four dams and fully implementing KBRA to a “status quo” No Action alternative. Because the SD is a “yes or no” decision and because both KHSA and KBRA must be implemented together and in their entirety, there are not many other alternatives available that would be consistent with the proposed NEPA/CEQA analysis. The information needs for the SD document and a NEPA EIS are largely the same, and preparation of the documents will proceed in parallel by the TMT to ensure consistency and that each final product is self-supporting.

If the Secretarial Determination is affirmative, planning for dam removal in 2020 and implementation of KBRA will be initiated. Many of these planning activities will require additional, more site-specific NEPA/CEQA analyses.

Watersheds and Ecosystems

A watershed is defined as a catchment that drains water, sediment, and dissolved materials to a common outlet at some point along a stream or river channel. Watershed size therefore varies from the very large basins, such as the Columbia River Basin, to very small streams. Broadly defined, watershed ecosystems can be described as communities of organisms (including humans) and their physical and chemical environment interacting as an ecological unit.

Understanding the structural elements and spatial scales of watersheds is essential for integrated science planning[8]. The regional scale is a broad geographical area with common macroclimate and sphere of human activities and interests. From historical and practical perspectives, the Klamath subbasins have served as the “operational” regional-scale units in previous planning efforts. The spatial elements of regions are called landscapes (fig. 1-2). Landscapes are distinguished by repeated patterns of ecological components, which include both natural communities like forest stands and wetlands and human-altered areas like agricultural lands. The dominant and interconnected land cover (e.g., forest) or land use (e.g., agriculture) over the majority of the landscape constitute a matrix. Forest and rangelands are dominant landscapes in the Klamath Basin.

Patches (e.g., wetlands and lakes) occur in, but are different from, the matrix and corridors (e.g., stream corridors) that are usually described as habitats or ecosystems. River and stream corridors and their constituent channels, floodplain, and upland fringes are special types of patches that link aquatic and terrestrial components of the watershed.

[7] See NOAA Klamath River Basin - 2010 Report to Congress (http://swr.nmfs.noaa.gov/klamath/).
[8] For more information see Federal Interagency Stream Restoration Working Group (1998) report entitled “Stream corridor restoration: principles, processes, and practices” (http://www.nrcs.usda.gov/technical/stream_restoration/newtofc.html).

A collection of patches, none of which is dominant enough to be interconnected throughout the landscape, is known as a mosaic. The mosaic in the Klamath Basin includes headwaters; wetlands, lakes and reservoirs; streams and rivers; and estuary and other coastal waters that might be influenced by freshwater flows. Ecosystems are dynamic and watersheds are altered by natural forces and human activities. Thus, the "shifting habitat mosaic of river ecosystems" conceptual model provides a useful organizing tool for planning watershed restoration and reestablishing connections between river and floodplain.

Ecosystems are continually shaped and reshaped by physical, chemical, and biological processes[9]. Ecosystem processes are any interaction among living and non-living elements of the environment that involve changes in character or state (e.g., fire). Ecosystem processes operate at naturally varying rates, frequencies, durations, and magnitudes that are controlled or constrained by anthropogenic or natural factors. They also operate at different time and space scales (e.g., nutrient dynamics, production cycles, growth and reproduction) and these must be considered in setting restoration goals, target species, and identifying metrics/schedules to assess management success (fig. 1-3). Some anthropogenic factors such as dams, agriculture and forestry, mining, fishing, and climate change are significant parts of the Klamath ecosystem as are their effects on natural processes and their interactions.

Disturbance is a relatively discrete event that disrupts or alters some portion or portions of ecosystems. Healthy ecosystems can accommodate most natural disturbances because they tend to be relatively short in duration and magnitude (for example, annual flooding) and do not severely impact their structure and function.

The Committee on Environment and Natural Resources Subcommittee on Ecological Systems[10] identified five contemporary causes of ecological change and emphasized how understanding their interactions will be critical to ecosystem-based management, consideration of alternative futures, and ultimately, the role of ecological forecasting in the conservation of our natural heritage:

- Extreme Natural Events
- Climate Change
- Land and Resource Use
- Pollution
- Interactive Effects

Forest Management

The possible cumulative effects of timber harvest on Klamath Basin watersheds and fish and wildlife habitat values are of concern. Hydrological and erosional impacts of logging and related road-building activities may move offsite and have downstream effects on fish and wildlife habitats and populations. The degree to which this happens depends on interactions of soils, bedrock geology, vegetation, storm events, logging technology, and human performance. Timber harvest can reduce evapotranspiration and increase annual streamflow resulting in downstream effects. Potential streamside effects can include reduced streamside canopies, increased sedimentation, elevated water temperatures, and reductions in the delivery of woody debris to aquatic habitats. In the Klamath River, these processes have impacted important salmon habitats. Within the U.S. Forest Service (USFS), a new philosophy of

[9] See "Guidance for protection and restoration of nearshore ecosystems of Puget Sound" (http://www.pugetsoundnearshore.org/technical_reports.htm).
[10] See "Ecological Forecasting: Agenda for the Future" (http//www.ecologicalforecasting@si.edu).

"all lands" management includes an ecosystem approach to evaluation of cumulative effects of planned forest practices that includes areas to be harvested, road building, placement of culverts, and potential effects of human settlements.

Aquatic Habitats

Habitat is the physical, chemical, and biological constituents of a specific unit of environment occupied by a specific plant or animal. They represent structural components of ecosystems that are primarily created and maintained by natural processes. Klamath Basin habitats have been affected by many factors including urbanization, agriculture, forestry, mining, hydropower, and fishing. Dams and other water-control structures have been controversial in this basin and others because of their direct impacts on anadromous fishes such as salmon, steelhead (*Oncorhynchus mykiss*), Pacific lamprey (*Lampetra tridentata*), eulachon (*Thaleichthys pacificus*), and green sturgeon (*Acipenser medirostris*). Dams affect river habitats by creating reservoirs, thus altering temperature and flow conditions and blocking access to upstream habitat. If significant enough, water removals can alter natural flows and ecosystem processes, such as nutrient and sediment transport. These changes may affect aquatic habitat conditions, prey bases, and overall biological productivity.

Water removals and reduced flows directly affect natural habitat conditions by changing water properties, such as dissolved oxygen, temperature, and salinity as well as nutrient loading and contaminant concentrations. For fish, these changes may result in barriers to rearing habitats and migratory corridors or spawning grounds. As habitat volumes shrink and space becomes limiting, cold water species, such as salmon and steelhead, may crowd into cooler thermal refugia. The effects of low dissolved oxygen conditions and pathogen introductions or spread into thermal refugia where fish concentrate may be profound. Reduced flows and water levels will affect stream morphology, affecting channel width, altering stream beds and banks, and potentially changing the composition of streamside vegetation. The resulting impacts on aquatic habitats can include changes in hydrologic properties such as temperature and dissolved oxygen, and simplification of habitat complexity and retentive capacities through changes in the availability of large woody debris. Changing flow and channel structure, increasing stream bank instability and erosion, and altering nutrient and prey sources also degrade river habitats. As flow rates and hydrologic properties change, free-flowing rivers become disconnected from their floodplains, and the hydrologic and geomorphologic processes that sustain fish populations and key habitats may be lost (table 1-1).

Potential impacts of dams to salmon are of particular interest in the Klamath Basin. By blocking upstream access, dams greatly reduce the amount of habitat available for reproduction, feeding, growth, and migration. These are all important processes in the life cycle of salmon and can be extended to other species. Adequate freshwater flow is critical to all life stages, from eggs to spawning adults, so reduced flow can have a negative effect on anadromous fish populations. Current temperature regimes in the Klamath River and its tributaries approach or exceed physiological optima that have been defined for salmon. Temperature extremes and other stressors can act in concert to compromise the immunology, health, and condition of juvenile and adult life stages. In the Klamath Basin, coho salmon (*Oncorhychus kisutch*) are protected under the Endangered Species Act (ESA), and their recovery remains in jeopardy, in large part due to anthropogenic changes in their freshwater habitats.

Fish Health

Infectious disease is increasingly recognized as an important component of the ecology of aquatic animals in the wild; however, the impact of disease among free-ranging stocks has been difficult to investigate. Recently, field and laboratory studies have begun to provide information on infectious diseases that are associated with significant mortality among natural populations of fish in both freshwater and marine ecosystems. This research has also served to highlight the critical role played by environmental conditions in the ecology of fish disease and the synergistic effects of both anthropogenic and natural stressors on the severity of these diseases.

Outbreaks of disease that result in substantial mortality among important stocks of fish in both the upper and lower subbasins are of special concern in the Klamath Basin. In the upper subbasin, losses of adult shortnose and Lost River suckers (*Chasmistes brevirostris* and *Deltistes luxatus*, respectively) have been associated with diseases caused by several endemic bacterial fish pathogens in fish that were highly stressed by adverse water quality following the collapse of large algal blooms. The effects of fish condition and stressors on disease resistance in young-of-the-year suckers are largely unstudied but there is increasing evidence that the presence of cyanotoxins associated with harmful algal blooms maybe involved. Similarly, highly visible losses of adult Chinook salmon in the Klamath River have occurred from endemic diseases in fish that were stressed by low flows and warm temperatures. A high prevalence of parasitic and bacterial infections are seen in juvenile Chinook and other salmonids that are believed to encounter endemic pathogens at higher than normal infection pressures due to altered habitats.

Certain pathogens have already been shown to cause significant mortality in salmonids in the Klamath River. In addition, modeling studies have demonstrated the potential negative impacts on salmon at the population level. During their outmigration as smolts, juvenile Chinook salmon are affected by the myxozoans *Ceratomyxa shasta* and *Parvicapsula minibicornis*, and the bacterium *Flavobacterium columnare*. As returning adults, infections by *F. columnare* and the external parasite *Ichthyophthirius* can result in high mortality under certain conditions. Reintroduction of anadromous fish to the upper subbasin is under active consideration and carries with it additional questions about the introduction, distribution, and transmission of infectious diseases of fish. Additionally, the known fish pathogens, *Aeromonas hydrophila*, *F. columnare,* and *Pseudomonas* spp. have been recovered from moribund adult suckers in the upper subbasin.

Conditions affecting the severity of disease in fish may be very different depending on the pathogen. The myxozoan parasites require alternate hosts to complete their life cycle and the densities or genetic strains of those hosts will influence infection severity in the fish host. Survival of many fish pathogens may be affected by physical parameters such as water quality, temperature, flow, or substrate as well as the availability of alternate hosts. In addition, the infection pressure on the fish host may be affected by factors such as water volume or flow that can control the number of infectious units per unit of water. One management action currently under study proposes to reduce pathogen effects in the Klamath River by releasing water at dams to create flushing flows that would reduce pathogen concentrations, reduce water temperatures, or alter habitat for alternate hosts. This effort will determine when flow increases would be most beneficial and what magnitude or duration would be needed to obtain a quantifiable benefit. In addition, it will be important to understand the full range of other environmental risks imposed by experimental flows.

There is a strong genetic influence in some salmonids on the susceptibility to *C. shasta*. Previous research in the Klamath has demonstrated some populations are more resistant, possibly as a result of their contact with the parasite during early rearing and migration. Little is known about the relative resistance of Chinook salmon and steelhead to *P. minibicornis*. For *F. columnare*, virulence for each species may vary by bacterial strain, and this is uncharacterized for strains from the Klamath Basin. There also is little information on the ecology on these and other important fish pathogens in the Klamath system or the effects of seasonality as it impacts disease resistance. Although temperature is an important component of seasonality, it cannot explain all the variation in immune function observed in salmonids.

Climate Change

Since 1900, temperatures in the Pacific Northwest have increased by 1.0 °C, which is 50 percent greater than the global average. Climate change models project that in the next 30–50 years the Klamath Basin will experience increased winter precipitation—as rain, not snow—and decreased summer precipitation. Imposed on these general trends in the future will be the El Nino/Southern Oscillation and the Pacific Decadal Oscillation (PDO), which influence warm and dry or cool and wet trends in the Pacific Northwest including northern California. Recent rapid, sustained declines in the mass of Cascade Mountain glaciers suggest climate change is already having a greater effect than past PDO-induced variations in the glacier records. Given these long records, the case for climate change having significant impacts in the Klamath Basin is unquestionable.

Increased concentrations of greenhouse gases will significantly change global climate in the next 100 years. Today's choices will decide whether climate change will present overwhelming or manageable challenges in the future. Therefore, effective management will require relevant science to inform mitigation and adaptation to the changes in our planet's climate. Although it is essential to appreciate the physical, chemical, and biological science of climate change, it will be critical to predict the social and economic outcomes of climate change if this information is going to be relevant and useful to decision makers in the Klamath Basin.

The effects of climate change on water temperature, water quantity, and water quality and linkages to atmospheric and meteorological events will bring profound changes to the Klamath Basin. Three key resource management issues in the Klamath Basin will be affected: agriculture, forestry, and fisheries, and these will generate new social, economic, and ecologic concerns overlying others in the Basin. The impacts of rising freshwater temperatures on the physiology of fishes, movement and migratory behaviors, and on physical habitats and their use must be determined to design and evaluate appropriate mitigation strategies. As flows change and temperatures increase, spring-fed rivers and streams and the underlying geology therein will be increasingly important to cold water fishes because of their resilience to changing precipitation, variable runoff, and warming. Groundwater effects on nutrient dynamics and aquatic productivity in spring-fed habitats will be critical for understanding changes in food webs.

The potential for synergistic effects resulting from climate change on key ecosystem processes is an area where predictive tools and scenario evaluations is needed. As an example, the interactions of climate change effects and species migrations and invasions are poorly understood, but may act in concert to change how the ecosystem functions.

Scientific studies are needed to understand, mitigate, and adapt to the effects of climate change on natural resources in the Klamath Basin. Integrated approaches will be necessary to assess credible climate change scenarios and mitigation strategies. Interdisciplinary studies using linked models are needed to address process changes and ecosystem function and should include:

- Surface and groundwater interactions to assess changes in surface flows and groundwater reserves.
- Hydrologic effects on stage and discharge at selected locations through each subbasin.
- Hydrodynamic effects on water depth and currents in key reaches.
- Hydraulic effects on fish habitats for target species and flows.
- Bioenergetics and food web effects on fish response.
- Population dynamics at watershed, region, and population scales. A wide spectrum of climate-induced flow scenarios will be tested.
- Socioeconomic assessments of changing conditions on human activities.

Ecological and socioeconomic linkages between climate change and marine fisheries require further examination. Climate change is already bringing shifts in species ranges towards the poles, and likely extinctions where dispersal capabilities are limited or suitable habitat is unavailable. Changes in resource distribution and abundance will impact the nature and value of fisheries. Populations with fast generational times show a stronger distributional response to temperature warming. Climate change will strongly influence species distribution and abundance as many species—for example, eulachon—may be unable to adapt to the increasing temperatures or other ocean changes such as the restructuring of trophic relationships.

Ecosystem Services

Ecosystem services are the various functions provided by the natural environment that are considered valuable to human well-being. These services include the production of raw materials, water management, nutrient cycling, erosion control, climate regulation, carbon storage, and many others. The United Nation's Millennium Ecosystem Assessment[11] describes four kinds of services provided by the natural environment:

- *"Provisioning services"* are the products people obtain from ecosystems, such as food, fuel, fiber, fresh water, and genetic resources.
- *"Regulating services"* are the benefits people obtain from the regulation of ecosystem processes, including air quality maintenance, climate regulation, erosion control, regulation of human diseases, and water purification.
- *"Cultural services"* are the non-material benefits people obtain from ecosystems through spiritual enrichment, cognitive development, reflection, recreation, and aesthetic experiences.
- *"Supporting services"* are those that are necessary for the production of all other ecosystem services, such as primary production, production of oxygen, and soil formation.

Ecosystem goods and services are vital to sustaining well-being, and to future economic and social development. This multidimensional way of viewing ecosystems is still evolving, especially with respect to resource valuations, but is attractive for its integration of science, policy, business, and public

[11]See "Ecosystems and human well-being: a framework for assessment" (http://www.maweb.org/en/Framework.aspx).

opinions. Decisions related to resource management, such as water for irrigation, low cost energy, and ocean salmon harvest, can be considered in a broader context of societal priorities, such recreation, employment, and economic activity (table 1-2). The implementation of ecosystem-based management is premised on the conservation of essential ecosystem components, processes, and related services.

Ecosystem Restoration

Success in protecting and restoring fish and wildlife resources and the ecosystems upon which they and human populations depend will continue to elude society until:

- The basic life history requirements of many species are better understood.
- The cumulative effects of human impacts on species and their habitats are quantified.
- Monitoring of ecosystem condition and processes can be implemented at a regional scale.

A multiplicity of management questions important to State, Federal, and tribal resource management agencies remain unanswered as a result of persistent scientific uncertainties. Fundamental information critically needed by managers on the life histories of fish and wildlife is missing. Large-scale restoration programs are unable to prioritize current activities or re-direct future program emphasis because they lack adequate research, monitoring, and evaluation capacities. Consequently, natural resources are under increasing pressure from human population growth and resulting impacts from climate change, contaminants, habitat loss, invasive species, water conservation, and other activities.

A diversity of high quality, connected habitats is necessary for organisms to complete their life cycle and maintain healthy, reproducing populations. Habitats of Klamath Basin fish, wildlife, and plant communities have become increasingly fragmented, reducing the ability of species to successfully migrate, forage, avoid predators, reproduce, and complete their life cycles. Consequently, many populations have declined and much of the diversity (genetic and life history) and resilience of these species to environmental disturbance (as expected to increase with climate change) has been lost. An understanding of the landscape processes that can both fragment and reconnect habitats and the corresponding population responses are critical to future management, restoration, and persistence of biological communities within the Basin and across larger scales.

Habitats of fish, wildlife, and plant communities have become increasingly fragmented, impacting the ability of species to migrate to superior food resources, to find shelter from predators, and to reproduce in dispersed areas that provide adequate rearing habitat. A major hypothesis to be tested is that the increasing reliance on disconnected headwater streams to maintain spring Chinook and steelhead production in the Klamath Basin (and elsewhere) has led to decreased diversity (genetic and life history) and decreased resilience of these species to the type of environmental disturbance expected with climate change. The effectiveness of programs to restore populations and biological communities are diminished by critical uncertainties regarding the role habitat connectivity plays in population function and persistence. This is particularly crucial because climate change, increased demand for water, and habitat loss represent continued challenges to the management of natural resources.

The loss or fragmentation of habitat reduces the ecological services that ecosystems can provide. The species most affected are those that depend on aquatic habitats where humans are most active; these tend to be located in coastal fringes of the United States. Some of the current habitat management and planning efforts underway by the FWS[12], The Nature Conservancy, Reclamation, NMFS, Tribes, and others in the Klamath Basin are presented in table 1-3.

The South Florida Case

An evaluation of whether dam removal will advance the restoration of salmon fisheries, including salmon and steelhead reintroduction into the upper subbasin, is part of the SD. An integrated science framework will be needed to conduct this evaluation and much can be learned from a restoration case history example, outside the basin, to determine how science can best inform decision making and restoration goals. A "lessons learned" presentation from the South Florida Everglades program allowed for comparison of similarities and dissimilarities with the Klamath Basin, a demonstration of the importance of the organization structure and its contribution to the decision making process, and the placement of process-oriented science within that structure in the near term.

An integrated science framework was applied to large-scale ecosystem restoration in South Florida. Restoration planners noted early-on a need for an ecological (science-based) approach that would recover biological diversity, ecological function, and the "defining characteristics" of the natural ecosystem. Humans were recognized in this science planning. Appropriate time and spatial scales were factored into the planning in recognition of the complexities of ecosystems and management institutions. Goal development included a wide representation of stakeholders to define shared visions for desired ecosystem conditions and a governance structure that included substantial public participation. The implementation of the restoration program used adaptive management to achieve desired outcomes by accepting uncertainties and regularly incorporating new understanding of ecosystem conditions. Management decision making was coordinated within government and non-governmental planning and activities.

From the beginning of this planning effort, there was a positive linkage of the environment to long-term economic development. The ecological approach forced management to focus on activities and land use with South Florida landscapes. The focus on restoration of natural processes, stressors and effects, and responses by high-level indicators similarly forced an approach that considered restoration at regional scales and over intergenerational time periods.

Efforts in South Florida to restore large geographic areas present many of the same issues that are encountered in the Klamath Basin. Thus, the South Florida experience provides an opportunity to examine how to move forward in developing a more basinwide integration of research, monitoring, and restoration of a system as big and diverse (ecologically, socially, economically) as the Klamath Basin.

[12] Management activities include: (1) Habitat Restoration—the rehabilitation of degraded or lost habitat to the original community that likely existed historically, including natural hydrology, topography, and native vegetation; or the rehabilitation of degraded or lost habitat to an ecological community different from what existed before, but which partially replaces original habitat functions and values and consists primarily of native vegetation; (2) Habitat Enhancement - the alteration of existing, degraded habitat to improve and/or increase specific fish and wildlife habitat functions and values; (3) Habitat Creation— the development of habitat types in order to mimic habitats that occur naturally in the immediate area and did not previously exist on the site; and (4) Habitat Management—the periodic, routine, short-term actions that manipulate the physical, chemical, or biological characteristics of habitat to replace or replicate natural events; e.g., wildfire, floods, and drought that occurred on the landscape prior to cultural intervention.

Importantly, from the onset South Florida managers relied on Conceptual Ecological Models (CEMS) to illustrate ecological linkages between the physical, chemical, biological, and social elements of the systems of interest. This allowed a suite of "causal hypotheses" linking the most important stressors with their major ecological effects to be described. By doing this, the managers were able to create a set of measurable indicators of success (i.e., performance measures) and a "level playing field" for evaluating, prioritizing, and funding science components. A CEM clearly identifies the drivers, stressors, effects, and attributes of a system and therefore allows one to link an ecosystem metric to management actions for planning adaptive management.

Many of the challenges encountered in South Florida included lack of data on reference conditions, the inability to identify cause-effect linkages, the inability to implement adaptive assessment when recovery times are long, separating "signal from noise," various technological challenges, and maintaining political and public support when recovery times are long. A key component to the program's success has been monitoring. Interpretation of monitoring in a science-management framework focused on the ability of planners to make informed decisions by providing sound science to (1) guide restoration implementation and operation, and (2) reduce risk and uncertainty.

Restoration efforts in the Klamath Basin will continue to occur with or without the KBRA and dam removal. It is an issue of time and scale. Large-scale restoration to bring salmon back to the basin will require large public expenditures and, as realized in South Florida, a new governance structure that involves all Klamath Basin stakeholders in a science-based, consensus-driven approach to ecosystem management to guide planning, implementation, and oversight processes. Under this structure, the selection of restoration goals and targets and inclusion of adaptive management objectives would be part of the public planning process that includes the many interests of Klamath communities.

Resource Management Concerns

The quantity and quality of the water in many freshwater habitats of the Klamath Basin have been declining for over a century. To illustrate, the draining of wetlands in the upper subbasin began in the 1890s. Farming, industrialization, residential expansion, and flood control have reduced instream flows of fresh water, changed the timing and severity of flood events, and increased the quantity of nutrients and contaminants draining from upland habitats.

Natural resource management issues in the Klamath Basin have been challenging, controversial, and very much water-related in recent years[13]. Dam removal and habitat restoration, climate change, threatened and endangered species, invasive species, fisheries and salmon reintroduction, and water resource uses were among the significant issues identified at the conference (table 1-4).

The resource issues and corresponding science needs were oriented toward aquatic ecosystems due to the KBRA. A commonly held view was that much of the research and monitoring that has been conducted, while legitimate, represents a somewhat scattered and fragmented effort in the collective whole leaving some important science areas little understood. Greater attention to comprehensive planning for ecosystem restoration and better coordination and communication of governmental planning processes are urgently needed. Scientific integrity is valued by Klamath stakeholders and many advocated for more transparency, including assurances about science quality and relevancy of funded activities to Klamath priorities. The stakeholders voiced their support for watershed science that would be integrated geographically, temporally, and across disciplines. Restoration should be process-oriented and management objectives evaluated through adaptive monitoring approaches.

[13] See "Science Needs" extracted from the Lower Klamath Basin Science Conference at http://www.usbr.gov/research/science-and-tech/conference/lowerklamath/rankingresults/sneeds_report.cfm.

Some of the information needs identified were very specific. Collectively, they reflect long-standing concerns for natural resources, local and regional economies, and conflicts with competing uses of water. Growing concern about possible climate change effects and its impacts on restoration and recovery efforts were evident. From a comprehensive planning perspective, the needs can be categorized in broad science areas with interlocked physical, biological, and socioeconomic goals to:

- Examine spatial and temporal trends at all levels of biological organization (e.g., genetic diversity; status and trends of population and communities; status and trends of habitats, landscapes, and ecosystems).
- Characterize and understand biological systems as a basis for management (e.g., molecular genetic studies; population and community dynamics; habitat, community, and ecosystem relationships).
- Examine spatial and temporal trends in the physical environment and how they relate to biological processes (e.g., ocean conditions; climate cycles; interactions among groundwater, surface water, and hydrology).
- Understand causes and effects of resource threats and predict their impacts (e.g., land-use changes, habitat and hydrological alterations and contaminants, invasive species, disease, climate change).
- Develop tools and strategies to facilitate ecosystem restoration and evaluate its effectiveness (e.g., next generation tools, watershed scale and adaptive management approaches, integrated monitoring, metrics of environmental health).

Focal Species for Restoration Planning

A natural focus of fish restoration efforts will be on endangered species and those animals about which biological and ecological information is limited or lacking (for example, fishes that support important fisheries). The focus of research and monitoring in the upper subbasin has been on population recovery efforts for Lost River and shortnose suckers. In the lower river, Pacific salmon (Chinook and coho) and steelhead have received much attention. The possible reintroduction of Chinook and steelhead into the upper subbasin increases the need for much better understanding about these species (e.g., life history, distribution and abundance, and genetic diversity). Pacific lamprey, green sturgeon, and eulachon represent other species requiring special protections and where information is limited. Information about the habitat complexity and competition between bull trout (*Salvelinus confluentus*) and brown trout (*Salmo trutta*) is needed by managers.

Given the aquatic ecosystem focus of this conference and the KBRA, additional attention to the identification of potential indicators of restoration success is needed. In terrestrial environments, avian indicators are being used as large-scale indicators of the Basin’s forest health, habitat use, and status and trends of key bird species. Because many species of fish in the Klamath Basin are long-lived and relatively predictable with respect to their feeding ecologies and habitat use, they too may be suitable indicators of aquatic ecosystem conditions. It is hypothesized that trends in population health and condition and species occurrence reflects the long-term integration of biological effects associated with changing water properties and food webs. Population dynamics research would benefit from inclusion of multi-species interactions (for example, predator-prey, competition, pathogens, and invasive species) and quantification of environmental influences (for example, stream flows and temperatures, hydrography, nutrient dynamics, and biological productivity) in freshwater and marine ecosystems. Linked physical and biological models are necessary to provide the sophistication required to assess aquatic productivity and ecosystem services.

Non-Salmonid Threatened and Endangered Species

The FWS is in the final stages of preparing a Recovery Plan for endangered suckers in the upper basin. Continued monitoring of the population status and trends of Lost River and shortnose suckers is a high priority of this recovery planning. Greater attention to the ecology of these juvenile suckers in Upper Klamath Lake also is a priority. At present, existing data suggest that algal toxins in the lake are affecting juvenile health and condition and may be causing a population bottleneck. A food web link may be involved and interdisciplinary science is required to address this issue (e.g., nutrient dynamics, bloom dynamics, circulation and transport processes, seasonal habitats of juveniles, and feeding ecology).

Construction activities of two large-scale restoration projects were recently completed. Continued long-term monitoring and evaluation of the effectiveness of dike removal at the Williamson River Delta Restoration Project and Chiloquin Dam removal on the Sprague River is needed. The latter effort would provide much needed new information on the spawning ecology and habitat use of the endangered suckers.

Eulachon is a lower basin non-salmonid ESA-listed fish which in the Klamath Basin is near extirpation. This fish was not only an important forage fish but an important part of Yurok tribal culture, being an early season food resource. It is the first fish to be listed that identified climate change as the primary jeopardy factor. Efforts are beginning to establish monitoring.

Salmon and Steelhead

The primary purpose of the KBRA and SD are bringing about salmon recovery in the Klamath Basin. W.F. Thompson visualized the interaction between salmon habitat and life history as “a chain of favorable environments connected within a definite season and place, in such a way as to provide maximum survival.” The image of a chain is important. Imagine a salmon life history-habitat chain with three or four broken links, habitats where the salmon cannot survive or where survival is low. The life history-habitat chain fits well with the “beads on a string” habitat mosaic described in this proceedings report to guide large-scale restoration planning for salmon and other aquatic species.

The life cycle of Pacific salmon forms a critical link in a cyclical, regenerative interaction between land, river, and ocean. The cultural and economic values of this resource in the Basin, including those associated with restoration, are unparalleled elsewhere in the nation. Pacific salmon are a keystone species, and logically their status would be an indicator of aquatic ecosystem health. In this context, one thrust would be to focus on environmental, socio-cultural, and economic conditions in watersheds from an ecological perspective, evaluating land and water practices and assessing dynamic changes (physical, chemical, and biological) in the hydrological system. Restoration science needs to examine environmental flow requirements for multiple stakeholders applying innovations, such as the Ecological Limits of Hydrologic Alteration (ELOHA)[14] method, to direct resources to areas of greatest ecological health or restoration potential. Scientific knowledge and predictive tools for decision making will be the essential foundation to the resolution of the complex and controversial resource issues surrounding salmon recovery.

[14] For information about tools for environmental flows see http://conserveonline.org/workspaces/eloha.

In 2000, the National Science and Technology Council recommended priority science needs in support of the President's Pacific Coastal Salmon Recovery Initiative[15] in a report entitled "*From the Edge*." These needs also hold true for the Klamath Basin and include:

- Definition of critical ecosystem features for the full life cycles of salmon species and stocks.
- Quantitative definition and assessment of risks (natural and human caused) during upstream, downstream, and estuary/ocean life stages.
- Clarification of fundamentals of biological diversity in salmon species, races, and stocks.
- Development of remedial technologies that work with nature rather than replacing it.
- Clarification of the regional variation in the physical, biological, social, cultural, and economic environments of salmon.
- Development of quantitative indicators and analytical methods to assess the status of salmon, characterize risk factors, and evaluate outcomes of remediation efforts to improve environmental conditions or reduce risks.

Adaptive Management and Long-Term Monitoring

Adaptive management is a structured, iterative decision-making process used when decision makers are faced with uncertainty. It is widely used in resource management and it has been specifically recommended for use in the Klamath Basin by National Research Council (NRC) reviews and by others. The basic steps of adaptive management include setting of goals, development of work plans to accomplish goals, implementing work plans and monitoring simultaneously, data analysis and comparison of measures with goals, and modifications of work plans to better accomplish goals. This process is iterative over appropriate time scales. Adaptive management generally is the recommended method of ecosystem management and it provides a structured method of including information that is learned through monitoring in the recovery process.

Many entities have begun to articulate possible restoration goals for the Klamath ecosystem. The Upper Klamath Basin Working Group identified the following goals and they are noteworthy for their community inclusiveness, ecosystem approach, and potential applicability to comprehensive planning:

- Improved water quality through the implementation of accepted Best Management Practices.
- Restoration of wetlands and riparian habitat.
- Enhancement of natural and structural water storage.
- Improvements to irrigation efficiency and water conservation.
- Economic growth and diversity through activities such as value-added natural resource products and ecotourism.
- Enhancement of fish and wildlife.

There is much to be learned from previous planning for the Klamath Basin and for large river ecosystem restoration efforts outside this basin. The Pacific Northwest Aquatic Monitoring Program provides one example of how to lead organized long-term research and monitoring by multiple entities using standardized methodologies and information management technologies. The broad goals described above are supported in greater detail in subsequent chapters.

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[15] From the Committee of Environment and Natural Resources report entitled "*From the edge – science to support restoration of Pacific salmon.*"

Monitoring is an essential part of adaptive management and, in fact, of any type of resource management. The lack of baseline and long-term trend data about ecological conditions has often confounded our understanding of causal linkages between anthropogenic effects and valued ecosystem services. There is widespread consensus that many of the pressing issues in the Klamath Basin would benefit from the implementation of a successful regional scale, integrated monitoring program.

The Klamath Bird Monitoring Network provides an example of successful integrated monitoring that was highlighted at the conference. The Klamath Bird Observatory and U.S. Forest Service have worked with many collaborators to develop the Klamath Bird Monitoring Network, a comprehensive bird-monitoring network in southern Oregon and northern California. This innovative partnership includes tens of thousands of extensive bird and habitat survey stations and dozens of intensive population demographic monitoring stations. Bird conservation objectives are considered within an ecosystem framework in order to inform managers and other stakeholders about avian population responses to changes in watershed processes, such as land-cover and land-use change, fire and flood disturbance, climate change, riparian/wetland ecology, and process linkages. Monitoring data allow the evaluation of species and community responses to large-scale watershed changes. Monitoring birds at different spatial and temporal scales has helped to inform the design of, and measure the effectiveness of, fire-adapted ecosystem restoration efforts; understand the effects of long-term restoration on wetland and riparian ecosystems; and integrate bird monitoring into large-scale anadromous fish and wildlife restoration efforts downstream of the Lewiston Dam on the Trinity River.

Managers of large-scale restoration programs must be able to prioritize current activities or re-direct future program emphases. High-level indicators that are indicative of ecosystem function and health, species status, or restoration goals must be identified within a robust research and monitoring design. Without a comprehensive and adaptive basinwide science approach, the resulting lack of ecological context, learning, and feedback mechanisms will continue to inhibit our ability to translate project scale work into knowledge that could improve restoration effectiveness. In the long run, there are economic impacts associated with piecemeal approaches, and this lack of accountability will quickly bring into question the long-term viability of recovery and restoration efforts in support of ESA-listed species or natural ecosystem conditions, respectively. California Department of Fish and Game and NMFS have recently published a monitoring plan for coastal salmonids which is comprehensive in covering salmonid status and trends as well as monitoring for hatchery and fisheries impacts.

Conceptual Foundation

The NRC reviewed the science related to restoration and management strategies for the Klamath River and called for a “big picture conceptual model” to connect scientific studies in an ecosystem context and to allow critical uncertainties to emerge from analysis of the model. The NRC found that the lack of such a model has prevented the current science from being effective in guiding management decision making and resolution of controversies.

A conceptual foundation is a set of scientific principles and assumptions that gives direction to management activities, including restoration activities, by defining the current understanding of the most important variables and interactive processes, identifying problems, and establishing the range of appropriate solutions given recognition of uncertainties in the science. As noted in the South Florida example, a well-designed, agreed-upon conceptual model provides the basis for informed decision making if it accurately describes key relationships between ecosystem attributes and processes in relation to environmental stressors.

A conceptual foundation or model for the Klamath Basin was presented at the meeting and is described more fully in this proceedings report. The pivotal chapter (Chapter 7) represents our best conceptual thinking at present for restoration of salmon runs and other key attributes of the Klamath River ecosystem. The authors describe boundaries, principles, and assumptions for the Klamath River Ecosystem, with a scientific retrospective analysis serving as the basis for a conceptual foundation for the Klamath ecosystem as derived from our collective understanding of natural and cultural attributes, interactions, constraints, and opportunities in a restoration context. Connectivity of ecosystem attributes and environmental stressors provides a sound basis for planning an adaptive management strategy to assist restoration planning. The watershed approach is central to this planning and provides a unified organizing tool to conceptualize ecosystem structure and function, including natural and cultural characteristics, to guide management activities to return the Basin to a more normal state.

About This Document

Chapter authors relied heavily on information presented during the conference's plenary, breakout, technical, and poster sessions. Additional scientific literature was consulted, as necessary, to support or more fully develop and explore concepts, or document information, presented at the conference. A list of key references is provided for readers seeking additional scientific information. In addition, a number of relevant websites were visited as a source of additional information used to describe aquatic ecosystems and interactions as they pertain to the KBRA and other contemporary natural resource issues in the Basin. The authors' selection of key scientific literature does not imply a comprehensive review of literature. These references are meant to provide a technical guide to readers seeking further information on key areas of scientific interest. Recognizing that not all readers will be natural resource scientists or managers and to promote broad information transfer to all Basin stakeholders, in most instances the key references were not specifically cited within the proceedings narratives. The exception is the Conceptual Foundation chapter. This manuscript was presented at the conference but was originally written for journal publication. Since then, it was extensively reviewed and included in its present form with the permission of the senior author.

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The authors wish to acknowledge all conference attendees for their thoughts and insights about the Klamath Basin ecosystem and sustaining processes. We are especially grateful to those participants who presented information in the plenary, technical, breakout, and poster sessions. Special thanks are extended to the organizing committee for the many months of pre-conference planning to develop the agenda, make local arrangements, and successfully execute the complicated logistics of a meeting of this size: Pete Adams (National Marine Fisheries Service), Debra Becker (USGS), Mike Belchik (Yurok Tribal Fisheries Program), Crystal Bowman (Quartz Valley Indian Reservation), David Busch (USGS), Susan Corum (Karuk Tribe), Clayton Creager (CA EPA, Surface Water Quality Bureau, Regional Water Quality Control Board), Debra Curry (USGS), Ken Fetcho (Yurok Tribe), Tracy Fuentes (USGS), Michael Hughes (The Klamath Tribes), George Kautsky (Hoopa Valley Tribe), Steve Kirk (Oregon Department of Environmental Quality), Curtis Knight (California Trout), Irma Lagomarsino (National Marine Fisheries Service), Dennis Lynch (USGS), William McFarland (USGS), Linda Prendergast (PacifiCorp Energy), Eric Peterson (Bureau of Reclamation), Jim Sedell (National Fish and Wildlife Foundation), Dan Snyder (USGS), Scott VanderKooi (USGS), Tommy Williams (National Marine Fisheries Service), Rod Wittler (Bureau of Reclamation), Doug Woodcock (Oregon Water Resources Department), and David Woodson (USGS). We also wish to acknowledge the financial support of the USGS, National Marine Fisheries Service, and National Fish and Wildlife Foundation for this conference.

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Finally, we wish to offer our special appreciation to Debra Becker and Dr. Ronald Kirby (USGS). Debra worked tirelessly in all aspects of the planning, organization, and management of the science conference and was instrumental in seeing the publication through completion. Dr. Kirby provided invaluable reviews of the technical and editorial content of this proceedings.

Key References

Bottom, D.L. 1995. Restoring salmon ecosystems: myth and reality. Restoration Management Notes 13(2): 162-170.

FISRWG. 1998. Stream Corridor Restoration: Principles, Processes, and Practices. By the Federal Interagency Stream Restoration Working Group (FISRWG; 15 Federal agencies of the U.S. Government).

Grumbine, R.E. 1993. What is ecosystem management? Conservation Biology 8(1): 27-38.

Christensen, N.L. and 12 authors. 1996. The report of the Ecological Society of America Committee on the scientific basis for ecosystem management. Ecological Applications 6(3): 665-691.

Coats, R.N., and T.O. Miller. 1981. Cumulative silvicultural impacts on watersheds: a hydrologic and regulatory dilemma. Environmental Management, 5(2): 147-160.

Harwell, M.A., J.F. Long, A.M. Bartuska, J.H. Gentile, C.C. Hawell, V. Myers, and J.C. Ogden. Ecosystem management to achieve ecological sustainability: The case of south Florida. Environmental Management 20(4): 497-521.

National Research Council. 2004. Endangered and threatened fishes in the Klamath Basin. The National Academies Press. Washington, D.C.

National Research Council, 2008. Hydrology, ecology, and fishes of the Klamath Basin. The National Academies Press. Washington, D.C.

Postel, S., and B. Richter. 2003. Rivers for life: managing waters for people and nature. Island Press, Washington, D.C.

Stanford, J.A., M.S. Lorang and F.R. Hauer. 2005. The shifting habitat mosaic of river ecosystems. Verhandlungen des Internationalen Verein Limnologie 29(1): 123-136.

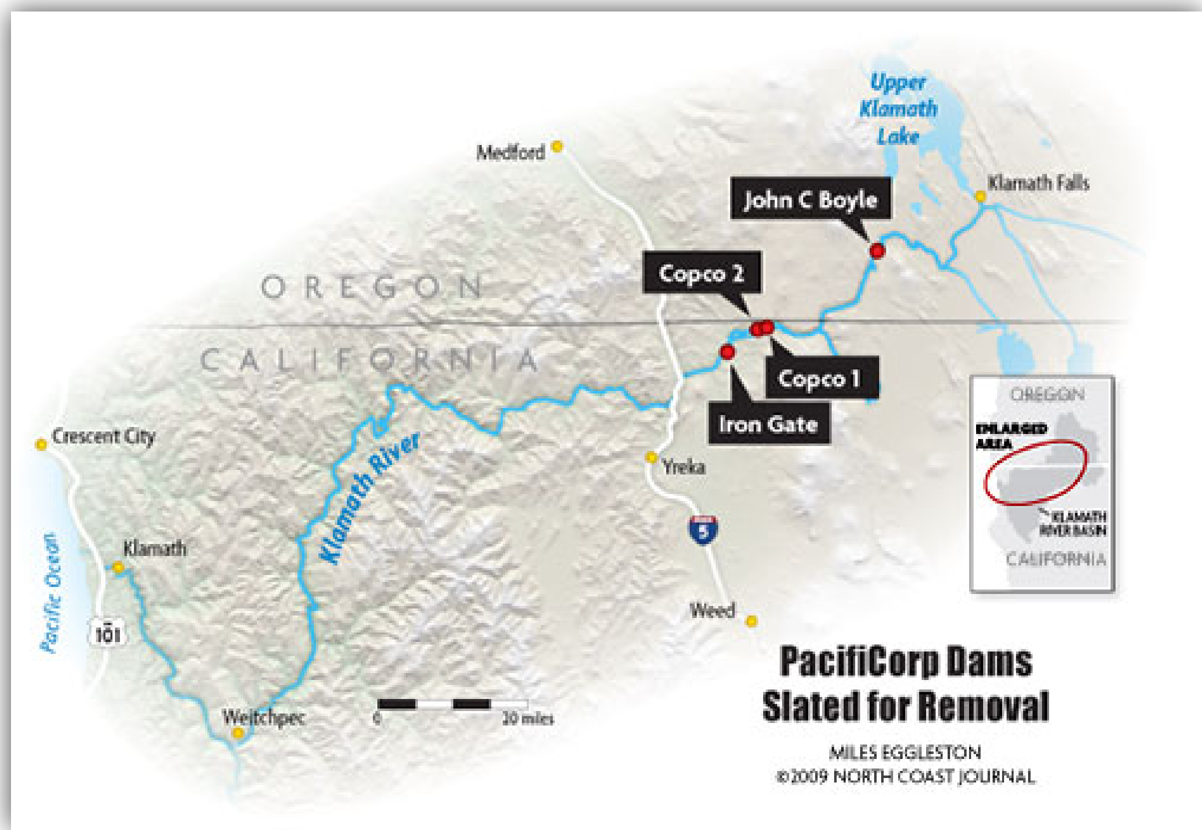

Figure 1-1. PacifiCorp dams slated for removal in the Klamath Basin.

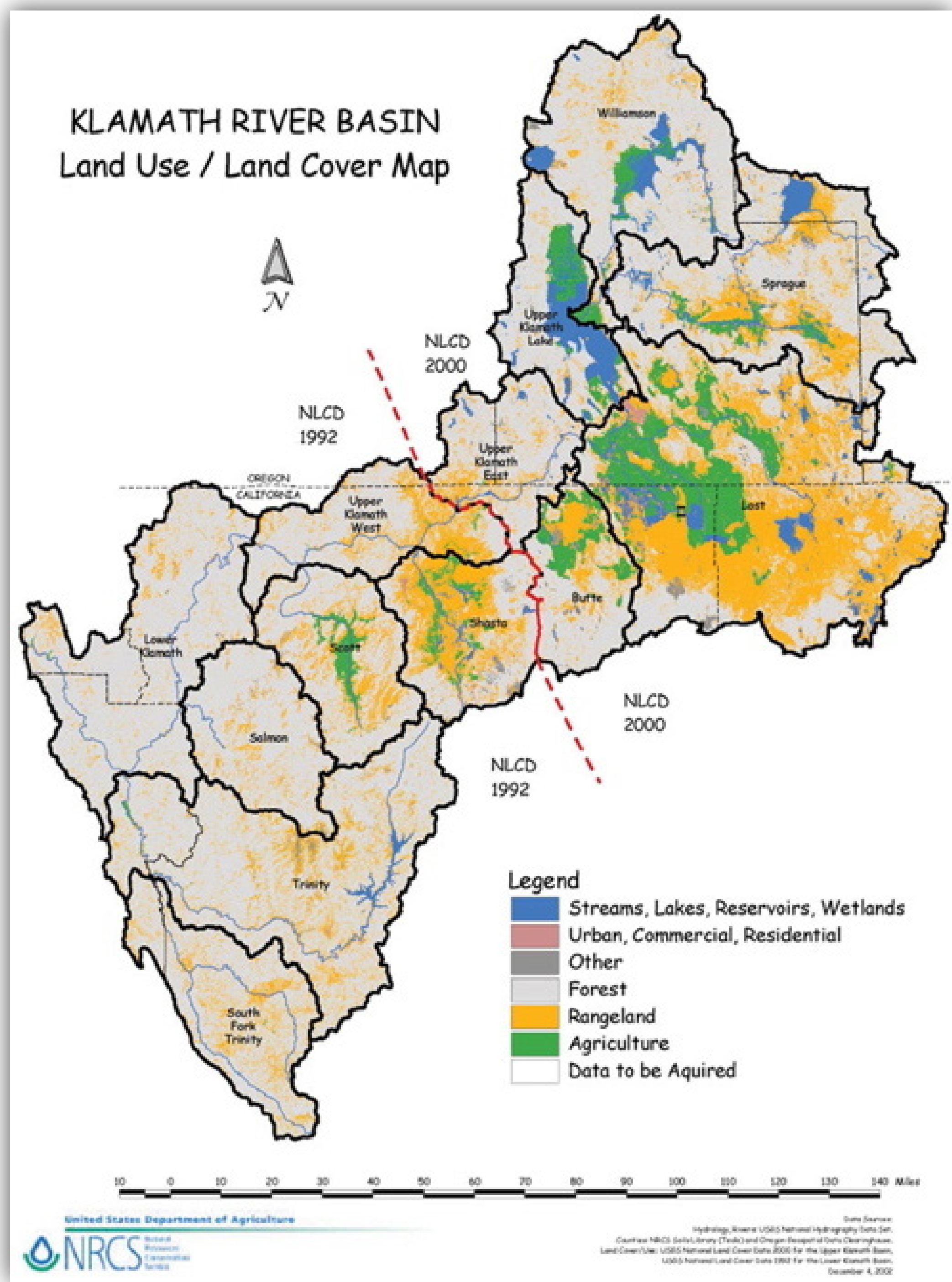

Figure 1-2. Klamath River Basin land use/land cover map.

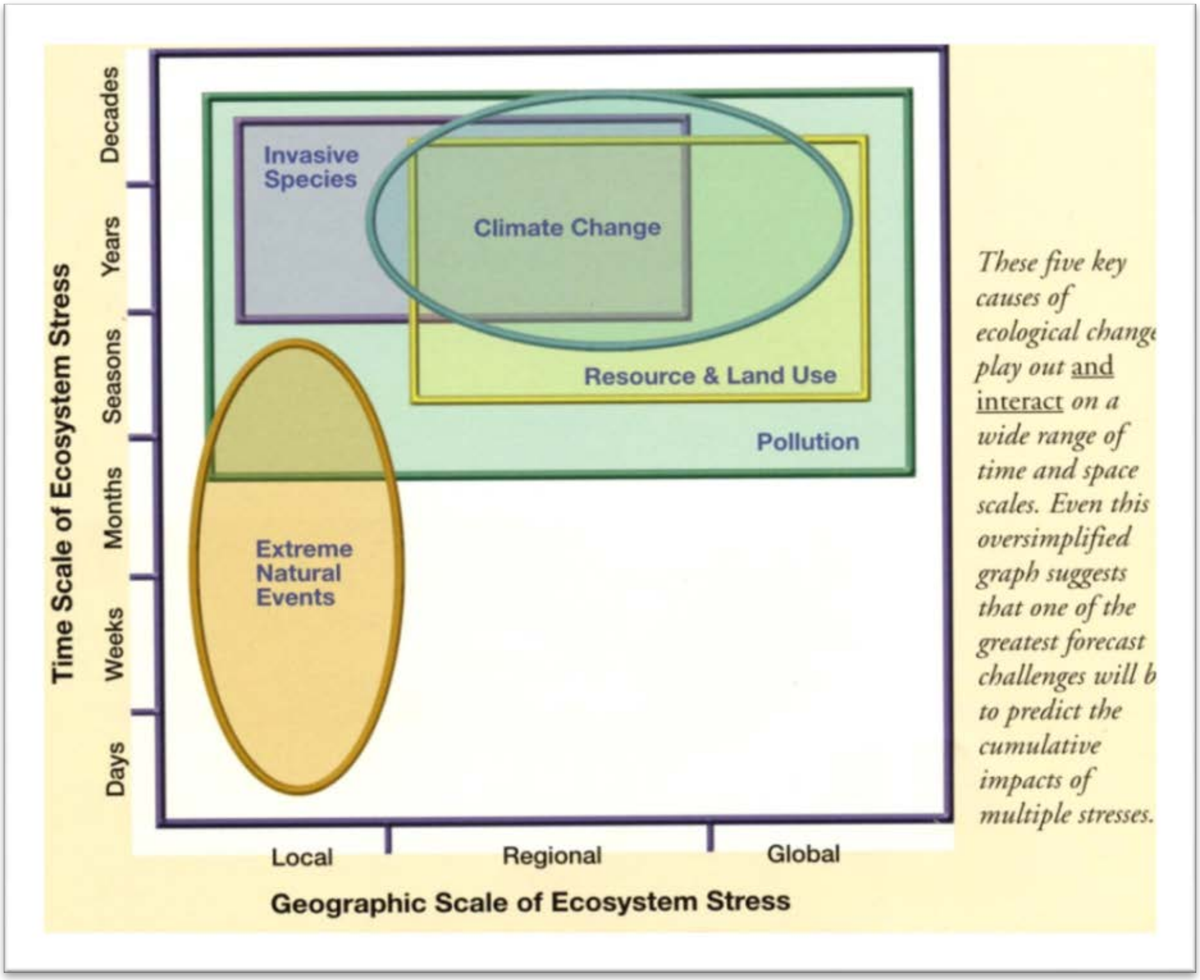

Figure 1-3. Temporal and spatial scales of ecosystem stress.

Table 1-1. Ecological functions performed by different river flow levels (adapted from Postel and Richter, 2003).

Flow Level	Ecological Roles
Low (base) flows	Normal level: • Provide adequate habitat space for aquatic organisms • Maintain suitable water temperatures, dissolved oxygen, and water chemistry • Maintain water table levels in floodplain, soil moisture for plants • Provide drinking water for terrestrial animals • Keep fish and amphibian eggs suspended • Enable fish to move to feeding and spawning areas • Support hyporheic organisms (living and saturated sediments) Drought level: • Enable recruitment of certain floodplain plants • Purge invasive, introduced species from aquatic and riparian communities • Concentrate prey into limited areas
Higher flows	• Shape physical character of river channel including pools, riffles • Determine size of streambed substrates (sand, gravel, cobble) • Prevent riparian vegetation from encroaching into channel • Restore normal water quality conditions after prolonged low flows, flushing away waste products and pollutants • Aerate eggs in spawning gravels, prevent siltation • Maintain suitable salinity conditions in estuaries
Large floods	• Provide migration and spawning cues for fish • Trigger new phase in life cycle (e.g., insects) • Provide nursery area for juvenile fish • Provide new feeding opportunities for fish, waterfowl • Recharge floodplain water table • Maintain diversity in floodplain forest types through prolonged inundation (i.e. , different plant species have different tolerances) • Control distribution and abundance of plants on floodplain • Deposit nutrients on floodplain • Maintain balance of species in aquatic and riparian communities • Create sites for recruitment of colonizing plants • Shape physical habitats of floodplain • Deposit gravel and cobbles in spawning areas • Flush organic materials (food) and woody debris (habitat structures) into channel • Purge invasive, introduced species from aquatic and riparian communities • Disperse seeds and fruits of riparian plants • Drive lateral movement of river channel, forming new habitats (secondary channels, oxbow lakes) • Provide plant seedlings with prolonged access to soil moisture

Table 1-2. Services provided by rivers, wetlands, and other freshwater ecosystems (from Postel and Richter, 2003).

Ecosystem Service	Benefits
Provision of water supplies	More than 99 percent of irrigation, industrial, and household water supplies worldwide come from natural freshwater systems
Provision of food	Fish, waterfowl, mussels, clams, and the like are important food sources for people and wildlife
Water purification/waste treatment	Wetlands filter and break down pollutants, protecting water quality
Flood mitigation	Healthy watersheds and floodplains absorb rainwater and river flows, reducing flood damage
Drought mitigation	Healthy watersheds, floodplains, and wetlands absorb rainwater, slow runoff, and help recharge groundwater
Provision of habitat	Rivers, streams, floodplains, and wetlands provide homes and breeding sites for fish, birds, wildlife, and numerous other species
Soil fertility maintenance	Healthy river-floodplain systems constantly renew the fertility of surrounding soils
Nutrient delivery	Rivers carry nutrient-rich sediment to deltas and estuaries, helping maintain their productivity
Maintenance of coastal salinity zones	Freshwater flows maintain the salinity gradients of deltas and coastal marine environments, a key to their biological richness and productivity
Provision of beauty and life-fulfilling values	Natural rivers and waterscapes are sources of inspiration and deep cultural and spiritual values; their beauty enhances the quality of human life
Recreational opportunities	Swimming, fishing, hunting, boating, wildlife viewing, waterside hiking, and picnicking
Biodiversity conservation	Diverse assemblages of species perform the work of nature (including all services in this table), upon which societies depend; conserving genetic diversity preserves options for the future

Table 1-3. Current restoration activities by habitat type in the Klamath Basin.

Restoration	Project Activities
Riparian zones	Purchase 4,136-acre property (the former Louie Ranch) that includes the main spring sources of the Shasta River and renamed it the Shasta Big Springs Ranch to ensure cold spring water remains in the creek. Reduced irrigation tailwater inputs by 80–90 percent through irrigation system improvements. Water efficiency planning and monitoring are further reducing agricultural diversion of cold spring waters and improving flows. Livestock exclusions are improving emergent aquatic vegetation and salmonid cover.
Riparian zones	Fencing for livestock management; alternative watering sources for livestock; nonnative plant removal/control; native plant establishment/diversification; erosion control; wildlife habitat improvements
Wetlands	Fencing; wetland restoration and enhancement; wildlife habitat improvements
Wetlands	Dike removal on Williamson River
In-stream	Habitat complexity and diversity improvements; hydrologic regime improvements; coarse woody debris and boulder supplementation; artificial barrier removal, modification, and creation: fish screens installation, non-native fish removal (e.g., Lower Klamath Riparian Restoration and Tribal Plant Nursery to improve habitats for threatened coho, Chinook, cutthroat trout, and steelhead).
River floodplain	Geomorphologic and vegetation interaction modeling to evaluate shading effects on the Klamath River
River floodplain	Chiloquin Dam removal
River floodplain	Hydrodynamic modeling to evaluate passive restoration at Big Springs Creek and Shasta River
River floodplain	Trinity River restoration: rehabilitation of banks and side channels by removing riparian berms allowing river to meander again
Upland slopes	Re-establishment of historic contours; silvicultural treatments including prescribed burning, thinning, tree planting, and juniper clearing; native plant establishment/diversification; non-native plant removal/control; fencing; alternativewatering sources for livestock; landslide treatments and erosion control; wildlife habitat improvements
Upland slopes	Surveys of plant species to determine geofluvial influences within the Sprague Basin
Estuarine wetlands	Yurok Estuarine Wetland Restoration Program: enhancing coastal wetland and riparian forest habitats, increasing juvenile salmon rearing capacity and improving hydrologic function of estuary and coastal tributaries
Roads	Road abandonment, decommissioning, and obliteration; road drainage improvements and stormproofing; culvert/stream crossing upgrades

Table 1-4. Resource management issues and science needs identified by Klamath Basin stakeholders at the conference.

Stakeholders[1]	Management Issues	Science Needs
Tribal	Water Resources	• Water quality/quantity monitoring • Groundwater/surface water influences on hydrology (some emphasis on lower Klamath River) • Protect ecological flows/health of aquifer • Non-point source contamination • Ecological effects of water diversions
	Living Resources	• Basic life history and ecology of freshwater fishes (e.g., green sturgeon, Pacific lamprey, eulachon, other species)
	Endangered Species	• Status and trends monitoring • Effects of harmful algal blooms • Delineation of important habitats • Life cycle modeling of population dynamics • Identification of restoration needs
	Hatcheries	• Wild-hatchery salmon interactions • Disease effects on wild salmon
	Sustainable Fisheries	• In-river/ocean stock assessments • Ocean survival of salmon • Estuary/nearshore importance for marine commercial species • Seasonal use of habitats by life history stages • System-wide understanding of salmon productivity and migration processes
	Fire Processes	• Effects of wild fire • Effectiveness of prescribed burns
	Salmon Reintroduction	• Stock selection for reintroduction • Introduction process (embryos or fry, time of year, etc.) • Environmental tolerances and preferences of salmon
	Ecosystem Restoration	• Groundwater effects on biological productivity • Restoration of natural processes • Multi-species interactions • Effects and control of internal/external nutrient loading in Upper Klamath Lake • Next generation tools for in-stream (focus on tributaries) • Develop metrics for environmental health (e.g., high-level indicators)
	Climate Change	• Effects of changing patterns of precipitation • Loss of aquifers and groundwater springs
	Traditional Ecological Knowledge (TEK)	• Incorporation of TEK in science planning and information synthesis
County	Water Resources	• Required allocations for restoration and reintroductions
	Dam Removal	• Short- and long-term effects on Klamath Basin economies (as possible basis for economic aid to impacted counties) • Effects on air quality, groundwater resources, plants, smoke, or other stressors

Stakeholders[1]	Management Issues	Science Needs
		• Integrity of science used in decision making and analysis of alternatives • Conduct "before/after" studies of effects with human dimensions included in research
	Ecosystem Restoration	• Focus on natural processes and human dimensions • Sustainability defined in economic, ecologic, and political perspectives • Improve technical support and assistance to counties
	Communicating Science	• Make data and information available • Clearly communicate scientific relevance • Develop political strategy to educate legislators at local, State, and Federal levels
Federal and State Managers	Water Resources	• Water quality/quantity monitoring • Water reclamation • Groundwater/surface water influences on hydrology (flow and water availability) • Meteorological effects on water supply in upper subbasin
	Dam Removal	• Implement robust mark-recapture program for salmon as part of KBRA • Effects of Chiloquin Dam removal on suckers
	Endangered Species	• Continued monitoring of adult suckers • Effects of harmful algal blooms • Environmental effects on population mortality • Effects of introduced/invading species • Natural recolonization processes for salmon and lamprey; • Control bull trout competitors (e.g., brown and rainbow trout)
	Living Resources	• Basic life history and ecology of freshwater fishes (e.g., green sturgeon, Pacific lamprey, eulachon, other species)
	Sustainable Fisheries	• Improved forecasts for fall Chinook and coho in Scott and Shasta Rivers • Develop population information for salmon and other species in a life cycle model • Maintain existing fish populations and habitats • Fish disease and Basin health • Salmon habitats and productivity in Scott, Shasta, and Trinity Rivers
	Fire Processes	• Effects of asynchrony in fire cycles • Spatial-temporal effects of fire-related debris flows on aquatic habitats and fish productivity • Effects of different fire management strategies • Spotted owl (*Strix occidentalis caurina*) ecology in fire dominated habitats • Old growth forest conditions, edge effects, restoration of old debris
	Salmon Reintroduction	• Effects of flow and ocean conditions on salmon populations • Stock selection for reintroduction • Reintroduction process (locations)

Stakeholders[1]	Management Issues	Science Needs
		• Rearing, survival, and fish passage studies • Determine optimal fish flow-emigration relationships (Chinook emphasis) • Effects of disease
	Ecosystem Restoration	• Next generation tools for in-stream (focus on tributaries) • Integrated monitoring and adaptive approaches to evaluate restoration effectiveness • Reconnecting fragmented landscapes (wetland focus) • Understand effects of grazing • Delineation of cold water refugia and their use by salmon
	Climate Change	• Ecosystem effects on Basin resources and communities • Effects of drier landscapes on fish communities and productivity • Basin-wide vulnerability analysis/effects on restoration activities
Non-Governmental Organizations	Water Resources	• Storage needs from system-wide approach • Sources and effects of nutrients in the Upper Klamath Lake • Agricultural and livestock effects on water quality (upper subbasin emphasis) • Develop nutrient reduction strategies • Economic and ecological effects of taking "land out of production" to increase water to the Upper Klamath Lake • Sources of springs and cold water refugia
	Dam Removal	• Evaluate socioeconomic effects
	Sustainable Fisheries	• In-river/ocean stock assessments • Ocean survival of salmon (new ocean harvest model needed) • Disease effects on salmon • Improved marketing of Klamath Basin salmon resources
	Ecosystem Restoration	• Groundwater/surface water influences on ecosystems • Implement a watershed approach • Evaluate trends in wind, climate, and temperature • Adaptive management and monitoring of Williamson River Delta • Ecosystem strategies to protect ranching, farming, and fish • Ecological significance of the hyporheic zone
	Climate Change	• Effects of invasive species

[1]Tribes represented included: Yurok Tribe, The Klamath Tribes, Hoopa Valley Tribe, Karuk Tribe, and Quartz Valley Indian Reservation. Counties represented included: Humboldt County, CA; Siskiyou County, CA; Klamath County, OR; Trinity County, CA; and Del Norte County, CA. Federal and State Managers represented included: California Department of Fish and Game, Oregon Department of Fish and Wildlife, U.S. Fish and Wildlife Service, NOAA Fisheries, and Bureau of Reclamation. Non-Governmental Organizations represented included: Pacific Coast Federation of Fisherman's Association, Upper Klamath Water Users Association, Klamath Water Users Association, The Nature Conservancy, Trout Unlimited, and PacifiCorp.

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