Aquatic Species and Habitats

Continuing human activities threaten the highly prized aquatic resources of the interior Columbia basin. Precipitous declines in native species, particularly Pacific salmon, and a large influx of introduced species have radically altered the composition and distribution of native fishes. Fortunately, areas of relatively high aquatic integrity remain, much of it on federally administered lands. These areas can provide a starting point for protecting and restoring aquatic resources throughout the basin if decisive action is taken.

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The peoples of the Pacific Northwest historically have placed high value on the region's aquatic resources. Salmon are emblematic of the Pacific Northwest and have been a cornerstone of the culture, economy, recreation, and history of the region for millennia. Yet native Pacific salmon in the Columbia River system are imperiled, as are other fishery resources within the basin. The Columbia River system hosts 52 native fish species, 13 of which are found nowhere else (McPhail and Lindsey 1986). Includeing subspecies and the Oregon portions of the upper Klamath and Great Basin systems, the entire basin supports 88 native fish taxa and 54 introduced species. Of the 88 native fish taxa, 45 (51 percent) are considered threatened, endangered, sensitive, or otherwise of special concern.

Many factors have contributed to declines of the Columbia basin's fishery resources, including dams and hydroelectric operations, introduction of nonnative species, ineffective or misguided hatchery practices, and excessive harvest (ISG 1996; NRC 1996). In addition, degradation and loss of freshwater habitats consistently are identified as pervasive problems throughout the basin and much of the western United States (Williams et al. 1989; Nehlsen et al. 1991; Young 1995). Continued declines in fisheries resources suggest that current management practices have not arrested the trends. The challenge to ecosystem management is finding a strategy to halt habitat degradation, maintain existing high-quality habitats, and recover declining fish and aquatic invertebrate resources.

Concern for salmon and other aquatic species and an appreciation of the role of federal land management motivate our assessment of aquatic species and habitats (see Lee et al. 1997). Our assessment involved four major steps. First, we examined geophysical and biological features that define the natural potential of the basin to support aquatic resources, and we identified major human influences. Second, we examined data from stream surveys to assess the effects of land management on channel features. We also compared these data with historical information to identify trends in selected areas. Third, we described the distribution and status of native and introduced fishes across the basin and used the distributional patterns of species and communities to indicate change. Finally, we synthesized our information and provided a regional context for federal management strategies to protect and restore aquatic and riparian habitats.

Biophysical Setting

The physical template of the interior Columbia basin is shaped by the interplay of geologic and geomorphic processes operating at multiple spatial and temporal scales. At the scale of watersheds and valley bottoms, the physiography of the basin is a relict of the Pleistocene (1.6 million to 10,000 years ago). Much of the coarse topography reflects glacial scour and massive flooding following glacial retreat. At the local scale of channels and hillsides, the physiography is influenced by the disturbance processes of more recent times—the last few thousand years. Hydrologic regimes in the basin vary both spatially and temporally. Timing, duration, and magnitude of extreme flows, connection with groundwater, water quality and quantity, and temperature are influenced by physiography and differences in precipitation and vegetation. The varied combinations of geologic histories, hydrologic processes, and sediment regimes arrayed across the basin are manifest in highly diverse aquatic habitats.

Ultimately the biophysical setting is defined by the combination of the physical template and the biological organisms inhabiting the basin. Natural disturbances, such as fire, floods, volcanoes, earthquakes, and changes in oceanic patterns, also influence the structure of aquatic communities. Human impacts can be extensive and severe because they affect both biotic and abiotic components. Because of inherent variability in the natural system, however, distinguishing human from natural causes can be problematic.

John Hutmacher

The colorful sockeye salmon, for which Redfish Lake in Idaho is named, return from the Pacific Ocean to only a select few freshwater lakes within the Columbia River basin.

Human Influence

Human impacts predate Euro-American settlement but increased dramatically with technological development. By the mid-1800s, European settlers had begun to substantially alter the basin's landscape and aquatic habitats. One of the more pervasive impacts is hydrodevelopment. Construction of large dams began around 1900 and has greatly reduced the range of migrating fish. Anadromous fish like chinook salmon *(Oncorhynchus tshawytscha)* and steelhead *(O. mykiss mykiss),* which spawn in fresh water but spend much of their lives in the ocean, were blocked from the upper Columbia River basin after the Grand Coulee (1941) and Chief Joseph (1955) Dams were completed. Since 1967, Hells Canyon Dam has blocked the access of anadromous fish to the Snake River and tributaries above the dam. Estimates of the amount of historical habitat now blocked by dams range as high as 73 percent (NWPPC 1986).

Today there are more than 1,200 large dams with storage capacity in excess of 62,000 cubic meters in the basin, and the total including small dams is at least an order of magnitude larger. Most dams lack fish passage facilities. Yet the extent to which these dams impede migration or affect spawning and rearing of native fishes or hasten the spread of nonnative fishes has not been documented. Water withdrawals for irrigation or other uses, a huge issue in the arid interior of the basin, can reduce instream flows significantly, altering or eliminating habitat. Water rights on most interior tributary streams were fully appropriated more than a century ago.

Riparian areas in the basin have changed dramatically as a result of human development. We estimated that up to 75 percent of the riparian shrublands that were present historically have been lost, much of it through conversion to agriculture. In addition, many riparian zones show a reduction in the large tree component in the riparian zone. This can affect the amount of shading provided to streams and the potential recruitment of large woody debris. The integrity of riparian vegetation and its extent along rivers have been changed and fragmented throughout the basin in response to forest conversion and streamside disturbance.

Changes in Channel Features

We used stream-inventory data from more than 1,900 streams running some 17,000 kilometers, in combination with landscape information, to detect and characterize land-use effects on aquatic habitats. For decades, various agencies have routinely inventoried streams within their jurisdictions to monitor stream-channel conditions. These inventories allow for comparison across broad geologic settings and management regimes and permit historical comparisons in some areas.

A statistical analysis of relationships among habitat features, landscape features, and disturbance variables suggested that streams within the assessment area have been significantly affected by human activities. Most notably, pool frequency was inversely correlated with road density and land management emphasis. These results are consistent with reported reductions in pool frequencies in streams in managed areas that were first sampled from 1934 to 1945, and again from 1988 to 1996 (McIntosh 1992, 1995; McIntosh et al. 1994). Streams in wilderness or roadless areas either retained or improved pool habitat dur-

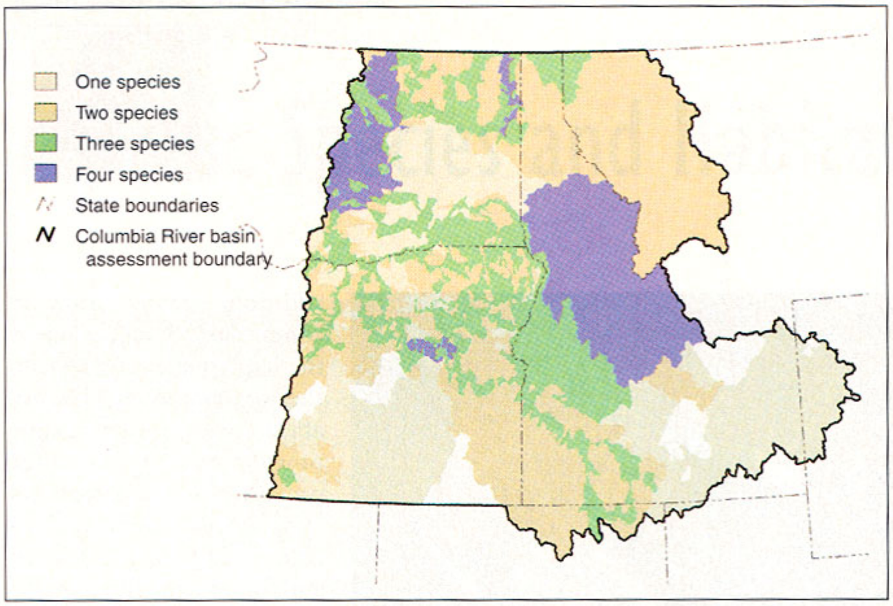

Figure 1. **Overlap in potential historical range of key salmonid species—four widely distributed anadromous fishes.**

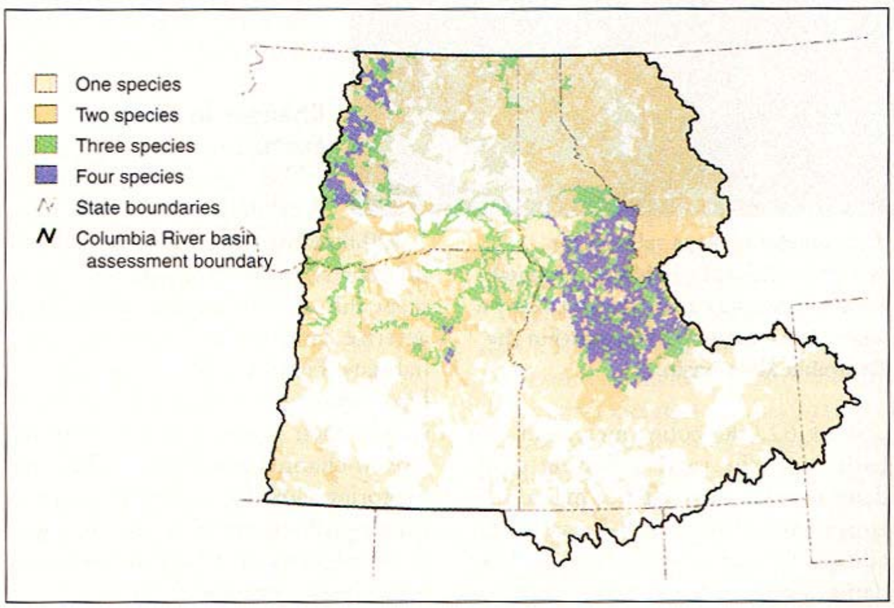

Figure 2. **Overlap in current range of key salmonid species.**

ing the last 55 to 60 years.

The abundance of instream wood is important in controlling pool frequency. Woody debris forms pools by causing hydraulic obstructions and forcing local scour, especially for larger, low-gradient channels. Wood frequency was correlated with pool frequency throughout the basin; the correlation between large woody debris and large pools was most notable on low-gradient streams. Wood effectively stabilizes channels, influences sediment routing, provides a major component of the instream organic matter, provides cover for fish and habitat for invertebrates, and increases overall channel complexity (Bilby and Ward 1991). These factors highlight the need to protect sources of instream wood.

Another important aspect of habitat quality that is influenced by land management is the amount of fine sediment (sediment less than 6 millimeters) on channel beds. Our results suggest a direct and significant relationship between road density and surface fines, corroborating a link between forest management practices and channel sediment characteristics.

Status and Distribution of Fishes

Our analysis of fishes was based on a compilation of existing data sources and a survey of more than 150 individuals with personal knowledge of the status and distribution of fishes throughout the basin. We considered the fishes at three levels of detail. First, we examined species assemblages. We summarized the known occurrences of all fish taxa (species, subspecies, and races) across the basin, defined species assemblages, and calculated richness and diversity indices. Second, we compiled information for 38 native taxa considered sensitive, threatened, endangered, or of special concern. Third, we examined the distribution and status (whether local spawning and rearing populations were strong or depressed) of four widely distributed salmonid species. These four species were divided into seven distinct subspecies and races, referred to as key salmonids. Key anadromous salmonids included steelhead and two races of chinook salmon. Resident taxa (those lacking anadromous forms) included bull trout *(Salvelinus confluentus),* westslope cutthroat trout *(Oncorhynchus clarki lewisi),* Yellowstone cutthroat trout *(O. clarki bouvieri),* and interior redband trout *(O. mykiss gibbsi).* Information from species assemblages was combined with summary statistics for the key salmonids in order to calculate relative indices of community integrity.

We identified 142 taxa of fishes in the basin, of which 54 (38 percent) are introduced species. Our analysis of the distribution and status of these fishes suggests four major findings. First, the composition, distribution, and status of fishes within the basin are very different now than historically. The overall changes are dramatic and extensive and in many cases irreversible. Some forms are extinct. Many others, especially anadromous fish, have been extirpated from large portions of their historical range. Our clearest understanding of fish status comes from the analysis of the seven key salmonids. Although several remain distributed through much of their historical ranges (*fig.1* and *fig. 2)*, declines in abundance, the loss of important life histo ties, local extirpation, and fragmentation and isolation of high-quality habitats are apparent. Resident key salmonids currently occupy 45 to 85 percent of their potential historical range within the basin, and anadromous species are limited to 28 to 46 percent of their historical ranges. Wild chinook salmon and steelhead are approaching extinction in many areas; strong populations were identified in 1 percent or less of the occupied range for steelhead and spring- and summer-run Chinook salmon.

If current distributions of the key salmonids are good indicators of aquatic ecosystem health and water quality, many systems remain only as remnants of what were larger and more complex, diverse, and connected systems. Even without further habitat loss, fragmentation and isolation may place remaining populations at risk. Except for select areas in central Idaho, western Wyoming, and the northern Cascade Mountains, most of the strong populations or high-quality habitat areas exist as patches of scattered watersheds. Many are not well connected or are restricted to much smaller areas than historically. Many important watersheds are associated with high-elevation, steep, and erosive landscapes. These extreme or variable environments may contribute to higher variability in population numbers and increased sensitivity to disturbances.

Our analysis of species assemblages led to similar conclusions. Although we were unable to accurately map the distribution of all species, the trends are clear. We found large numbers of introduced species throughout all major river systems. The changes are most severe in the warmer mainstem rivers, but higher-elevation tributaries are also affected.

Second, fish distributional changes on lands under federal management reflect the intensity of management activity; similar effects were observed on private lands but could not be quantified to the same extent. Our best indicator of management intensity was predicted road density. Using predictions from the landscape team (Hann et al. 1997), we calculated geometric

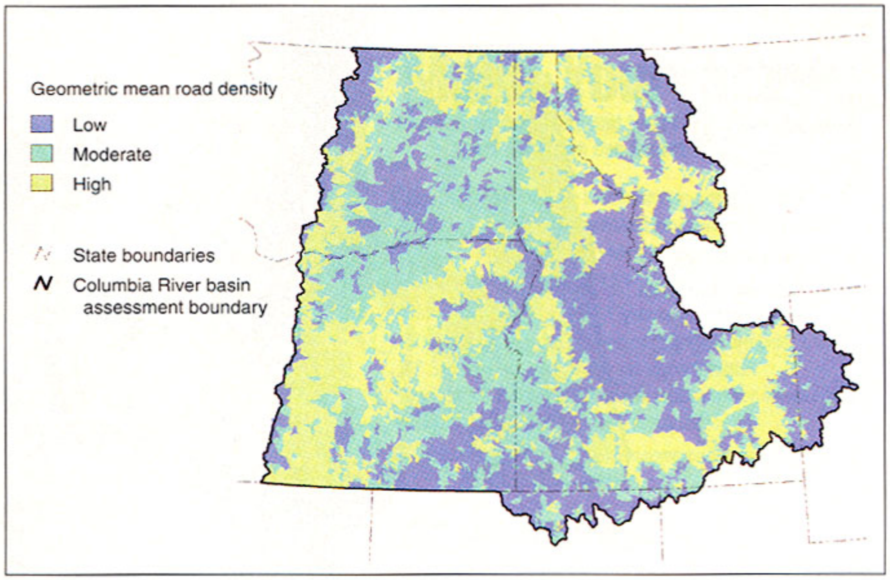

Figure 3. **Distribution of projected road densities. Density classes are defined based on geometric mean road density (mi/mi^2) within each subwatershed; low (0-0.4), moderate (0.4-1.165), and high (> 1.165) encompass equal thirds of the basin.**

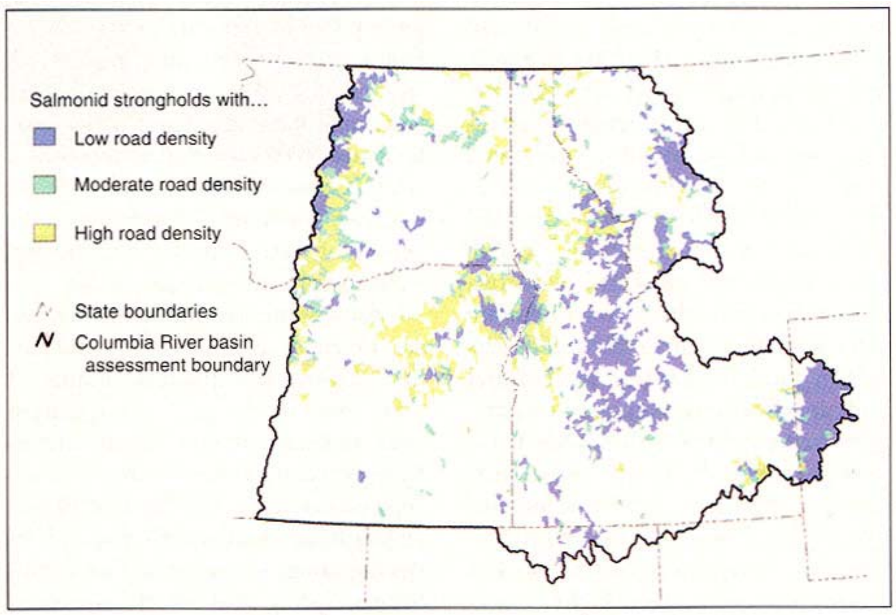

Figure 4. **Distribution of strong populations of key salmonids color-coded by road densities of areas where they are found.**

mean road densities for each of the more than 7,500 subwatersheds in the assessment area *(fig. 3)*. Overlaying the location of key salmonids shows that 54 percent of the strong populations are found in the third of the basin with the lowest road densities *(fig. 4)*. Most of the remaining strongholds (31 percent) are found in areas with high road densities, illustrating how past land management often focused on midelevation, forested areas that historically may have supported some of the most productive aquatic systems. Further statistical analyses demonstrated that increasing road densities and their attendant effects are significantly associated with declines in the status of the resident key salmonids. These fish are less likely to use streams in moderate to highly roaded areas for spawning and rearing, and if found there, they are less likely to be at strong population levels. This is a consistent and unmis-

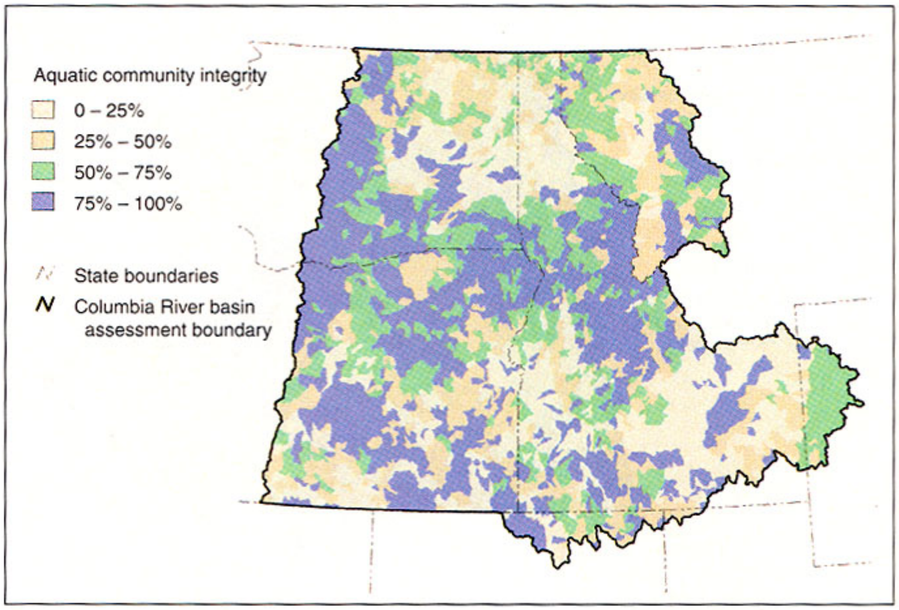

Figure 5. **Aquatic community integrity based on a combination of native species diversity and the status of key salmonid species. Values reflect relative ranking across the basin (i.e., equal partiles), not absolute scores.**

takable pattern based on an empirical analysis limited primarily to forested lands managed by the Forest Service and the Bureau of Land Management.

Third, core areas remain for rebuilding and maintaining functional native aquatic systems despite broad-scale changes. Despite their reduced numbers and distributions, native trouts remain the most widely distributed taxa within the basin. The more serious problems are in the larger rivers and in the low-elevation agricultural and range lands; the situation is somewhat better in the forested lands. Conditions remain the best in those areas that have experienced the least human-caused disturbance. A higher proportion of strong populations of key salmonids are found in higher-elevation forested lands, and the proportion declines with road density. Most of the high-integrity areas, based on the presence of strongholds and native diversity, fall within forested environments *(fig. 5)*; exceptions are the areas inherently rich in native fish species.

Fourth, rare and sensitive fishes have special problems or management needs related to their limited distributions. Many of these taxa occur in isolated areas of the Columbia River basin, in isolated subbasins of the Great Basin, or are restricted to the upper Klamath basin. They typically occur in relatively depauperate areas, perhaps with only one or two native fish species present and in very restricted areas, often occupying one or two small habitat patches within watersheds (averaging 8,000 hectares in size). Consequently, broad-scale or midscale assessments that focus on diversity of native species may undervalue distributions of rare species.

Many of the rare and sensitive fishes are vulnerable to human effects and random natural disturbances because of their restricted range, low population sizes, and fragile habitat requirements. Spring-dwelling fishes, for example, occupy unique desert habitats that are easily disturbed by off-road vehicles, livestock grazing, and other surface disturbances. Spring aquifers and associated substrates also may suffer from withdrawal of groundwater, geothermal exploration, or other subsurface drilling. The native lake-dwelling suckers of the Klamath basin, for example, have declined to the extent that the species are hybridizing within the remaining spawning areas. Natural disturbances, such as drought and fire, may increase the risk of extinction in altered habitats.

Aquatic Conservation Strategy

Developing an integrated ecosystem management strategy that will protect and maintain aquatic system integrity and functioning requires boldness and innovation. In today's contentious public arena, it also requires considerable resolve and stamina (see Walters 1997). Simple solutions, such as setting aside small, scattered watersheds, will not likely be adequate to maintain even current distributions and diversity.

If maintaining or restoring the integrity of aquatic ecosystems is an important goal, dramatic and decisive action may be necessary to stop further alterations and restore degraded areas. Managers could consider a three-pronged strategy:

First, conserve watersheds and habitats of high intrinsic value or condition for aquatic species. These include areas supporting strongholds for one or multiple species, areas of high genetic integrity or adaptive significance, areas that support narrowly distributed endemic or listed species, and areas important to water quality.

Second, reconnect and expand the mosaic of strong populations for the key salmonids, which are still widely distributed. For wide-ranging fishes such as salmon, steelhead, and other migratory resident trouts, this includes protecting water quality and passage in migratory corridors, in addition to spawning and rearing areas.

Third, contain nonnatives. Land management agencies and state and tribal fishery management agencies could cooperate to reduce or eliminate stocking of nonnative and hatchery-reared fish in areas capable of supporting self-sustaining native species.

Although watershed protection is important, evidence suggests that the integrity of aquatic systems can be maintained in some intensively managed areas. Intensive land use does not necessarily preclude strong populations or areas with high integrity, but the scope of our assessment prohibited detailed examination of individual watersheds. Thus, we cannot discern whether intensively managed areas with high integrity are anomalies, where the effects on streams lag behind the change on lands, or places where intensive management and fish can coexist. A more careful examination of these areas may guide future management of disturbances in important watersheds.

To aid discussions on restoration and restoration priorities, we developed a simple classification of subbasins (approximately 280,000 hectares) throughout the basin. The classification scheme provides a spatially explicit description of aquatic issues, needs, and opportunities that can be associated with similar descriptions for terrestrial ecosystems. The classification is based on the extent of contiguous, well-connected subareas with high aquatic integrity and strong populations. The range of subbasins—from those with viable populations to those characterized by isolated and fragmented populations—provides managers with a basis to develop conservation and restoration strategies.

The effective conservation of aquatic diversity and resilience will require maintaining complex habitats and networks of those habitats at multiple scales and across multiple ownerships. To maintain or rehabilitate a network of habitats that spans the gradient of environments, and not merely accept the chance pattern of habitats left by historical management, requires not just multiscale focus but political will.

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