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Historical Changes in Fish Habitat for Select River Basins of Eastern Oregon and Washington

Abstract

From 1934 to 1942 the Bureau of Fisheries surveyed more than 8,000 km of streams in the Columbia River basin to determine the condition of fish habitat. Changes in fish habitat over time were evaluated by resurveying a subset of the historically surveyed streams in the Tucannon, Asotin, Grande Ronde, Yakima, Wenatchee, and Methow river basins from 1990 to 1992. Historical reviews show many streams as degraded from past land management practices (e.g., timber harvest, splash dams, stream channelization, livestock grazing, and mining) before the 1930s. Our basin resurveys show a decrease in large pools ($\geq$ 20-m^2 area and $\geq$ 0.9-m depth) in managed watersheds (multiple-use, $p < .05$), while large pools in unmanaged watersheds remained the same or increased ($p < .05$). Results for these six river basins suggest a regional pattern to this change. Large pools increased in the Mid-Columbia region (Yakima, Wenatchee, and Methow basins; $p < .05$) regardless of management history, with the increase being twice as great in unmanaged watersheds. In the Blue Mountain region (Tucannon, Asotin, and Grande Ronde basins), large pools decreased significantly ($p < .05$). The current frequency of coarse woody debris was significantly higher ($p < .05$) in unmanaged than in managed basins. Differences in land-use histories for the mid-Columbia and Blue Mountain regions partially explain current fish habitat conditions and the declines in anadromous fish runs. Strategies to protect, restore, and maintain anadromous and resident fish habitat need ecosystem approaches that protect as well as restore the remaining habitats.

Introduction

In this paper we examine changes to fish habitat in selected river basins of eastern Oregon and Washington since the 1930s. The Pacific Northwest Research Station (PNW) has used Bureau of Fisheries (BOF, now National Marine Fisheries Service) fish habitat surveys conducted from 1934 to 1942, with current surveys, to detect changes in pool and substrate conditions over the past 60 years. To provide context and possible explanations for changes in fish habitat, we examined the land-use history of these basins. Additional historical information about the ecological health of river basins in eastern Oregon and Washington is given in Wissmar *et al.* (1994a,b).

Stream ecosystem integrity is coupled to the condition of upland areas and adjacent riparian areas (Gregory *et al.* 1991, Naiman *et al.* 1992). Riparian areas are sources of organic matter (e.g., coarse woody debris, litter), which forms the energy and nutrient base for many aquatic organisms. In addition, riparian areas strongly influence water temperature. Upland areas also provide coarse woody debris (CWD) along with sediment, especially in small, permanently and seasonally flowing streams that may not hold fish. The creation and maintenance of productive aquatic ecosystems depends on maintaining the connectivity between stream, riparian, and upland areas. This connection is particularly strong in mountainous regions.

Pools and substrate composition are critical habitat components for anadromous salmonids (*Oncorhynchus* spp.) in all phases of their freshwater life histories. Pools provide rearing habitat for juvenile fish, resting habitat for adult fish (Bjornn and Reiser 1991), and refugia for adults and juveniles from natural disturbances, such as drought, fire, and winter icing (Sedell *et al.* 1990). Substrate composition affects the quality and quantity of spawning habitat, the availability of summer and winter cover for juvenile fish, and aquatic productivity (Bjornn and Reiser 1991). Salmonids are particularly sensitive to the effects of fine sediments (<6 mm) in spawning gravels (Bjornn and Reiser 1991, Everest *et al.* 1987). A considerable body of literature has shown the detrimental effects of fine sediments on salmonid reproduction (Chapman 1988, Everest *et al.* 1987).

Decreased pool and substrate quality and quantity also affect aquatic biodiversity. The loss of fish habitat diversity caused by land-use practices alters fish community composition and reduces species diversity (Bisson *et al.* 1992, Bisson and Sedell 1984, Reeves *et al.* 1993). Research on Oregon

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coastal streams (Reeves *et al.* 1993) showed that species diversity in logged basins is lower than in similar, unharvested streams.

The scientific community agrees on the functional role of CWD in creating and maintaining high-quality fish habitat (Bisson *et al.* 1987, Hicks *et al.* 1991, Sedell *et al.* 1988). Coarse woody debris serves a wide array of physical and biological functions in stream ecosystems. In addition to cover and habitat complexity for fish, it also provides for sediment storage, channel roughness, reduced erosional effects of high flows, and enhanced pool development and maintenance. Several studies have shown that the loss of CWD causes reduced salmonid production (Bisson *et al.* 1987, Everest *et al.* 1985).

"Forest health," as it is generally perceived, is focused on the issue of dead and dying trees. To transcend this perception, managers and researchers must see the picture of forest health as one of watershed health, fully recognizing the intricate linkages between aquatic and terrestrial ecosystems. Stream ecosystems are the ultimate integrator of all watershed disturbances. If management plans aimed at restoring eastside forests fail to recognize and protect the critical linkages between terrestrial and aquatic ecosystems, the "health" of stream ecosystems and fish populations will continue to decline. Traditional approaches to stream restoration (i.e., in-stream structures) are at best band-aid measures with a high degree of uncertainty for success, especially in damaged systems (Beschta *et al.* 1991, Frissell and Nawa 1992, Li *et al.* 1992). Protecting aquatic ecosystems is by far the most efficient, cost-effective, and lowest-risk strategy to ensure long-term sustainability of these ecosystems (Reeves *et al.* 1991, Reeves and Sedell 1992). Management must center on a long-term, holistic approach that protects and maintains ecological processes at the scale of large watersheds (Naiman *et al.* 1992, Wissmar *et al.* 1994b).

Sedell and Everest (1990), McIntosh (1992) and McIntosh *et al.* (1994) have documented changes in the quality of fish habitat since 1934. The primary change has been the loss of large pools ($\geq$20-m^2 area and $\geq$0.9-m depth) in watersheds managed for multiple use. These changes appear to be due to the effects of land-management activities, such as timber harvest, livestock grazing, agriculture, and mining. Multiple studies have documented the effects of land management activities on ecosystem processes and functions, such as increased sedimentation, mass failures, and peak flows, as well as decreased CWD, bank stability, habitat complexity, and water quality (Meehan 1991).

Recent listing of chinook (*Oncorhynchus tshawytscha*) and sockeye salmon (*O. nerka*) in the Snake River basin under the Endangered Species Act (ESA) makes it imperative that a comprehensive, integrated approach to watershed health be initiated. In addition, the American Fisheries Society has documented 76 native anadromous salmonid stocks in the Columbia River basin that are at a high or moderate risk of extinction (Nehlsen *et al.* 1991). Over 200 stocks are already extinct in the Columbia River basin (Nehlsen *et al.* 1991). Status of resident fish, such as bull trout (*Salvelinus confluentus*), which are being considered for listing under ESA throughout their range in eastern Oregon and Washington, must also be fully considered.

Many factors have contributed to the demise of these fish species. They include habitat loss and degradation, influence of hatchery practices, overexploitation in sport and commercial fisheries, and impediments to upstream and downstream movement by hydroelectric dams (Nehlsen *et al.* 1991, Northwest Power Planning Council 1986, Williams *et al.* 1989). These factors have not affected fish survival singularly, but cumulatively.

Increased survival in freshwater habitat, along with improved passage and reduced harvest, will be critical to the survival of these fish stocks. Fish habitats currently in good condition need protection and degraded habitats need restoration. Both protection and restoration are critical components of any ecosystem management plan developed to deal with forest health in river basins. Streams need less fine sediment, more shade, and increased habitat complexity to restore fish habitat to conditions that will support self-sustaining fish populations. Current strategies to protect and restore streams (Anderson *et al.* 1992, Hewjum *et al.* 1994, USDA 1993) call for enlarging riparian buffers, reducing road densities, and eliminating or reducing livestock grazing and any other activities detrimental to stream ecosystems.

Materials and Methods

Bureau of Fisheries stream surveys, together with resurveys, have been used by the PNW to detect changes in fish habitat in the Columbia River basin since 1934. We compared current surveys with the BOF surveys to detect changes in pool and substrate composition in the Blue Mountain and

Mid-Columbia regions. In addition, resurveys were used to evaluate current amounts of CWD in streams throughout the two regions.

From 1990 to the present, PNW examined streams across a broad range of geologic conditions, land ownerships, and land-use histories (McIntosh 1992, McIntosh *et al.* 1994, Sedell and Everest 1990). In conducting the resurveys, we attempted to examine streams across the Pacific Northwest to encompass as much variation as possible. This study does not account for the different potential of watersheds to create and maintain fish habitat because of differences in bedrock, soils, climate, stream discharge, vegetation, and structure. Ongoing research is being conducted in an attempt to analyze these results based on the inherent differences in watersheds.

Fish Habitat Surveys

The BOF surveys were initiated to determine the condition of streams in the Columbia River basin that provide potential spawning and rearing habitat for anadromous salmonids (Rich 1948). These records are the earliest and most comprehensive documentation of the condition and extent of anadromous fish habitat available. The BOF surveys systematically inventoried more than 8,000 km of streams in the Columbia River basin from 1934 to 1942.

Rich (1948) provided a detailed description of methods used in the BOF surveys. Data for the BOF surveys were systematically collected at continuous 100-yd intervals for the entire section surveyed, generally from the mouth to the upstream extent of anadromy. Within each 100-yd unit, the surveyors estimated channel width, estimated bottom substrate composition by size-classes and percentage per class, and counted the number of pools by size-class.

Historically surveyed streams were resurveyed by using the Hankin-Reeves method (Hankin and Reeves 1988). This sampling technique involves stratifying streams according to channel units (e.g., pool, riffle, glide). Channel units for the resurvey were based on morphological characteristics rather than on an arbitrary length, as were the BOF surveys. The Hankin-Reeves method provides data that are comparable with the BOF surveys.

To examine changes in fish habitat over time, we classified individual streams according to the land-management history of the basin. Basins were classified as either managed or unmanaged. Managed basins were predominantly multiple-use areas (e.g., for timber, livestock, agriculture, and mining production). Unmanaged basins were minimally affected by human disturbance (i.e., wilderness and roadless areas). We recognize that many unmanaged basins were affected by grazing and mining historically. In the absence of suitable data, we surmise that grazing use has declined in unmanaged basins similar to managed basins.

Pool Habitat

Analysis of changes in pool habitat was based on large pools ($\geq$20-m^2 area and $\geq$0.9-m depth). To account for hydrologic variability and provide a conservative estimate of changes in pool frequencies, we effected an intentional bias by discarding marginal pools from the BOF surveys and including marginal pools in the resurveys. In the BOF surveys, marginal pools were those noted as shallow or small and were not included in the analysis. Marginal pools added to the 1990 total were large pools ($\geq$0.8 m depth). In effect, the data represent two biases: a bias for fewer pools historically and a bias toward more pools in the resurveys. A two-sample *t*-test was used to compare pool frequencies between the BOF surveys and the resurveys.

Substrate Composition

To assess changes in substrate, we compared mean substrate composition, dominant substrate, and fine sediments between the two surveys. One significant failure of both surveys is the lack of an error term for estimates of substrate composition. Both the BOF and current estimates were not corrected for observer bias, eliminating any means of quantifying the variability associated with the estimates. This limits the usefulness of the data to determining trends in substrate conditions.

Coarse Woody Debris

In the resurveys data were collected on the quantity of CWD in channels. The BOF survey did not collect data on CWD. We counted the number of pieces and noted the positions of CWD as single pieces or in jams ($\geq$ two pieces). The minimum size for CWD was $\geq$ 0.1-m diameter and $\geq$ 2.0-m length. A two-sample *t*-test was used to compare the frequency of CWD in managed and unmanaged basins.

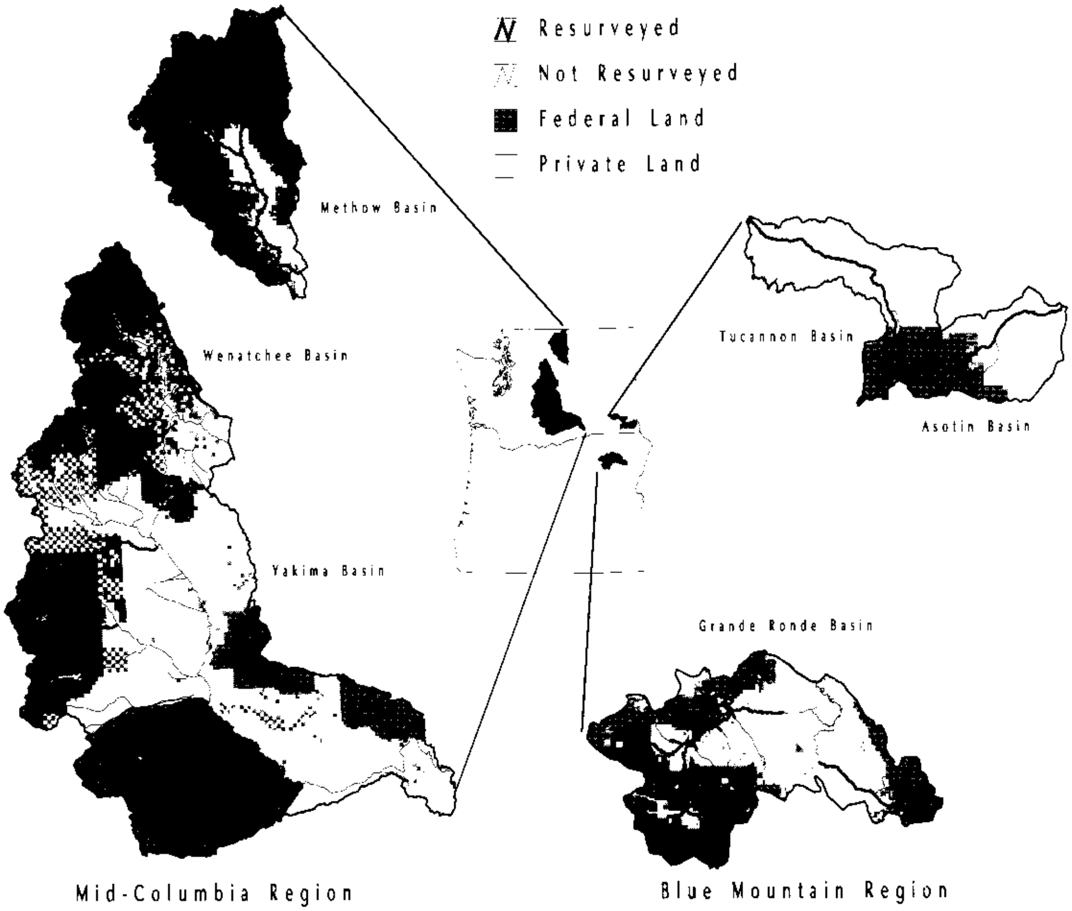

Figure 1. Map of study basins and surveyed streams in eastern Oregon and Washington.

Land-Use History

The available records of land-use history for the study basins, along with more general regional records, were examined to characterize the land management history before and after the BOF surveys. The disturbance history provides the context for identifying potential causal mechanisms for changes in fish habitat. The information complements the land-use and disturbance history available from both public and private sources (Wissmar *et al.* 1994b).

Study Area

In this study, we examined river basins in eastern Oregon and Washington where resurveys were conducted between 1990 to 1992. These resurveys included portions of the Tucannon, Asotin, Grande Ronde, Yakima, Wenatchee, and Methow river basins. We separated these river basins into two regions for further comparison. The Blue Mountain region consisted of the Tucannon, Asotin, and Grande Ronde basins, and the Mid-Columbia region contained the Yakima, Wenatchee, and Methow basins (Figure 1).

Blue Mountains Region

Tucannon River basin. The Tucannon River basin, in southeast Washington, drains an area of 1,300 km^2. The BOF surveyed the Tucannon River and its major tributaries in 1935; the resurveys were limited to the Tucannon River. More than 70% of the basin is private land, and the remainder is public land. Headwater portions of the basin are wilderness areas, and the forested reaches below the wilderness are managed for multiple use by the Forest Service. From the Forest Service boundary to the mouth, the remainder of the basin is private land. Private lands are managed predominantly as dry croplands and rangelands (USDA Soil Conservation Service 1991).

The basin supports summer steelhead (*O. mykiss)* and spring chinook; spring chinook is listed as threatened under the ESA, and summer steelhead is listed as a species of special concern by Nehlsen *et al.* (1991). Historically the Tucannon supported coho salmon (*O. kisutch)*, which is now extinct in the basin. Bull trout is also found in the upper portions of the basin.

Asotin Creek basin. Asotin Creek is in southeast Washington, draining an area of 828 km^2. The upper mountainous, forested portions of the basin are managed for multiple use by the Forest Service. Lower portions of the basin are private and are used for dryland crops and rangeland (USDA Soil Conservation Service 1991).

The Asotin basin supports spring chinook and summer steelhead. Spring chinook is listed as threatened under the ESA, and Nehlsen *et al.* (1991) list summer steelhead at a moderate risk of extinction. Current populations of anadromous fish in the Asotin basin are far below historical levels.

Grande Ronde River basin. The Grande Ronde River basin, in northeast Oregon, encompasses ~12,810 km^2. The BOF surveys were limited to the upper portion of the basin, from the Grande Ronde valley to the headwaters. About 50% of the Upper Grande Ronde River basin is public land managed by the Forest Service; most of the land is mountainous and timbered. The valley bottoms are predominantly privately owned, and the primary uses are livestock grazing and agriculture (McIntosh 1992, Northwest Power Planning Council 1990).

Historically, the Upper Grande Ronde River basin had large runs of anadromous salmonids. The basin supported spring chinook, coho, and summer steelhead (Northwest Power Planning Council 1990). These runs have been reduced to a small fraction of their pre-development numbers, with coho being extinct in the Grande Ronde and spring chinook listed as threatened under the ESA.

Mid-Columbia Region

Yakima River basin. The Yakima River basin, in south-central Washington, drains an area of 15,942 km^2. More than 60% of the land in the Yakima basin is publicly owned, and the remainder is in private ownership. Irrigated agriculture is the current economic base, with livestock production and forestry also contributing to local economies (Northwest Power Planning Council 1989).

Historically, the basin supported summer steelhead, coho, chinook, and sockeye salmon. Predevelopment run sizes (pre-1870) were estimated at 790,000 adults (Northwest Power Planning Council 1989, Table 1). By the turn of the century, most runs were depleted, with coho and sockeye near extinction (Uebelacker 1980). Currently, coho, summer chinook, and sockeye salmon are extinct in the basin, and summer steelhead, fall, and spring chinook are listed as stable (The Wilderness Society 1993).

Wenatchee River basin. The Wenatchee River basin is in north-central Washington; it drains an area of 3,437 km^2. The basin is about 80% public land, mostly in the mountainous, forested regions. Irrigated agriculture, along with livestock and forestry, is the current economic base.

Historically, the Wenatchee had large runs of steelhead, chinook, and sockeye salmon, as well as a small coho salmon run. Coho were extinct in the basin by the 1940s. Recent research (Mullan *et al.* 1992) suggests that current wild run sizes appear to be similar to historical populations (Table 1). Although the current population seems stable, the species composition of the run has shifted significantly. Chinook salmon comprise most of the run; sockeye salmon populations are reduced and coho salmon are extinct in the basin. Summer steelhead is listed as a species of special concern by Nehlsen *et al.* (1991) primarily because of the effects of hatchery introgression.

Methow River basin. The Methow River basin is in north-central Washington; it drains an area of 4662 km^2. About 80% of the basin is public land managed by the Forest Service, predominantly in the upper portions of the basin. The lower portions are privately owned. Logging and livestock production is the economic base of this sparsely populated basin, with fruit orchards also playing a significant role (Mullan *et al.* 1992).

Before settlement by Euro-Americans, the Methow supported significant runs of chinook and coho salmon, along with steelhead, with coho being the most abundant (Mullan *et al.* 1992, Table 1). Currently, chinook salmon and steelhead

TABLE 1. Estimates of historical salmon and steelhead runs in the Yakima, Wenatchee, and Methow River basins (Northwest Power Planning Council 1989, Mullan *et al.* 1992).

Species/race	Run size Historical	Present
Yakima River Basin	790,000	7,018[a]
Wenatchee River Basin	280,600	306,700[b]
Methow River Basin	63,800	91,100[c]

[a]Based on mean run size for all anadromous salmonids from 1983 to 1987.

[b]Based on mean run size for all anadromous salmonids from 1967 to 1987.

[c]Based on mean run size for all anadromous salmonids from 1967 to 1987.

remain, and coho salmon are extinct in the basin. Mullan *et al.* (1992) suggest that current runs exceed the historical runs in the Methow basin, with chinook replacing coho (Mullan *et al.* 1992). Wild steelhead is listed at a high risk of extinction by Nehlsen *et al.* (1991) primarily because of the impacts of irrigation and hatchery introgression.

Results

Changes in fish habitat in eastern Oregon and Washington (Table 2) were similar to the results for the Columbia River basin (Table 3). The trend towards decreased pool frequencies in managed watersheds was not significant ($p > .05$) but showed a regional pattern. Pool frequencies in unmanaged watersheds increased significantly (2.0-5.9 pools/km, $p < .05$) (Table 2). Trends in substrate composition were variable. The survey results indicated that the frequency of CWD was significantly greater ($p < .05$) in unmanaged watersheds (Table 4). In the following sections, we examine the changes in individual river basins to further illustrate these changes.

Blue Mountain Region

The PNW, in cooperation with Oregon State University, resurveyed 260 km of streams in the Blue Mountain region from 1990 to 1992 in the Tucannon, Asotin, and Grande Ronde basins. The surveyed streams went from headwaters to low-gradient, alluvial rivers, across both public and private lands. None of the streams surveyed in the Blue Mountain region could be classified as unmanaged, leaving no minimally disturbed benchmark against which to evaluate change.

Pool Habitat

Resurveys in the Blue Mountain region show that the frequency of pools decreased by 57% (mean = 5.6 to 2.4 pools/km, $p < .05$, Table 5) in managed watersheds. The Tucannon River was the

TABLE 2. Changes in the frequency of large pools for streams in managed and unmanaged watersheds of selected river basins in eastern Washington and Oregon from 1934 to 1992.

	Km surveyed	1934-42 #/km	1990-92 #/km	Percentage change
Managed				
Tucannon River, WA	64.5	2.4	6.5	171%
Yakima River, WA	65.4	1.8	3.8	111%
Methow River, WA	146.0	1.7	3.4	100%
Wenatchee River, WA	33.6	4.9	7.7	57%
Asotin Creek, WA	37.5	3.1	2.1	−33%
Grande Ronde River, OR	157.9	6.1	2.1	−66%
Total (n = 21)	505.0	4.3	3.1	-28%
Unmanaged				
Methow River, WA	30.2	1.0	3.4	240%
Wenatchee River, WA	80.2	2.5	7.5	200%
Yakima River, WA	18.8	1.6	3.9	144%
Total (n=5)	129.2	2.0	5.9	195%[a]

[a]Differences between the BOF surveys and current surveys significant at $p < .05$

TABLE 3. Changes in the frequency of large pools for streams in select managed and unmanaged basins in the Columbia River Basin from 1934 to 1992.

	Km surveyed	1934-42 #/km	1990-92 #/km	Percentage change
Managed basins	1411.0	7.5	5.4	−28%[a]
Unmanaged basins	265.0	3.9	6.9	77%[a]

[a]Differences between the BOF and current surveys significant at $p < .05$

TABLE 4. Current frequency of coarse woody debris (≥0.1-m diameter and ≥2.0-m length) for streams in selected managed and unmanaged watersheds of eastern Oregon and Washington.

	Coarse woody debris	
	Pieces (#/km)	Jams (#/km)
Managed		
Grande Ronde basin, OR	36.0	5.9
Yakima River basin, WA	32.8	5.8
Wenatchee River basin, WA	26.7	3.5
Methow River basin, WA	69.2	12.3
MEAN	41.8	7.1
Unmanaged		
Yakima River basin, WA	72.7	13.8
Wenatchee River basin, WA	72.5	11.9
Methow River basin, WA	40.2	8.1
MEAN	66.1[a]	11.5[a]

[a]Differences between managed and unmanaged basins significant at $p < .05$.

only stream that showed an increase in pool frequencies (2.4 to 6.5 pools/km). There were no unmanaged watersheds for comparison in this region.

Our most extensive overview of changes in fish habitat was from the Grande Ronde basin (McIntosh 1992); surveys in the Tucannon and Asotin basins were limited to the Tucannon River and Asotin Creek. The BOF surveys in the Grande Ronde were in the upper basin, from the Grande Ronde valley to the headwaters. In 1990 all historically surveyed streams in the Upper Grande Ronde River basin were resurveyed (McIntosh 1992). These streams extend across a variety of landscapes (e.g., mountainous, meadow), land-use histories (e.g., logging, mining, agriculture) and land ownerships (i.e., public, private).

Survey results indicate that pool habitat decreased significantly ($p < .05$) throughout the Grande Ronde basin despite differences between streams. The frequency of large pools in the BOF surveys ranged from 0.0 to 14.6/km (mean = 6.1/km, Table 2). In 1990 pool frequencies ranged from 0.0 to 7.0/km (mean = 2.1/km, Table 2). The loss in large pools ranged from 20% to 87%, with a mean of 66% (Table 5). In the BOF surveys pool frequencies were highly variable (VAR = 23.2) among the different streams, but the 1990 survey showed that pool frequencies were similar (VAR = 3.2) for all streams. The decreased variability in pool frequencies showed that habitat diversity decreased significantly.

Substrate Composition

Trends in substrate composition varied among the three basins. No change was found in substrate composition for Asotin Creek, but the Tucannon

TABLE 5. Changes in the frequency of large pools for selected streams in managed watersheds of the Blue Mountain region from 1934 to 1992.

	Km surveyed	1934-42 #/km	1990-92 #/km	Percentage change
Tucannon River basin				
Tucannon River	64.5	2.4	6.5	171%
Asotin Creek basin				
Asotin Creek	37.5	3.1	2.1	−33%
Grande Ronde basin				
Rock Creek	2.2	0.0	0.9	90%
Jordan Creek	3.1	0.0	0.0	NC
Five Points Creek	2.8	1.8	1.8	NC
Meadow Creek	18.6	2.5	2.0	−20%
Sheep Creek	9.2	14.6	6.8	−53%
Catherine Creek	30.7	9.2	3.6	−61%
N Fk Catherine Creek	6.6	4.7	1.7	−64%
Grande Ronde River	73.4	4.0	1.1	−73%
McCoy Creek	4.7	9.1	1.7	−81%
Beaver Creek	3.3	10.0	1.5	−85%
S Fk Catherine Creek	3.3	11.2	1.5	−87%
TOTAL	259.9	5.6	2.4	−57%[a]

[a]Differences between the BOF surveys and current surveys significant at $p < .05$

River showed a shift toward larger substrates. Fine sediments remained at low levels in Asotin Creek (6%) and the Tucannon River (7%). Substrate composition in the Upper Grande Ronde River basin shifted toward finer substrates. Substrate composition changes throughout the basin, with finer sediments being deposited downstream in the Grande Ronde River.

Analysis of mean substrate composition suggested no change in fine sediments in the Upper Grande Ronde River basin although fine sediments were 20% of the substrate composition in the Grande Ronde River. The spatial distribution of fine sediments relative to anadromous salmonid habitat was examined by plotting the percentage of surface fines for individual channel units from the downstream to upstream extent of the Upper Grande Ronde River. This spatial analysis showed that fine sediment in the headwater portions of the Upper Grande Ronde River greatly exceeded 20% of the substrate composition throughout most of this reach (McIntosh 1992). In addition, most of the stream channels throughout the headwaters are highly embedded, generally exceeding current standards of 35% (USDA Forest Service 1991, 1992a).

Land-Use History

Our survey of land-use history was limited to the upper Grande Ronde basin. Future work will examine the Tucannon and Asotin basins in greater detail. The history of Euro-American development and land use in the Grande Ronde basin may be indicative of the general pattern for the Blue Mountain region of northeast Oregon and southeast Washington. Wissmar *et al.* (1994b) detail the land-use history of the John Day basin, showing its similarity to the Grande Ronde basin.

At the time of the BOF surveys, the Upper Grande Ronde River basin had already experienced considerable human-induced disturbance. Available records of land-use history for this basin were examined to characterize land-use history before and after the BOF surveys. Records of timber harvest, road construction, and livestock grazing were available from the Wallowa-Whitman National Forest.

Mining. Mining was the first influence of Euro-Americans in the Upper Grande Ronde River basin. The headwaters of the basin have been mined for gold since 1870, with extensive dredge mining in the early 1900s. Gold mining has

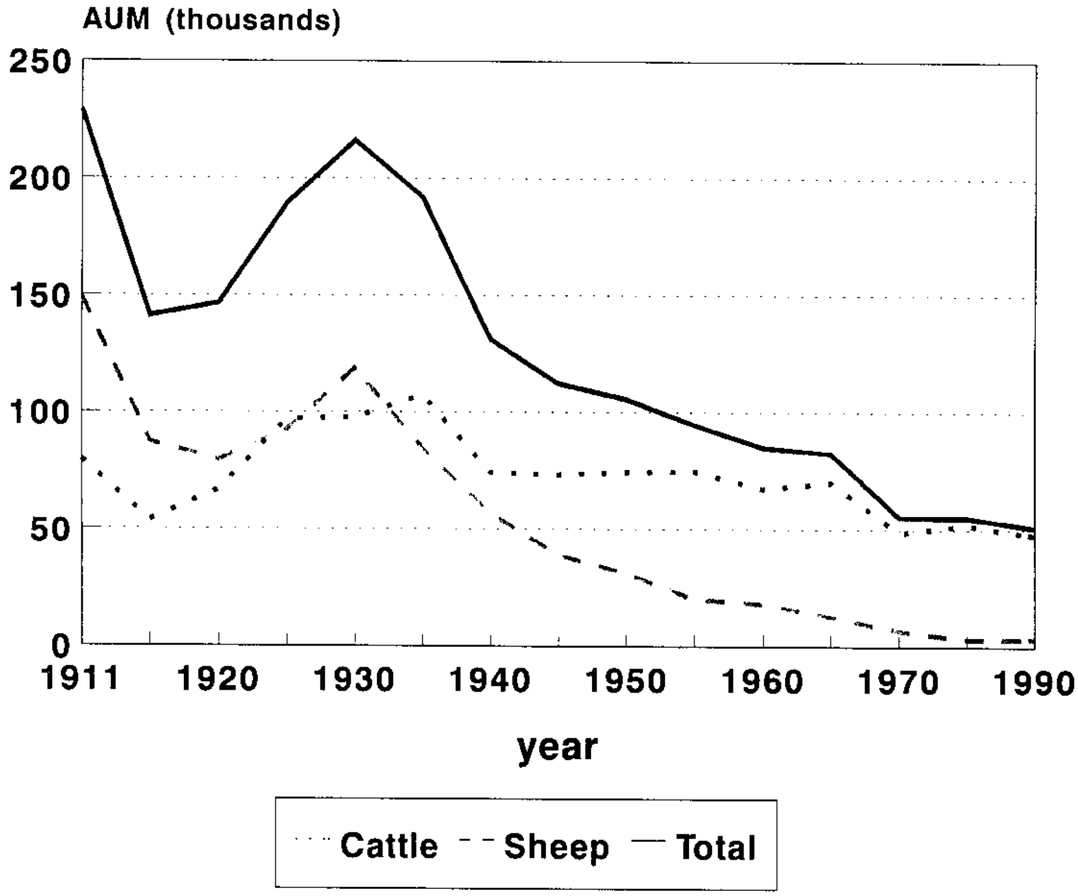

Figure 2. Grazing use (animal unit month) for livestock and elk on the Wallowa-Whitman National Forest, 1911 to 1990.

significantly altered the river and its floodplain throughout the headwaters. Extensive mine tailings from dredging throughout the upper river constrict the mainstem channel and provide a continuous source of sediment. This reach of the river currently provides most of the spring chinook spawning habitat in the Upper Grande Ronde.

Livestock grazing. Early records of livestock grazing in the Upper Grande Ronde basin suggest that parts of the basin were overgrazed by the 1880s (Skovlin 1991). Records of annual grazing use were available from the Wallowa-Whitman National Forest from 1911 to 1990. Over that period, grazing by livestock (cattle and sheep) declined 78% (Figure 2). The decline in grazing was largely due to the collapse of the sheep industry in northeast Oregon. Cattle represent > 90% of the grazing animals today.

Timber harvest. The historical record of timber harvest in the Upper Grande Ronde River basin shows that logging began in the late 1800s (Farnell 1979). Harvest has increased steadily since 1896, with the most intensive logging coming after 1950 (Figure 3), primarily in response to insect outbreaks (Wickman 1991).

Although harvest has increased over time, the effects of spatial patterns of harvest and harvest methods must also be considered. Harvest in the early part of the century was restricted to riparian areas and the adjacent hillslopes, and primarily selected for mature ponderosa pine (*Pinus ponderosa*). Logs were moved to the mills first by log drives and splash dams (1890-1919), then by rail (1910-1954), and finally by roads (1930-present).

In the latter part of the century, higher elevation and headwater sections of the basin were

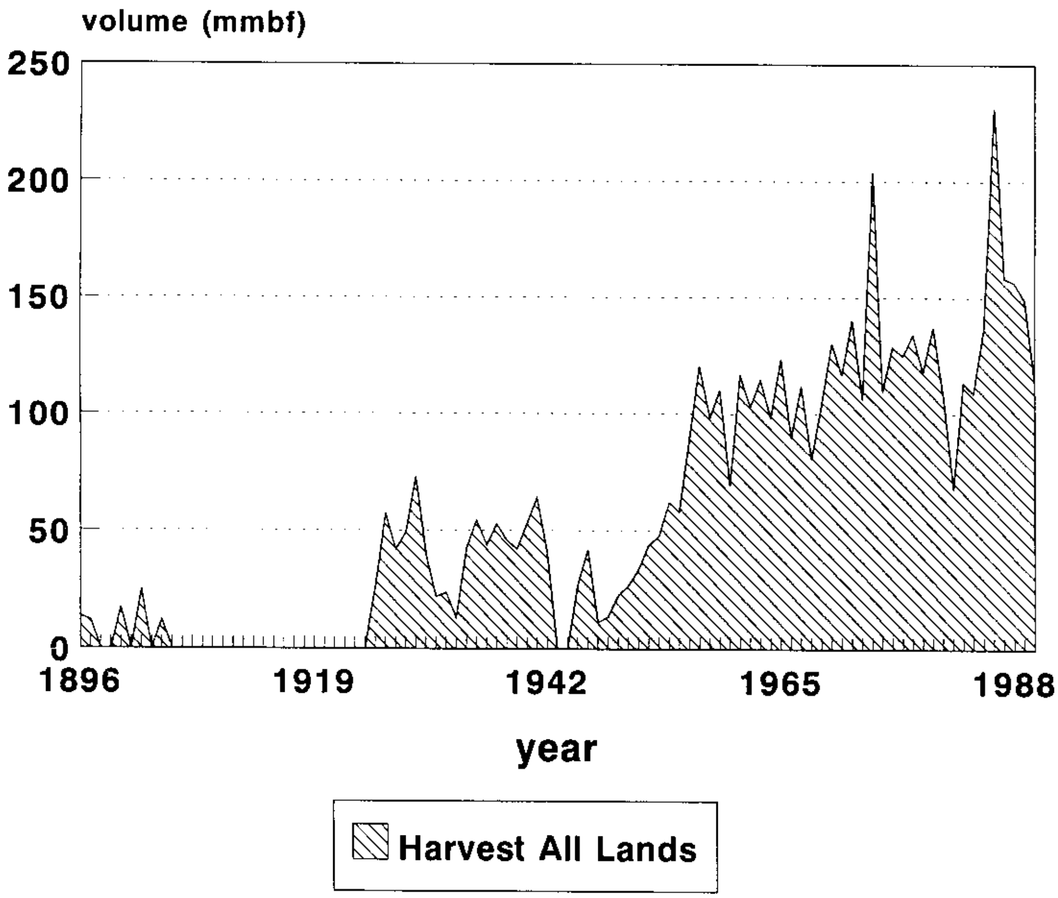

Figure 3. Volume of timber harvested (mmbf) for Union County, Oregon, 1896 to 1990.

accessed as road construction increased. From 1954 to 1978, road mileages increased more than twofold (3,200-7,200 km), doubling again from 1978 to 1989 (7,200-16,000 km, Figure 4). Clear-cutting and selective harvest became the preferred methods of harvest from the 1950s to the present.

Stream channelization. The influences of stream channelization appear in the Upper Grande Ronde basin. Stream channelization projects attempted to protect private property from flooding by "locking" the stream channel in place with riprap and levees. The periods of most intensive activity were often in response to major floods, such as the 1964 flood.

Mid-Columbia Region

From 1990 to 1992, the PNW, in cooperation with the University of Washington and the Wenatchee and Okanogan National Forests resurveyed over 370 km of historically surveyed streams in the Yakima, Wenatchee, and Methow River basins. The surveyed streams range from small, mountainous streams to large, alluvial rivers. These streams extend across both private and public land and have various land-use histories. Although these surveys represent a small sample of BOF streams in these basins, we believe they represent the types of change that streams in this region have undergone since Euro-American settlement.

Pool Habitat

Survey results show that large pool habitats increased significantly ($p < .05$) in both managed and unmanaged watersheds in the Yakima, Wenatchee, and Methow River basins since 1934 (Table 6). Of the 11 streams we surveyed, only

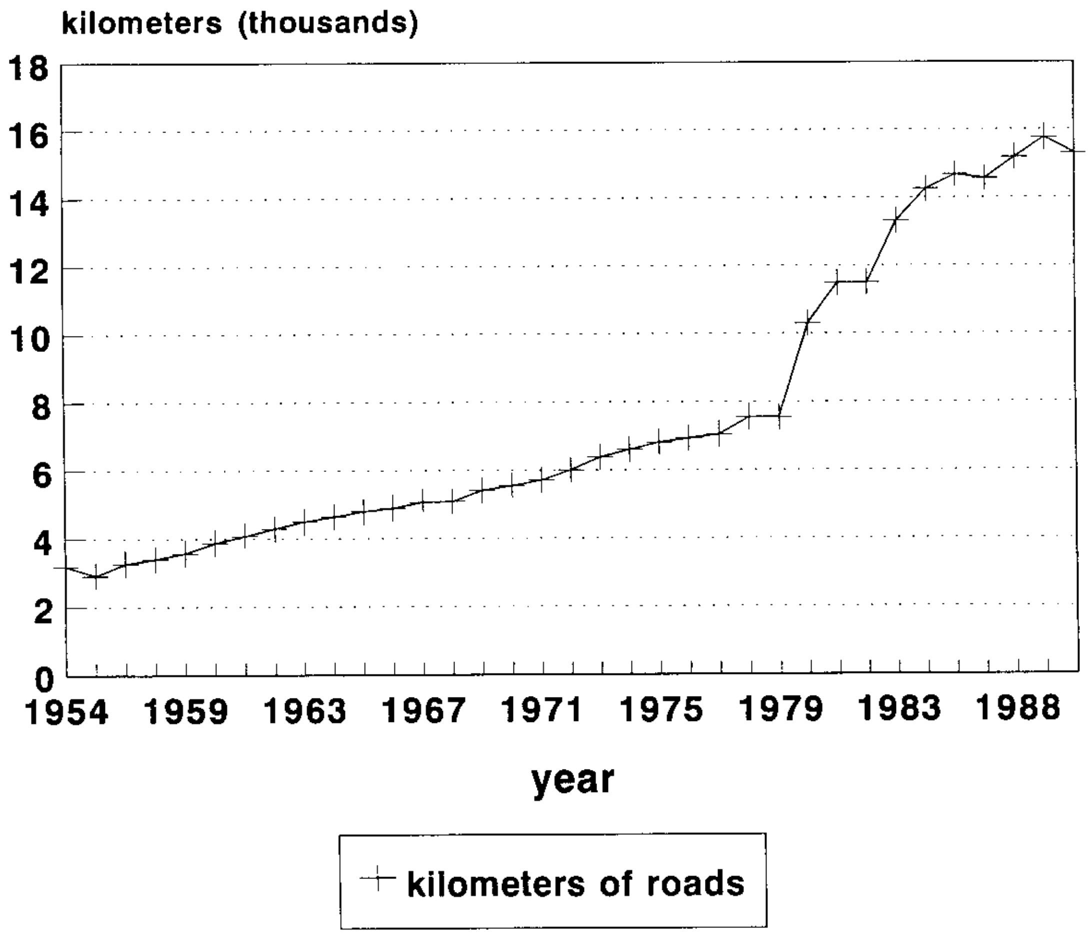

Figure 4. Road mileage (km) on the Wallowa-Whitman National Forest, 1954 to 1990.

the American River had a decrease (3.3-2.4 pools/km) in pool habitat. Pool frequencies were similar for both managed (mean = 2.2 pools/km) and unmanaged watersheds (mean = 2.0 pools/km) in the BOF surveys. In the resurveys, the increase in pool habitat was twice as great in unmanaged watersheds (2.0-5.9 pools/km) as in managed watersheds (2.2-4.1 pools/km).

Pool habitats increased by a similar magnitude in both managed (1.8-3.8/km, 111%) and unmanaged (1.6-3.9/km, 144%) portions of the Yakima basin. In the Wenatchee and Methow basins, a twofold to threefold greater increase in pool frequencies was found in unmanaged versus managed watersheds.

Substrate Composition

The resurveys indicated that changes in substrate composition were highly variable. Substrate composition appeared to change little in unmanaged watersheds; changes in dominant substrate were common in managed watersheds. In the Yakima basin, substrate composition shifted toward larger substrates in the Little Naches River and Taneum Creek (Smith 1993), but it remained the same in Rattlesnake Creek. No substrate data were available for the American River. Fine sediments increased in Taneum Creek (7-18%). Increased fine sediment, along with high levels of embeddedness, suggested that fine sediments have increased since 1934 (Smith 1993).

TABLE 6. Changes in the frequency of large pools for streams in selected managed and unmanaged watersheds in the Mid-Columbia region from 1934 to 1992.

	Km surveyed	1934-42 #/km	1990-92 #/km	Percentage change
Managed				
Yakima River basin				
Taneum Creek	17.3	0.5	3.4	580%
Little Naches River	15.6	1.7	4.6	171%
Rattlesnake Creek	8.0	1.9	4.6	142%
American River	24.5	3.3	2.4	−27%
Wenatchee River basin				
Nason Creek	33.6	4.9	7.7	57%
Methow River basin				
Chewack River	33.9	1.0	3.5	250%
Methow River	69.7	1.4	3.0	114%
Twisp River	42.5	2.8	3.9	37%
TOTAL	245.1	2.2	4.1	86%[a]
Unmanaged				
Yakima River basin				
Rattlesnake Creek	18.8	1.6	3.9	144%
Wenatchee River basin				
Jack Creek	6.9	1.9	8.0	321%
Icicle Creek	14.2	3.7	10.2	171%
Chiwawa River	59.1	1.8	4.2	133%
Methow River basin				
Chewack River	30.2	1.0	3.4	240%
TOTAL	129.2	2.0	5.9	195%[a]

[a]Differences between the BOF surveys and the current surveys significant at $p < .05$.

Changes in dominant substrate were also variable for surveyed streams in the Wenatchee River basin. Of the unmanaged streams, Jack Creek and the Chiwawa River remained the same, but Icicle Creek shifted to smaller substrate classes. Nason Creek, the managed stream, also shifted toward smaller substrates.

Comparisons of substrate composition of the streams in the Methow River basin suggested no significant trends. The exception was the Methow River, where the dominant substrate shifted to smaller substrates.

Land-Use History

The early Euro-American development of the Mid-Columbia region followed a similar pattern to that of the Blue Mountain region. After the 1930s, development in the Mid-Columbia region was different from the Blue Mountain region. Mining was one of the first activities during the settlement era, beginning in the 1850s (Wissmar *et al.* 1994b). The floodplain and streambed have been affected more extensively by mining for nonmetallic resources (e.g., gravel, sand, limestone) (Wissmar *et al.* 1994b).

Livestock grazing. Livestock grazing began in the 1850s; cattle populations peaked in the 1880s and sheep populations peaked at the turn of the century and again during World War I (Smith 1993). Before 1890 effects of grazing were concentrated in the lower portions of the basin. As grazing pressures increased, use expanded to all portions of the basins. Cattle and sheep used the high meadows for summer range, moving to the valley bottoms for winter. By 1907, public outcry over overgrazing was heard in the Yakima basin (Cooperative Western Range Study 1938). In the 1930s livestock populations declined from historical peaks and allotment management systems replaced the open range (S. Carter, Supervisor's Office, Wenatchee National Forest, Wenatchee, WA, unpubl. data).

Timber harvest. The earliest records of timber harvest show logging began in the late 1800s in the Mid-Columbia region (Plummer 1902). Until the 1950s, timber harvest was largely limited to selective logging of mature conifers from the valley bottoms and adjacent hillslopes (Smith 1993), with little harvest on public lands until the 1960s. From the mid-1970s to the present, clearcutting became a common practice, and the volume of timber harvested increased significantly. Accompanying these practices was a substantial increase in road construction.

The highest timber harvests for the Mid-Columbia region were recorded in the 1980s (Mullan *et al.* 1992). Even with increased harvest in the past decade, 65% of the Wenatchee and 75% of the Okanogan national forests, remain in wilderness or roadless designation (USDA Forest Service 1989, 1990). Timber harvest in this region has not been either as intensive or extensive as that documented for the Blue Mountain region.

Irrigation and dams. Irrigated croplands are the dominant form of agriculture in the Mid-Columbia region (Mullan *et al.* 1992). Extensive fruit orchards and croplands are present in all the major river valleys, providing the primary economic base for the region (Northwest Power Planning Council 1989). The major effects early in the century were from dams and irrigation diversions with inadequate bypass or screening facilities. For example, a hydroelectric dam near the mouth of the Methow River completely blocked the upstream migration of anadromous salmonids from 1912 to the 1930s. This barrier caused the extinction of coho salmon in the basin and severely reduced other anadromous runs (Mullan *et al.* 1992, Wissmar *et al.* 1994b). Currently, inadequate screening and variable streamflows remain a problem in many areas. For a more thorough review of the effects of irrigation and dams, see Wissmar *et al.* (1994b).

Coarse Woody Debris

Resurveys showed that the frequency of CWD was significantly higher ($p < .05$) in unmanaged than in managed basins of eastern Oregon and Washington (Table 4). The frequency of CWD pieces and jams was 58% and 62% greater in unmanaged basins than in managed basins. The exception was the Methow basin, where the frequency of CWD was greater in managed than in unmanaged watersheds.

Data on current frequencies of CWD in the Blue Mountain region were limited to surveys in the Grande Ronde basin. Current Forest Service surveys show that streams in managed watersheds throughout the upper Grande Ronde basin have a low frequency of CWD, while unmanaged portions have higher frequencies (USDA Forest Service 1991, 1992a). The frequency of CWD in the upper Grande Ronde was similar to other managed river basins surveyed in eastern Oregon and Washington, but far less than in unmanaged basins.

Discussion

This historical study shows that fish habitat has changed in selected river basins of eastern Oregon and Washington since 1934. Pool habitat decreased significantly in the Blue Mountain region and increased in the Mid-Columbia region. Substrate conditions shifted toward smaller substrates in managed watersheds and remain unchanged in unmanaged watersheds. Fine sediments also increased in some basins, especially the Grande Ronde. Current frequencies of CWD are much higher in unmanaged than in managed watersheds.

The changes in pool habitat are distinct for the two regions. Pool habitat increased in the Mid-Columbia region whether the watershed is managed or unmanaged, although the increase is twice as great in unmanaged watersheds. In the Blue Mountain region, the loss in pool habitat is large and consistent. The exception is the Tucannon River, where pool habitat increased significantly. Our field observations suggest that recovering riparian vegetation and reduced sedimentation contribute to improved conditions in the Tucannon. The headwaters of the Tucannon are largely intact because of wilderness protection. Although the trend toward improved fish habitat is positive, the Tucannon and Grande Ronde basin water temperatures are at sublethal to lethal for salmonids throughout much of the summer (Theurer *et al.* 1985, Bohle 1994).

Shifts in substrate composition for streams in managed watersheds suggested altered sediment supplies. Changes in substrate size can signify impacts of sediment inputs (Dietrich *et al.* 1989) and bedload transport in the stream (Heede 1980). Given current and past management practices, both have likely occurred (Dunne and Leopold 1978, Richards 1982). These changes can result in channel-widening, leading to increased water temperatures (MacDonald *et al.* 1991), decreased pool volumes (Lisle and Hilton 1992), and changes in species composition (Reeves *et al.* 1993). Increases in fine sediments can significantly lower egg survival (Bjornn and Reiser 1991, Everest *et al.* 1987) and decrease or eliminate pool habitat (Lisle and Hilton 1992).

Significantly lower amounts of CWD in managed watersheds, coupled with the history of CWD removal, show the extent to which the functional role of CWD decreased in the managed systems. The loss of CWD reduces habitat complexity, channel roughness, and sediment storage, and may contribute to lower salmonid survival (Bisson *et al.* 1987). These decreases in CWD in managed systems appear to be due to the effects of past land management practices, such as splash dams, debris-removal programs, and riparian timber harvest (Sedell *et al.* 1991). These practices may also influence future recruitment of CWD in managed stream ecosystems. Analysis of current forest practices rules in Oregon and Washington suggests that the recruitment of CWD will decrease with each succeeding harvest rotation (Heimann 1988, Oregon Department of Forestry 1992).

The status and trends in pool habitat, substrate conditions, and CWD indicate that streams in managed watersheds are simplified compared with those in unmanaged watersheds. Managed streams show decreased frequencies and diversities of habitat types (i.e., pools, riffles, side-channels), CWD, and other structural elements common to unmanaged streams (Reeves and Sedell 1992). This study suggests the general trend for the entire Columbia River basin is toward a loss in pool habitat on managed lands and stable or improving conditions on unmanaged lands. Water quality (i.e., temperature, turbidity) may also be reduced in many of the managed streams.

Fish habitat conditions in river basins surveyed in the Mid-Columbia region appear to be recovering to some extent from past land management practices. In contrast, fish habitat conditions in the Blue Mountain region declined significantly over the past 5 decades. A possible explanation is the differing land management history documented for the two regions. Minimal human disturbance affected the surveyed portions of the Mid-Columbia region from the 1930s to the 1970s, while the opposite occurred in the river basins of the Blue Mountain region. The cumulative effects of land management practices have exacerbated or magnified the effects of any one factor operating in isolation.

The historical records show that during early Euro-American settlement (1850 to 1930), these two regions experienced similar land-use histories. During this period the major influence on stream ecosystems is attributed to livestock grazing. Sheep grazed the high meadows while cattle grazed the floodplains in numbers that far exceeded the capacity of the range (Platts 1991, US EPA 1990). Anecdotal reports and photographs depict summer ranges so heavily stocked with sheep, they look like snow drifts. The legacy of this period is still evident throughout the eastern Oregon and Washington as witnessed by the terraced hillslopes caused by the constant trodding of millions of hoofs through the decades.

Although livestock use has declined since the 1930s, concern for aquatic ecosystems increased with the shift from sheep to cattle. In general, cattle can have a greater effect on streamside areas than sheep (Platts 1991, Wissmar *et al.* 1994b). Although improved rangeland conditions tended to occur in the upland areas, little improvement was noted in riparian areas. For a more detailed discussion on range conditions and the influences of grazing on riparian ecosystems see Platts (1991) and Wissmar *et al.* (1994b).

With the decline of the livestock industry in the 1930s, the similarity in land-use histories for the two regions ended. The Blue Mountain region was along the main migration route to the Pacific Northwest (e.g., Oregon Trail), which caused this area of Oregon to be developed more rapidly. The Mid-Columbia region was relatively isolated. As the livestock industry throughout eastern Oregon and Washington declined, the timber industry began to expand in eastern Oregon. Demand for timber was the result of expanding railroads and growing populations. The timber industry boomed after World War II, steadily increasing to the present. Local economies in eastern Oregon have been dominated by timber since.

Recent research (Mullan *et al.* 1992, Wissmar *et al.* 1994b) suggests that the land-use history in the Mid-Columbia region differed from that west of the Cascades and in the Blue Mountain region, where land-use patterns appeared to have different influences on riverine ecosystems. As livestock grazing declined, development pressures were concentrated in the larger river valleys (e.g., Yakima and Wenatchee), where irrigated agriculture became the economic base. Headwater and tributary portions of the basins were minimally affected. This pattern corresponds with land allocations on the Wenatchee and Okanogan national forests; more than 65% of their land base occurs in wilderness or roadless areas. Human activities increased in the upper portions of the basins as timber harvest and road construction began in the late 1950s. These activities shifted over time from selective harvest to clearcutting. Since the 1970s, timber harvest increased throughout the Mid-Columbia region (Wissmar *et al.* 1994b).

The period of reduced human development (1930-1970s) in the tributary portions of Mid-Columbia basins, followed by much later entry for timber harvest, may explain the trend toward increased pool habitat. Pool frequencies were the same for managed (2.2 pools/km) and unmanaged (2.0 pools/km) watersheds in the BOF surveys. In the current surveys, the increases were twice as great in the unmanaged (5.9 pools/km) than in managed (4.1 pools/km) watersheds. The data suggest that unmanaged systems may be more structurally intact (i.e., CWD, habitat diversity, riparian vegetation), allowing a positive interaction with the stream processes (i.e., peak flows, sediment routing) that shape and maintain high-quality fish habitat over time.

Although the trends toward increased pool habitat in the Mid-Columbia region are encouraging, poor fish habitat conditions remain in many managed watersheds. High water temperatures, inadequate stream flows, and high levels of fine sediments have been documented in many managed watersheds, especially in the Yakima basin (Fast *et al.* 1991, Northwest Power Planning Council 1989, Smith 1993). Given the late entry for timber harvest, fish habitats may not be expressing the cumulative effects of harvest activities of the past 20 yrs. Protecting stream ecosystems should be a management priority to continue these improving trends.

Our data suggest that fish habitats are in better condition in the Mid-Columbia than in the Blue Mountain region. This conclusion is further strengthened by the stable condition of most anadromous runs in the Mid-Columbia region (Mullan *et al.* 1992, Nehlsen *et al.* 1991, The Wilderness Society 1993). In contrast, most anadromous runs in the Blue Mountain region are listed by ESA or are identified as stocks at varying degrees of risk by Nehlsen *et al.* (1991) or The Wilderness Society (1993). The exception is summer steelhead in the Grande Ronde, which is identified as stable (The Wilderness Society 1993). Anadromous runs to both regions are subjected to the effects of 8 to 10 mainstem Columbia River dams.

Conclusions

From these snapshots over time, it is apparent that the response of fish habitat to differing natural and human-induced disturbances varies greatly. Although precise, quantifiable relationships between long-term trends in fish abundance and land-use practices are difficult to obtain (Bisson *et al.* 1992), the body of literature concludes that land-use practices cause the simplification of fish habitat (Hicks *et al.* 1991, Bisson *et al.* 1992, Meehan 1991)

The conclusions of this paper must be viewed with caution. A broad regional overview of this nature can fail to identify known areas of concern. A few anadromous stocks in the Mid-Columbia region are at risk, especially steelhead (Mullan *et al.* 1992, Nehlsen *et al.* 1991, The Wilderness Society 1993). Alternatively, *most* anadromous runs to the Mid-Columbia region are stable (Mullan *et al.* 1992, The Wilderness Society 1993). In the Blue Mountain region, few anadromous runs are stable; most are severely depressed and declining (Nehlsen *et al.* 1991, The Wilderness Society 1993). The results of this study suggest that this difference may be due to better habitat conditions in the Mid-Columbia region.

Strategies to protect and restore anadromous and resident fish habitat must be based on a watershed approach that protects the remaining habitat and restores historical habitats (Johnson *et al.* 1991, Reeves and Sedell 1992, USDA 1993). The Forest Service is currently developing such a strategy (PACFISH) to be applied across the range of anadromous salmonids throughout the western United States (USDA Forest Service 1992b). Management plans addressing forest health in eastern Oregon and Washington must explicitly incorporate a watershed strategy that recognizes the critical linkages between the uplands, riparian areas, fish habitat, and fish populations. Land management activities that contributed to the forest health problem (i.e., selective harvest and fire suppression) have had an equal or greater effect on aquatic ecosystems. If we are to restore and maintain high-quality fish habitat, then protecting and restoring aquatic *and* terrestrial ecosystems is essential.

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