United States
Department of
Agriculture

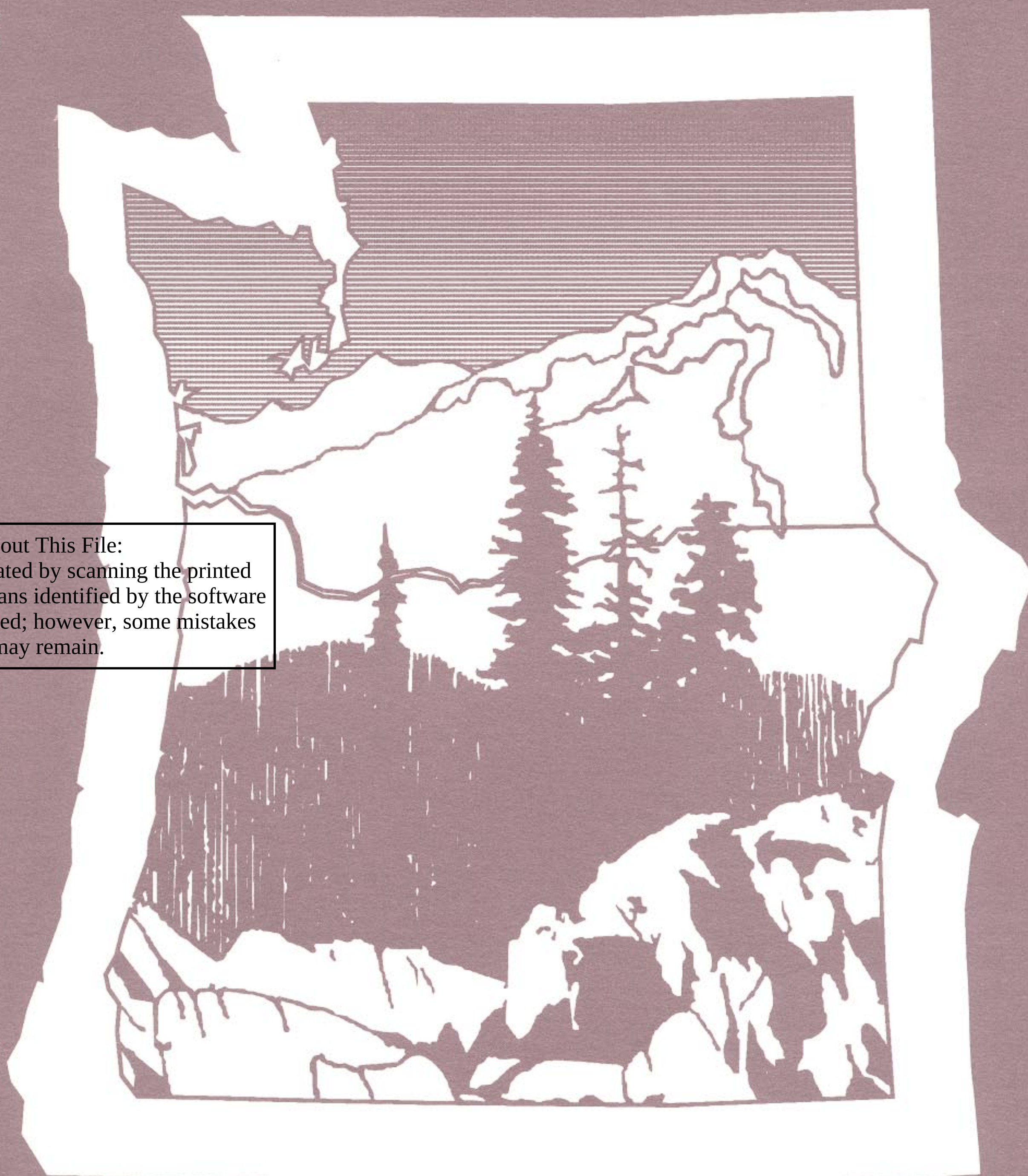
Forest Service

Pacific Northwest
Research Station

General Technical
Report
PNW-GTR-321
February 1994

Management History of Eastside Ecosystems:
Changes in Fish Habitat Over 50 Years, 1935 to 1992

Bruce A. McIntosh, James R. Sedell, Jeanette E. Smith, Robert C. Wissmar, Sharon E. Clarke, Gordon H. Reeves, and Lisa A. Brown



AUTHORS

Bruce A. McIntosh is a faculty research assistant at Oregon State University in Corvallis, Oregon. James R. Sedell is a research aquatic ecologist for the Pacific Northwest Research Station, U.S. Department of Agriculture, Forest Service at the Forestry Sciences Laboratory in Corvallis, Oregon. Jeanette E. Smith is a research assistant in the School of Fisheries at the University of Washington in Seattle, Washington. Robert C. Wissmar is a professor of aquatic ecology in the School of Fisheries and Center for Streamside Studies at the University of Washington in Seattle, Washington. Sharon E. Clarke is a faculty research assistant in the Department of Forest Science at Oregon State University in Corvallis, Oregon. Gordon H. Reeves is a research fisheries biologist for the Pacific Northwest Research Station, U.S. Department of Agriculture, Forest Service at the Forestry Sciences Laboratory in Corvallis, Oregon. Lisa Brown is a research assistant in the Department of Fisheries at Oregon State University in Corvallis, Oregon.

Management History of Eastside Ecosystems: Changes in Fish Habitat Over 50 Years, 1935 to 1992

Bruce A. McIntosh, James R. Sedell, Jeanette E. Smith, Robert C. Wissmar, Sharon E. Clarke, Gordon H. Reeves, and Lisa A. Brown

From Volume III: Assessment

Paul F. Hessburg, Science Team Leader and Technical Editor

Eastside Forest Ecosystem Health Assessment

Richard L. Everett, Assessment Team Leader

Published by:
U.S. Department of Agriculture, Forest Service
Pacific Northwest Research Station
General Technical Report PNW-GTR-321
February 1994

In cooperation with:
U.S. Department of Agriculture, Forest Service
Pacific Northwest Region

ABSTRACT

McIntosh, Bruce A.; Sedell, James R.; Smith, Jeanette E.; Wissmar, Robert C.; Clarke, Sharon E.; Reeves, Gordon H.; Brown, Lisa A. 1994. Management history of eastside ecosystems: changes in fish habitat over 50 years, 1935 to 1992. Gen. Tech. Rep. PNW-GTR-321. Portland, OR: U.S. Department of Agriculture, Forest Service, Pacific Northwest Research Station. 55 p. (Everett, Richard L., assessment team leader; Eastside forest ecosystem health assessment; Hessburg, Paul F., science team leader and tech. ed., Volume III: assessment.)

From 1934 to 1942, the Bureau of Fisheries surveyed over 8000 km of streams in the Columbia River basin to determine the condition of fish habitat. To evaluate changes in stream habitat over time, a portion of the historically surveyed streams in the Grande Ronde, Methow, Wenatchee, and Yakima River basins were resurveyed from 1990 to 1992. Streams were chosen where the primary impacts were natural disturbance (unmanaged), such as wilderness and roadless areas, and where human impacts (managed) were the major disturbances. In addition, historical changes in land-use, stream-flow, and climate regimes were also analyzed. Many of these streams had been degraded from land-use activities (riparian timber harvest, splash dams, stream channelization, livestock grazing, and mining) prior to the historical survey. While the general trend throughout the Columbia River basin has been towards a loss in fish habitat on managed lands and stable or improving conditions on unmanaged lands, the data for these four river basins suggest there is a regional pattern to this change. Based on this information, along with data on the status of anadromous fish runs in these basins, fish habitat has shown some improvement from past abuses in eastern Washington, while continuing to decline in eastern Oregon. This appears to be the result of different land-use histories in the two regions. The river basins of eastern Washington apparently had a period of recovery after World War I from past land-use practices, as the impacts of development decreased. In contrast, river basins of eastern Oregon have been affected continuously by land-use practices over the entire development period (1850-present). From this information, it is clear that land-use practices have degraded fish habitat throughout eastern Washington and Oregon. Strategies to protect, restore, and maintain anadromous and resident fish populations and their habitat, must be based on a watershed approach that protects the remaining habitat and restores historical habitats.

Keywords: Anadromous fish, fish habitat, historical changes, land-use practices, pools, restoration, stream-flow.

Contents

INTRODUCTION

The recent listing of Snake River spring/summer Chinook (*Oncorhynchus tshawytscha*) and sockeye salmon (*O. nerka*) under the Endangered Species Act has elevated concern over the continued survival of anadromous salmonids in the Columbia River basin. The American Fisheries Society lists 76 native anadromous salmonid stocks in the Columbia River basin that are at a high or moderate risk of extinction (Nehlsen and others 1991, fig. 1). In addition, Oregon Trout lists over 200 stocks that are already extinct in the Columbia River basin (Nehlsen and others 1991). Adding to this problem is the status of resident fishes, such as bull trout (*Salvelinus confluentus*), which have been listed by the American Fisheries Society as species of special concern throughout their range in Oregon and Washington (Howell and Buchanan 1992, Williams and others 1989).

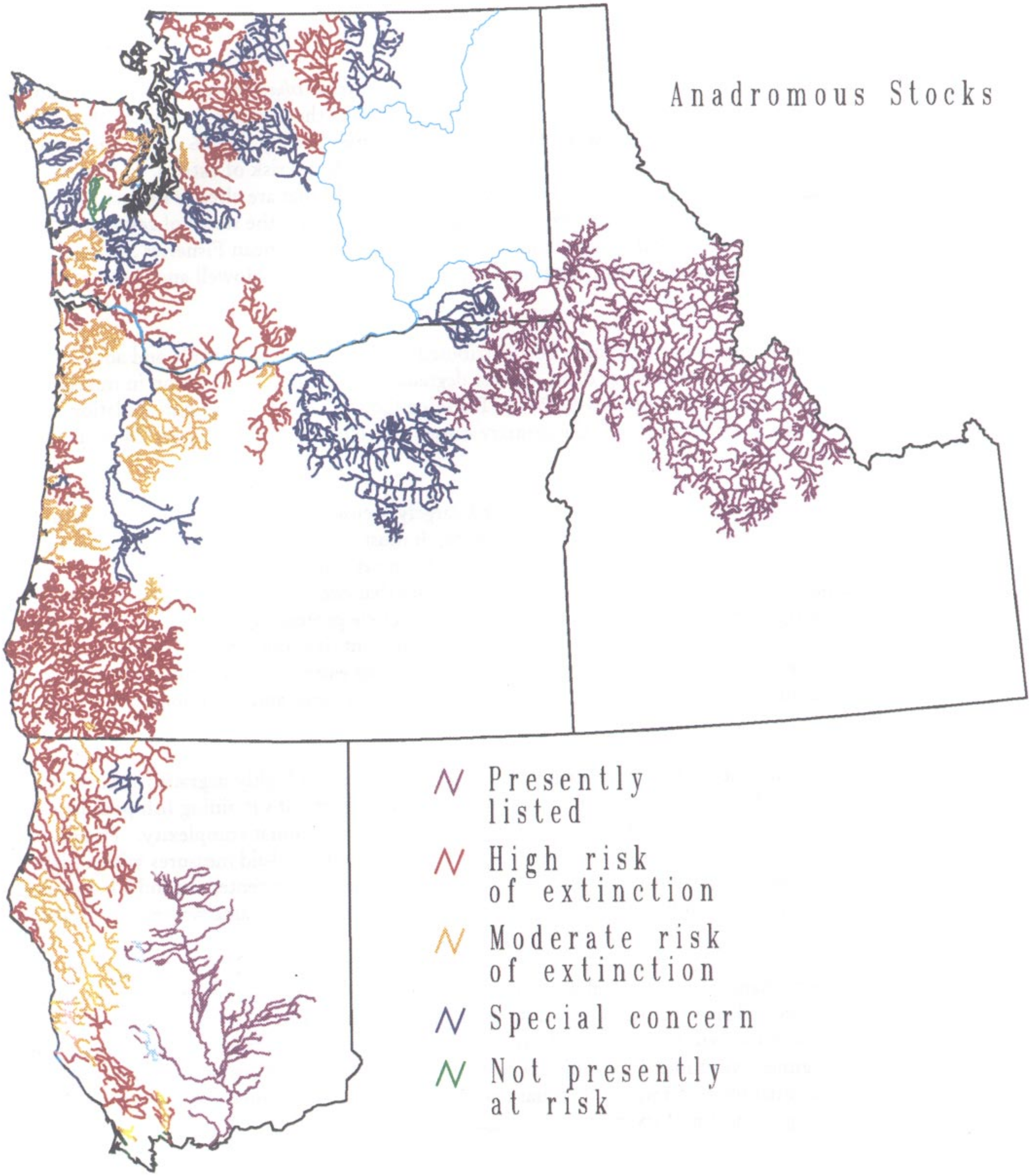
Declines in anadromous salmonid stocks have been attributed predominantly to juvenile and adult mortality from passage through Columbia River dams, habitat degradation, and over exploitation in mixed-stock fisheries (Nehlsen and others 1991, Northwest Power Planning Council 1986). Habitat degradation and the introduction of exotic fishes have been the primary causes of declines in resident fishes (Howell and Buchanan 1992, Williams and others 1989).

The question of forest health, as it is generally perceived, largely focuses on the issue of dead and dying trees. To transcend this perception, management and research must begin to frame the picture of forest health as one of watershed health. Because resident and anadromous fish stocks are at risk throughout the Columbia River basin, research must begin to link the processes that occur along the interfaces between the uplands and the riparian zone (Gregory 1991). The issues include protecting, maintaining, and restoring riparian vegetation, large woody debris, nutrient cycling, sediment dynamics, habitat complexity, water quantity, and water quality. If prescriptions aimed at restoring eastside forests fail to recognize and protect these critical linkages and processes, the health of stream ecosystems and fish populations is sure to continue to decline.

Streams in managed watersheds of eastern Oregon and Washington are in a highly degraded state relative to unmanaged systems. To restore fish habitat to a state that will support self-sustaining fish populations, these streams are in need of less fine sediment, more shade, and increased habitat complexity. Traditional approaches to stream restoration, such as in-stream structures, are at best band-aid measures with a high degree of uncertainty for improvement. To ensure success, management must center around a long-term, holistic approach that protects and maintains ecological processes at the scale of large watersheds (Naiman and others 1992).

This paper documents changes in stream habitat over the past 50 years and examines the current condition of stream habitat in selected river basins of eastern Oregon and Washington. In reviewing changes in stream habitat, we also surveyed, with varying degrees of specificity, changing patterns of land-use, streamflow, and climate regimes over time. From this overview, we identified watersheds with high-quality fish habitat or a high potential for restoration. Wissmar and others (1993, this volume) give a more general overview of the ecological health of river basins throughout the eastside.

Figure 1 (next page). Status of anadromous fish stocks in the Western United States (Pacific Northwest Research Station 1992; based on Frissell 1990; Johnson and others 1991; and Nehlsen and others 1991).


Anadromous Stocks
Presently listed
High risk of extinction
Moderate risk of extinction
Special concern
Not presently at risk

CHANGES IN FISH HABITAT IN SELECTED EASTSIDE RIVER BASINS OVER THE PAST 50 YEARS

A series of reports published from 1949-1952 by the U.S. Fish and Wildlife Service are the primary basis for current estimates of the loss of anadromous fish habitat in the Columbia River basin. The reports were brief, qualitative accounts of over 8000 km of stream surveys conducted by the Bureau of Fisheries from 1934-46 (Bryant 1949; Bryant and Parkhurst 1950; Fulton, 1968, 1970; Northwest Power Planning Council 1986; Parkhurst 1950a, 1950b, 1950c, Parkhurst and others 1950; Thompson 1976).

The Bureau of Fisheries surveys were undertaken with the objective of determining the condition of streams in the Columbia River basin that provided, or had provided, spawning and rearing habitat for salmon and steelhead (Rich 1948). Recently, the original field notes from the Bureau of Fisheries surveys were discovered. The data are now being archived and stored in the Forest Science DataBank at Oregon State University. These records are the earliest and most comprehensive documentation available on the condition and extent of anadromous fish habitat in the Columbia River basin. They provide the best available data for quantifying change and setting benchmarks for future restoration of anadromous fish habitat throughout the basin.

The Pacific Northwest Research Station has been using the Bureau of Fisheries surveys, in conjunction with current surveys, to determine how the condition of stream habitat in the Columbia River basin has changed over the past 50 years. The Pacific Northwest Research Station study, conducted from 1987 to the present, has examined streams across a broad range of geological conditions, land ownerships, and land-use histories (McIntosh 1992, Sedell and Everest 1990).

More than 1500 km of streams throughout the Columbia River basin have been examined. Preliminary results indicate that the frequency of large pools ($\geq 20\ m^2$ and ≥ 1.0 m deep) in streams within managed watersheds decreased by 28 percent over the past 50 years (table 1). Considerable variability was found in the magnitude and direction of change between basins, but pool habitat has decreased. Over the same period, the frequency of large pools has increased in unmanaged watersheds by 77 percent (table 2). The direction for all unmanaged watersheds surveyed was towards improved habitat. Pool loss in managed watersheds, while pools have increased in unmanaged watersheds, indicates that land management activities, such as logging, road construction, livestock grazing, and agricultural practices, have caused this decrease in pools.

Pools and substrate composition are important to anadromous salmonids for all phases of their freshwater life. Pools provide rearing habitat for juvenile fish, resting habitat for adult fish before spawning, and refugia for adults and juveniles from catastrophic events such as drought, fire, and winter-icing (Sedell and others 1990). Substrate composition affects the quantity and extent of spawning habitat, provides summer and winter cover for juvenile fish, and influences aquatic biological production. A considerable body of literature has demonstrated the detrimental effect of fine sediments on salmonid reproduction (for review, see Chapman 1988, Everest and others 1987).

Changes in the pool and substrate composition of stream habitat are also a biodiversity issue. Research on Oregon coastal streams (Reeves and others 1993) has shown that species diversity in logged basins was lower than in similar streams in unharvested basins. The loss of stream habitat diversity from land-use practices has altered fish community composition and reduced species diversity (Bisson and Sedell 1984, Bisson and others 1992, Reeves and others 1993).

For this paper, we will use the Bureau of Fisheries survey to determine changes in fish habitat in four river basins of eastern Washington and Oregon. The Yakima, Wenatchee, and Methow River basins of Washington, will be examined, along with the Grande Ronde River basin in Oregon. We will also evaluate the current level of large woody debris in resurveyed streams.

Table 1. Changes in the frequency of large pools (20 m2 area and 1.0 m deep) for managed portions of selected river basins in the Columbia River Basin from 1935 to 1992.

Frequency of large pools				
	Kilometers surveyed	1935-1945 #/km	1987-1992 #/km	Percent change
Tucannon River, WA	83.8	1.8	4.9	172%
Yakima River, WA	65.5	1.8	3.8	111%
Methow River, WA	146.1	1.8	3.5	94%
Wind River, WA	57.0	4.7	7.9	68%
Abernathy Creek, WA	13.4	3.8	6.1	61%
Wenatchee River, WA	33.6	4.9	7.7	57%
Lewis River, WA	7.7	6.6	9.1	38%
Coweeman River, WA	42.5	5.2	6.6	27%
Elochoman River, WA	34.6	7.7	7.7	NC
Grays River, WA	33.3	8.8	7.7	-13%
Clatskanie River, OR	24.9	7.0	5.9	-16%
Asotin Creek, WA	41.8	2.8	1.8	-36%
Cowlitz River, WA	87.1	13.6	8.1	-40%
Salmon River, ID	185.9	8.8	5.0	-43%
Willamette River, OR	232.3	9.0	4.1	-54%
Lewis and Clark River, OR	16.7	10.3	4.4	-57%
Clearwater River, ID	8.4	4.8	1.7	-65%
Grande Ronde River, OR	157.9	6.1	2.1	-66%
Total	1273.0	7.2	5.2	-28%

Table 2. Changes in the frequency of large pools (20 m2 area and 1.0 meter deep) for wilderness or unmanaged portions of selected river basins in the Columbia River Basin, from 1935 to 1992.

Frequency of Large Pools

	Kilometers Surveyed	1935-1945 #/km	1987-1992 #/km	Percent Change
Willamette River, OR	1.6	2.5	12.4	396%
Methow River, WA	30.2	1.0	3.4	240%
Wenatchee River, WA	80.2	2.5	6.4	156%
Yakima River, WA	18.8	1.6	3.9	144%
Salmon River, ID	134.2	5.3	6.8	28%
Total	265.0	3.9	6.9	77%

Changes in fish habitat in streams of eastern Oregon and Washington are very similar to the results for the Columbia River basin as a whole. At the time of the Bureau of Fisheries survey, pools were nearly twice as frequent in managed as in unmanaged systems. Currently, the opposite is true. Streams that were recently surveyed in managed watersheds have lost 31 percent of their large pools, and the corresponding figure for unmanaged watersheds is a threefold increase (fig. 2, table 3). Current U.S. Department of Agriculture, Forest Service standards for pools are listed in table 4 (U.S. Department of Agriculture Forest Service 1991). Few of the streams surveyed meet these standards. In the following sections, we will examine the changes in individual river basins to better illustrate these changes.

Figure 2 (next page). Regional pattern of changes in large pool frequencies for selected river basins of eastern Oregon and Washington.

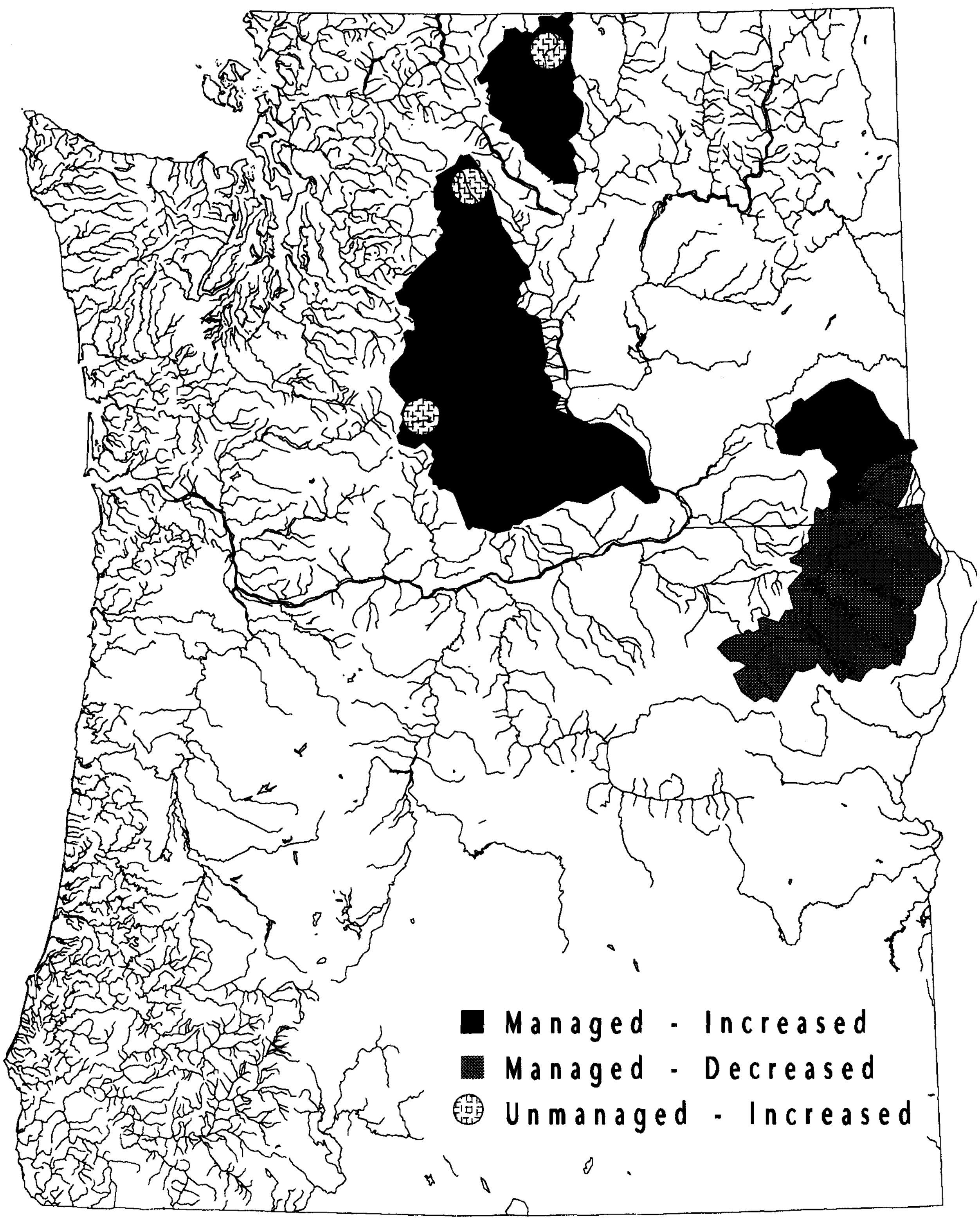

Managed - Increased
Managed - Decreased
Unmanaged - Increased

Table 3. Changes in the frequency of large pools in managed and unmanaged portions of selected river basins in eastern Washington and Oregon.

Frequency of Large Pools	Kilometers Surveyed	1935-1945 #/km	1987-1992 #/km	Percent Change
MANAGED BASINS				
Tucannon River, WA	83.8	1.8	5.0	178%
Methow River, WA	146.0	1.7	3.4	100%
Yakima River, WA	67.7	1.9	3.2	68%
Wenatchee River, WA	33.6	4.9	7.7	57%
Asotin Creek, WA	41.8	2.8	1.8	-36%
Grande Ronde River, OR	157.9	6.1	2.1	-66%
Total	530.8	4.2	2.9	-31%
Frequency of Large Pools				
	Kilometers Surveyed	**1935-1945 #/km**	**1987-1992 #/km**	**Percent Change**
UNMANAGED BASINS				
Methow River, WA	30.3	1.0	3.4	240%
Wenatchee River, WA	80.0	2.5	7.5	200%
Yakima River, WA	18.8	1.6	3.9	144%
Total	129.1	2.0	6.0	200%

Table 4. U.S. Forest Service standards for large pools in Region 6

A) Alluvial gravel or low gradient streams (<2%)

standard - streams will have one or more primary poolsa every 5 to 7 bankfull channel widths.

B) Boulder-rubble or moderately steep gradient streams (>3%).

standard - streams will have one or more primary pools [a] every 3 bankfull channel widths.

[a] = primary pools occupy 50 percent of the low flow channel width and have a maximum depth 0.9 m

Current Levels of Large Woody Debris for Selected River Basins of Eastern Oregon and Washington

The scientific community generally agrees on the functional role of large woody debris in creating and maintaining high quality fish habitat (Bisson and others 1987, Everest and others 1987, Gregory and Ashkenas 1990, Hicks and others 1991, MacDonald and others 1991. Large woody debris serves a wide array of physical and biological functions in stream ecosystems, which include providing cover and habitat complexity for fish, sediment storage, in-channel roughness, reducing the erosional effects of high flows, and enhancing pool development and maintenance. Many studies have shown that the loss of large woody debris reduces salmonid production (Bisson and others 1987, Everest and others 1985, MacDonald and others 1991.

Unfortunately, the Bureau of Fisheries survey did not collect data on large woody debris for comparison with the current surveys. We collected data that quantifies the number of pieces of large woody debris in a given stream and how it is arrayed, that is: Does it occur as single pieces or as aggregations (≥ 2 pieces)? The survey results indicate that the frequency of large woody debris and debris complexes is about 50 percent greater in unmanaged streams than in managed streams (table 5). Current standards for the Forest Service, Pacific Northwest Region, require more than 60 pieces of large woody debris/km (≥ 0.3 m and ≥ 11.0 m length) in eastside streams. Given that the minimum size for large woody debris in the resurveys is much smaller (≥ 0.1 m diameter and ≥ 2.0 m length) than the regional standard, the resurveys are an overestimate of large woody debris relative to current standards. This further illustrates how little large woody debris is in managed streams.

Table 5. Current amounts of large woody debris (LWD, > 0.1 m diameter and 2.0 m length) in selected managed and unmanaged river basins of eastern Oregon and Washington

Managed Streams	LENGTH (KM)	LWD (#/KM)	LWD COMPLEXES (#/KM)
Grande Ronde Basin	148.7	40.0	5.9
Yakima River Basin	8.1	32.8	5.8
Wenatchee River Basin	33.6	26.7	3.5
Methow River Basin	146.1	69.2	12.3
TOTAL	336.5	MEAN 42.2	6.9
Unmanaged Streams	**LENGTH (KM)**	**LWD (#/KM)**	**LWD COMPLEXES (#/KM)**
Yakima River Basin	18.8	72.7	13.8
Wenatchee River Basin	80.0	72.5	11.9
Methow River Basin	30.3	40.2	8.1
TOTAL	129.1	MEAN 61.8	11.3

The frequency of large woody debris has decreased in managed systems because of extensive debris removal programs initiated in the 1950s and continued into the 1980s, along with riparian timber harvest (Sedell and others 1991). In addition, the recruitment of large woody debris in managed streams has been greatly reduced by past and present riparian timber harvest. Analysis of current forest practices rules in Oregon and Washington suggest that the future recruitment will decrease with each succeeding rotation (Heimann 1988, Oregon Department of Forestry 1992). The reduction of large woody debris in managed systems contributes to decreased habitat complexity and cover, higher stream temeratures, reduced sediment storage and routing capabilities, and the instability of stream channels and floodplains.

Changes in Fish Habitat-Grande Ronde River Basin, Oregon

In 1990, more than 150 km of streams were resurveyed in the Upper Grande Ronde River basin for comparison with the historical surveys (McIntosh 1992). This survey included more than 70 km of the Grande Ronde River and all major tributaries that provide habitat for spring Chinook. From these surveys, McIntosh (1992) documented a loss of more than 65 percent in pool habitat in the Upper Grande Ronde River basin, along with high levels of fine sediments throughout Chinook salmon spawning habitat. This work has provided the Pacific Northwest Research Station with its most in-depth overview of the change in anadromous fish habitat in the Columbia River basin.

At the time of the 1941 Bureau of Fisheries survey, the Upper Grande Ronde River basin had experienced considerable human-induced disturbance. The available records of land-use history for the Upper Grande Ronde River basin were examined to characterize and quantify, where possible, land-use practices before and after the 1941 survey. These included records of timber harvest, road construction, and livestock grazing, from various sources. In addition, to provide an overview of land-use practices, more general information on insect outbreaks, splash dams, and mining was also studied and incorporated.

Study Area-The Upper Grande Ronde River basin, in the extreme northeast corner of Oregon, encompasses an area of about 3000 km^2 (fig. 3). A major tributary of the Snake River, the basin extends 342 km from the headwaters to the mouth; it is characterized by two major drainages, the Grande Ronde River and Catherine Creek.

About 50 percent of the Upper Grande Ronde River basin, mostly mountainous and timbered, is public land managed by the Forest Service. The valley bottoms are predominantly private land used mainly for livestock grazing and agriculture.

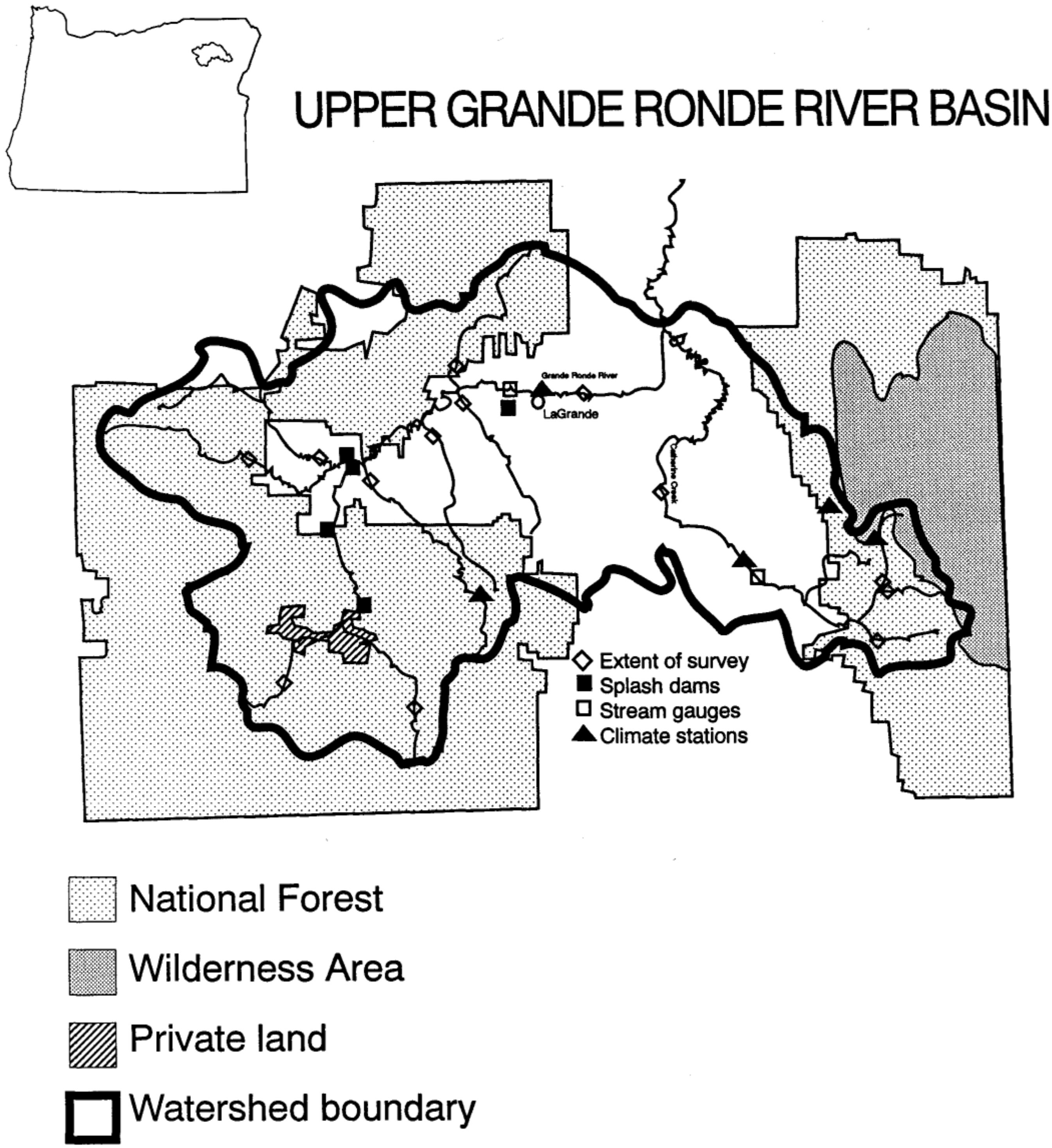
Historically, the Upper Grande Ronde River basin had large runs of anadromous salmonids. The basin supported large runs of spring Chinook, and summer steelhead (*O. mykiss*) (Northwest Power Planning Council 1990). These fish stocks have been reduced to a small fraction of their predevelopment numbers, with spring Chinook listed as threatened under the Endangered Species Act. The declines in productivity have been attributed primarily to juvenile and adult mortality from passage through Columbia River dams, habitat degradation, and over exploitation of mixed-stock fisheries (Northwest Power Planning Council 1986). Within the basin, habitat degradation, both in-channel and riparian, with the attendant high summer and low winter water temperatures is considered the most serious problem. The causes are believed to be stream channelization, livestock grazing, road building, timber harvest, and mining (James 1984, Northwest Power Planning Council 1990, Oregon Department of Fish and Wildlife 1987).

Land use history: mining-Among the first effects of Euro-Americans to the upper Grande Ronde River basin was mining. The headwaters of the basin have been mined for gold since 1870, with extensive dredge mining in the early 1900s. Throughout the headwaters, gold mining has significantly altered the river and its floodplain. Extensive mine tailings from dredging occur throughout the upper sections, constricting the channel and providing a continuous source of sediment. When this section was surveyed in 1941, the surveyors noted that:

> *The operations of the Indiana Mine have certainly raised havoc with the upper portions of the river. In a great many instances the river is present in sound only. It was possible, at the time of the survey, to drive a car up the middle of the stream bed. What was left of the river was flowing, out of sight, underneath the rubble. Dredging and filling has put the rubble on top of the water. At any rate they have left a monument that will remain a dirty blot on the landscape for years to come.*
>
> (field notes from 1941 Bureau of Fisheries survey).

Ironically, because the tailings are a part of a national historic site, they are off-limits to alteration or channel rehabilitation. At the same time, this reach of the river also provides the majority of the spring Chinook spawning habitat in the upper Grande Ronde.

Figure 3 (next page). Upper Grande Ronde River Basin, Oregon.



Drainage area: 3000 km^2 (1150 mi^2)

Livestock grazing-Early records of livestock grazing in the Upper Grande Ronde basin suggest that the area had been overgrazed by the 1880s (Skovlin 1991). Records of actual grazing use were available from the Wallowa-Whitman National Forest, covering the period 1911 to 90. Over that period, grazing use by domestic livestock (cattle and sheep) declined 78 percent (fig. 4), largely from the collapse of the sheep industry in northeast Oregon (J. Anderson, pers. comm.). Cattle grazing now constitutes more than 90 percent of grazing use from domestic livestock.

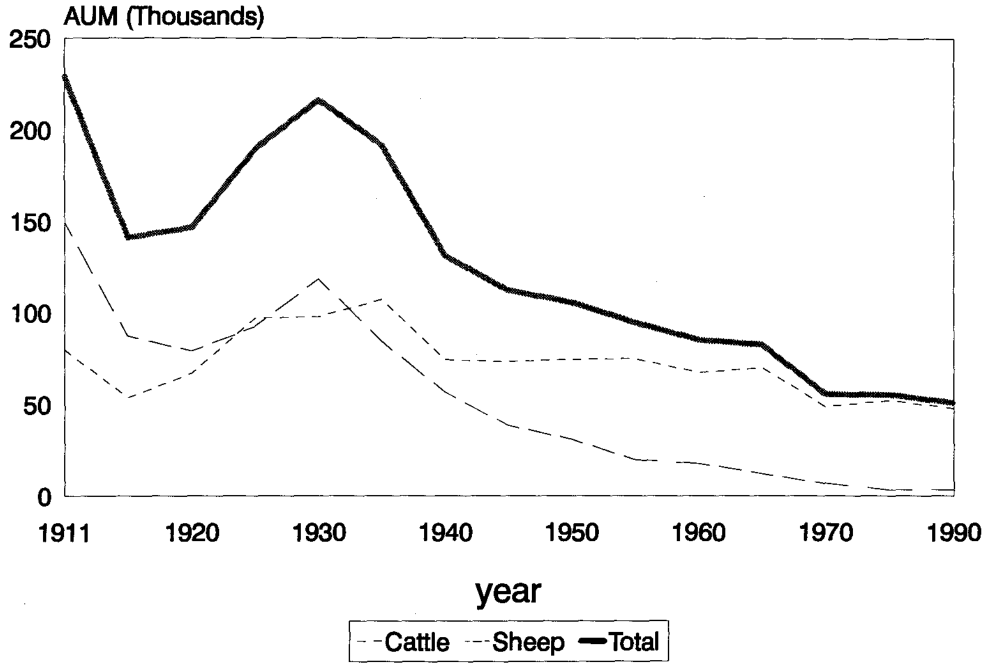


Figure 4. Grazing use (animal unit month) by livestock on the Whitman portion of the Wallowa-Whitman National Forest, 1911 to 1990.

While grazing by domestic livestock has been declining, grazing use by elk appears to have increased. Elk populations were very low during the early part of the century because of overhunting. In 1919, elk hunting was closed and intensive efforts were begun to rebuild the herds. Records of grazing use by elk began to be kept in 1965. Data before that is based on estimates. These countervailing trends suggest that grazing intensity has stayed fairly constant since 1945 (fig. 5), although the effects of livestock and elk grazing may be different.

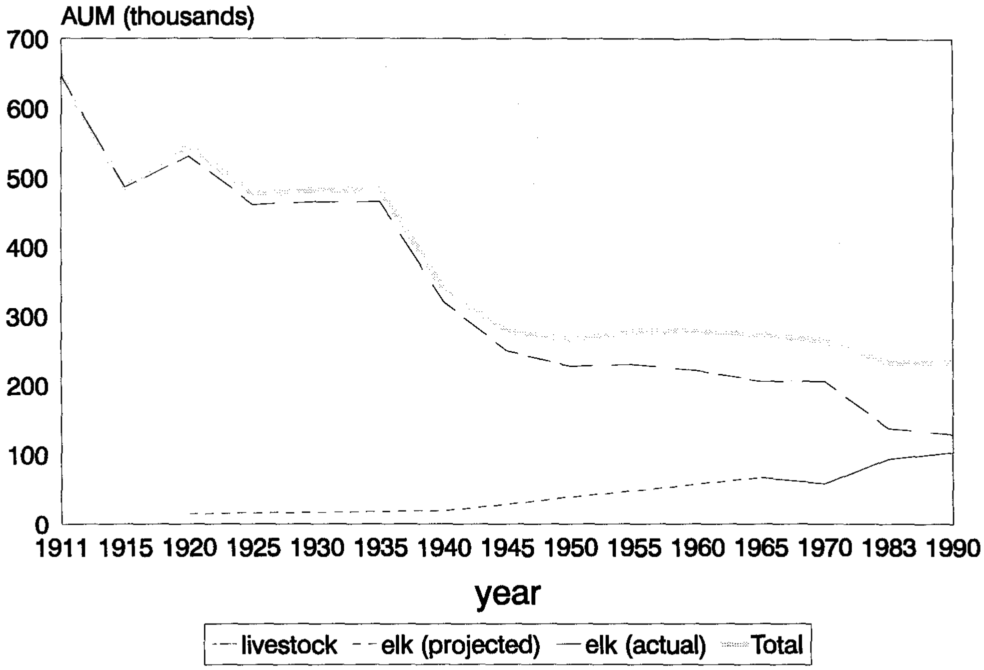


Figure 5. Grazing use (animal unit month) by livestock and elk on the Wallows-Whitman National Forest, 1911 to 1988.

Timber harvest-The historical records of timber harvest in the Upper Grande Ronde River basin, indicate that logging began in the late 1880s (Farnell 1979). Harvest rates have varied from 1896 to 1990, but show a steadily increasing trend (fig. 6). Timber harvest averaged 36 million fbm/year before the 1941 survey (1896 to 1940) and increased to 98 million fbm/year from 1941 to 90, an increase of 172 percent. Although harvest rates have increased over time, the spatial patterns of harvest must also be considered. Ownership patterns (fig. 3) show that the Forest Service manages higher elevation and headwater portions of the basin, and the lower elevations are private land. Harvest in the early part of the century was restricted to riparian areas and the adjacent hillslopes. In the latter part of the century, higher elevation and headwater sections of the basin were accessed and logged as road construction increased.

In the early 1900s, logging was largely limited to private lands in the basin. Before the coming of the railroad and the building of roads, from the late 1800s to 1919, the Grande Ronde River was a major logdriving river. Splash dams were built on the Grande Ronde River at Perry and at Vey Meadows, on Dark Canyon, Meadow, and Fly Creeks (fig. 3) to provide sufficient flow to drive logs at all seasons (Farnell 1979). Splash damming and associated log drives are believed to have had devastating effects on all forms of aquatic life, along with causing considerable damage to the stream channel (Sedell and others 1991).

By 1919, the Union Pacific Railroad had extended its tracks to the upper portions of the basin, encompassing the Grande Ronde River and all the major tributaries. The improved access allowed for more reliable delivery of timber, eliminating the need for splash dams and log drives. As the railroad extended its reach up the basin, more areas became accessible (Farnell 1979). The railroads were used until 1954. Old railroad grades are visible throughout the basin, in most places either adjacent to the stream channel or within the floodplain. These grades serve as artificial geomorphic controls, constraining the stream channel and truncating floodplain processes and functions.

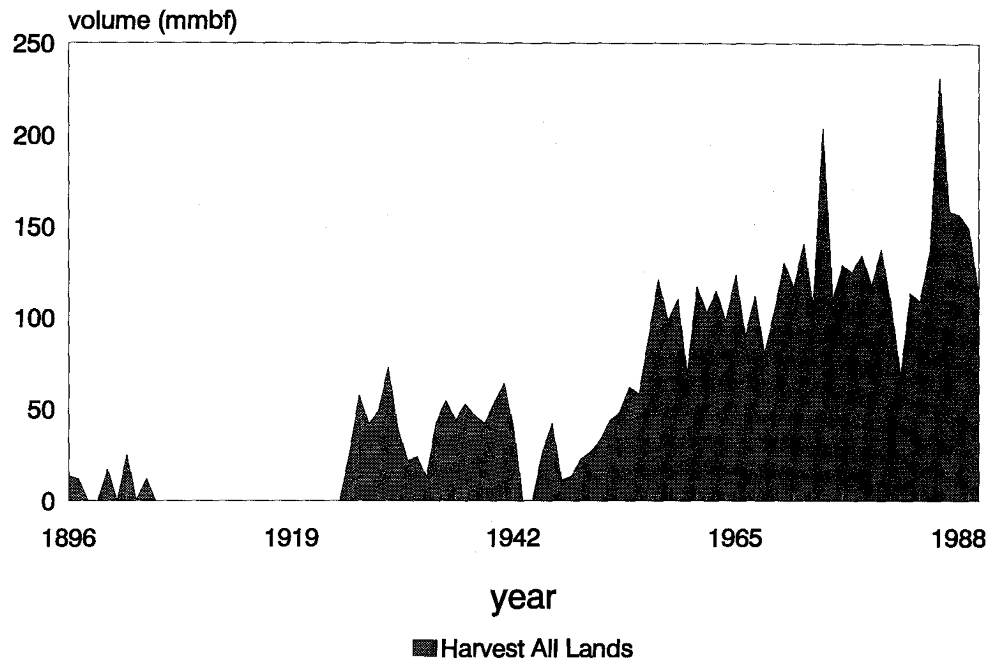


Figure 6. Volume of timber harvested (mmbf) for Union County, Oregon, all land ownerships, 1896 to 1990.

Until the late 1940s, the Forest Service harvested little timber on the Wallowa-Whitman National Forest. In response to insect outbreaks, intensive salvage logging began in the late 1950s. By 1960, harvest was about evenly split between public and private lands. The trend from the 1950s to 1989 has been for increasing rates of timber harvest (fig. 7).

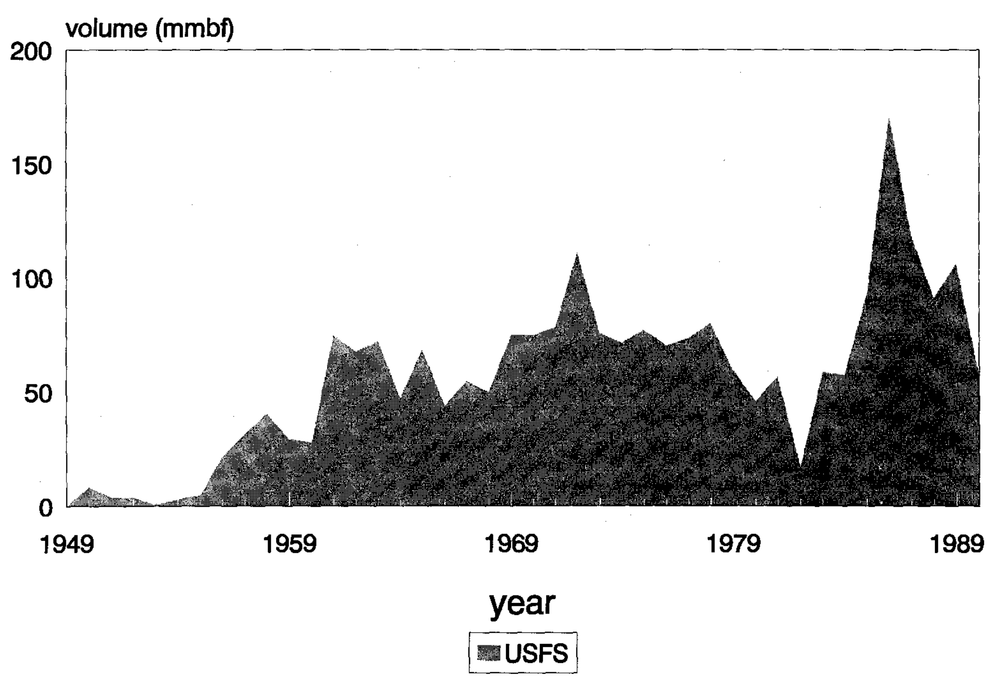


Figure 7. Volume of timber harvested (mmbf) on public land, Union County, Oregon, 1949 to 1989.

Road construction-Road building activities have followed the same pattern as timber harvest (fig. 8). According to Farnell (1979), road construction was minimal until the 1920s because timber was being harvested close to the Grande Ronde River and its tributaries. When the Forest Service began salvage operations in the late 1950s, road building began in earnest. The number of kilometers of roads increased steadily from 1957 to 1978 and, from 1978 to 1989, it more than doubled, from 7200 to 16,000 km. Road densities in the Upper Grande Ronde, as reported by the Wallowa-Whitman National Forest, average 2.5 km/km^2 for the basin and 4.4 km/km^2 when roadless areas are excluded. Along the Grande Ronde and most of its tributaries, roads have encroached upon the channel or the floodplain and have greatly constricted the channel's ability to interact with the floodplain.

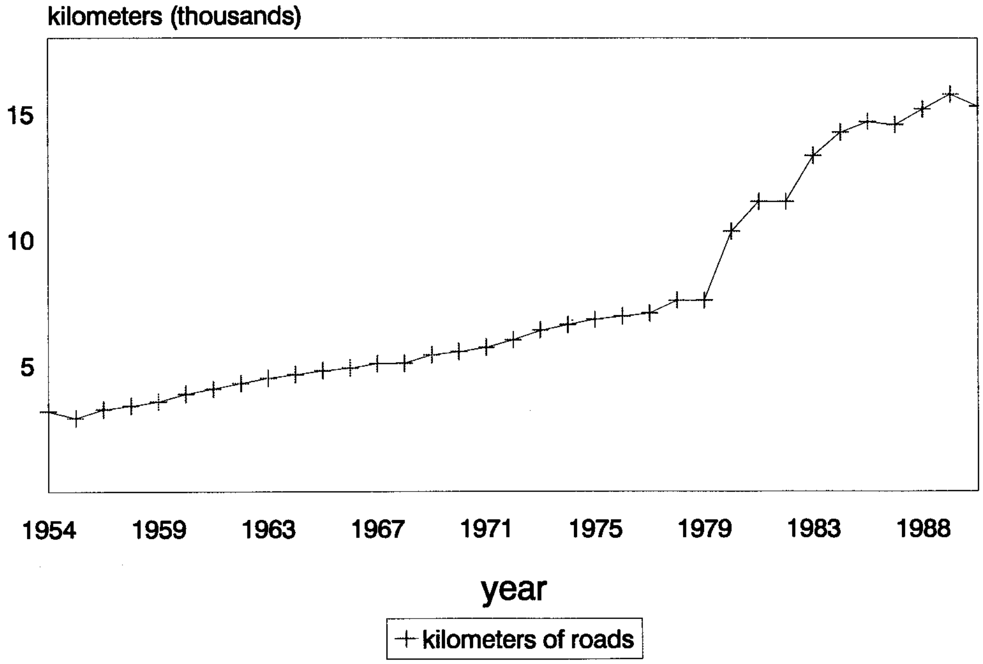


Figure 8. Road mileage (kilometers) on the Wallowa-Whitman National Forest, 1954 to 1990.

Stream channelizatlon-The influences of stream channelization are also evident in the Upper Grande Ronde basin. Stream channelization projects were conducted by the Soil Conservation Service, Bureau of Reclamation, and the Union County Soil and Water Conservation District. The 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.

The McCoy Meadows area in the Upper Grande Ronde is illustrated in figure 9. McCoy Creek was channelized in response to the 1964 flood, as shown in the abrupt transition from the 1964 pre-flood photograph to the 1970 photo. What was once a highly complex and dynamic meadow stream ecosystem has been degraded to a single stream channel, isolated from any interaction with its floodplain. The area above the road (middle of picture) was channelized between 1970 and 1980.

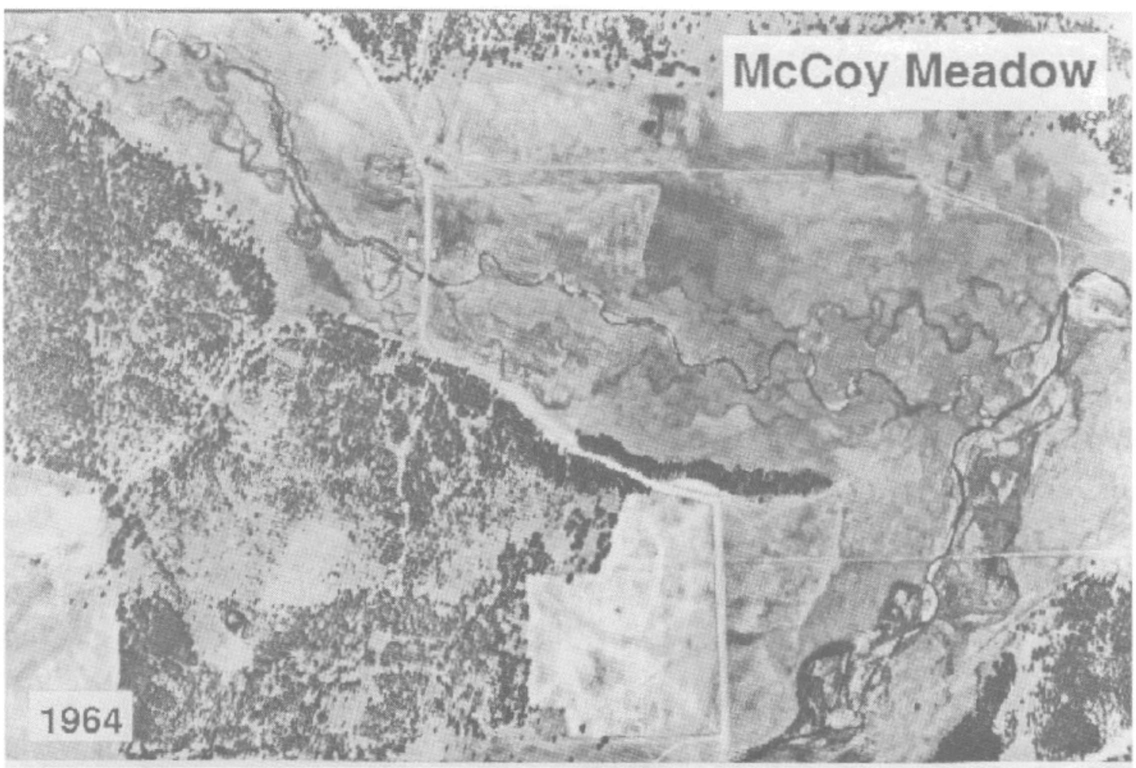


Figure 9. Time sequence of aerial photographs for McCoy Meadows, from 1937-1980, showing the effects of stream channelization.

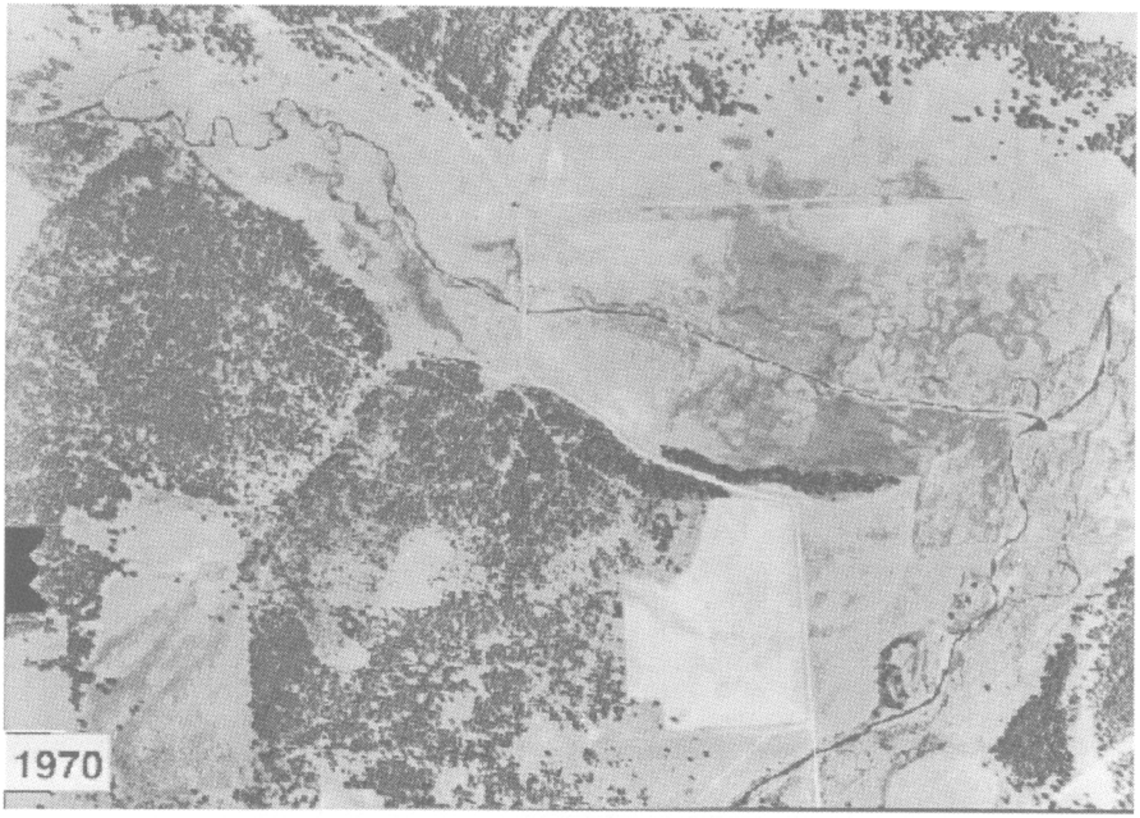


Figure 9. (cont.) Time sequence of aerial photographs for McCoy Meadows, from 1937-1980, showing the effects of stream channelization.

Insects and disease-The history of insect and disease outbreaks and their effect on forest health is well documented for the Blue Mountains of northeast Oregon (Wickman 1991). Repeatedly, over the course of this century, a variety of insects have attacked millions of acres of forestland in northeast Oregon, leaving a landscape suffering declining forest health on what Wickman termed "a mega scale."

Changes in fish habitat in the Upper Grande Ronde River basin from 1941 to 1990: pool habitat-Analyses of changes in pool habitat were based on large pools (≥ 20 m^2 area and ≥ 0.8 m depth) and total pools (≥ 20 m^2 area and ≥ 0.5 m depth).

In 1941, the frequencies of total pools/km for the Grande Ronde River and associated tributaries were diverse, ranging from 3.8 to 26.2/km (mean = 12.2/km, table 6). In 1990, pool frequencies ranged from 1.4 to 7.4/km (mean = 4.3/km, table 6). The loss in total pools/km ranged from 43 to 83 percent (table 6), with a mean of 65 percent. One stream, Five Points Creek, stayed the same, but the 1941 survey had indicated that this tributary was already in poor condition at the time of the survey. In 1941, pool frequencies were highly variable among the different streams, but the 1990 survey showed that pool frequencies were similar for all streams.

Table 6. Changes in the frequency of total pools for surveyed streams in the upper Grande Ronde River Basin, 1941 to 1990.

	Kilometers	1941	1990	Percent
Managed Watersheds	Surveyed	#/km	#/km	Change
Five Points Creek	2.8	3.8	3.8	NC
N Fk Catherine Creek	6.6	5.6	3.2	-43%
Rock Creek	2.2	12.0	6.4	-47%
Meadow Creek	18.6	7.3	3.5	-52%
S Fk Catherine Creek	3.3	11.8	4.9	-59%
Catherine Creek	30.7	12.7	4.2	-67%
Jordan Creek	3.1	26.2	7.4	-72%
McCoy Creek	4.7	19.1	5.1	-73%
Grande Ronde River	73.4	6.3	1.4	-78%
Beaver Creek	3.3	16.9	2.8	-83%
TOTAL	**157.9**	**12.2**	**4.3**	**-65%**

Changes in the frequency of large pools showed a pattern similar to the pattern for total pools. In 1941, large pool frequencies ranged from 0.0 to 14.9/km (mean = 6.2/km, table 7). The frequency of large pools ranged from 0.0 to 7.0 (mean = 2.0/km, table 7) in 1990. This frequency represents a loss of large pools from 20 to 87 percent, with a mean of 66 percent. Five Points Creek and Jordan Creek showed no change, and Rock Creek showed a slight improvement (0.0 to 0.9 large pools/km). A substantial decrease occurred in the variability of large pool frequencies from 1941 to 1990, further emphasizing the trend towards less diverse stream habitat.

Substrate composition-The trend in substrate composition in the Upper Grande Ronde River basin was towards finer substrates (table 8). Even in those streams where the dominant substrate did not change, smaller substrates substantially increased (table 9). With the tributaries channeling finer substrates to the main channel, substrate composition is changing throughout the basin. Changes in the size of substrate indicate a shift in the particle size of bedload transported by the stream (Heede 1980).

The analysis of mean substrate composition indicated no change in fine sediments in the Upper Grande Ronde River and substantial decreases in Catherine Creek. To detect changes in the spatial distribution of fine sediments over time, the percentages of surface fines for individual channel units were plotted from the downstream to upstream extent of the Upper Grande Ronde River.

Table 7. Changes in the frequency of large pools for surveyed streams in the Grande Ronde River Basin 1941 to 1990.

	Kilometers	1941	1990	Percent
Managed Watersheds	**Surveyed**	**#/km**	**#/km**	**Change**
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	**157.9**	**6.1**	**2.1**	**-66%**

Table 8. Changes in dominant substrate for surveyed streams in the Grande Ronde River Basin, 1941 to 1990.

Stream	1941 Dominant Substrate	1990 Dominant Substrate	Change
Rock Creek	MR (47%)	MR (35%)	NC
Jordan Creek	MR (48%)	SR (43%)	-
Five Points Creek	MR (43%)	MR (36%)	NC
Meadow Creek	MR (45%)	SR (39%)	-
Catherine Creek	MR (29%)	MR (34%)	NC
N Fk Catherine Creek	MR (35%)	MR (41%)	NC
Grande Ronde River	MR (41%)	SR (39%)	-
McCoy Creek	MR (43%)	MR (45%)	NC
Beaver Creek	MR (46%)	MR (35%)	NC
S Fk Catherine Creek	MR (38%)	LR (38%)	+

MR = medium rubble, SR = small rubble, NC = no change, - = decrease

Table 9. Shift in the percentage of bottom substrate composition for surveyed tributaries of the Upper Grande Ronde River, above La Grande, 1941 and 1990

	1941		1990	1941		1990
Stream	**SR**	**SR**	**Change**	**MR**	**MR**	**Change**
Five Points Creek	21%	33%	+	43%	35%	-
Rock Creek	18%	29%	+	47%	34%	-
Jordan Creek	37%	47%	+	47%	27%	-
Beaver Creek	23%	30%	+	46%	34%	-
Meadow Creek	22%	41%	+	46%	35%	-
McCoy Creek	26%	43%	+	41%	46%	+

SR = small rubble, MR = medium rubble

This spatial analysis indicated that surface fines (MS, < 6 mm) in the headwater portions of the Upper Grande Ronde River exceed 20 percent of the substrate composition throughout most of this reach. Throughout the headwaters, most of the stream channels are highly embedded, generally exceeding current standards of 35 percent (P. Boehne, pers. comm.). Generally, these conditions are recognized as being detrimental to salmonid reproduction (Everest and others 1987). The surface fines detected in the 1990 survey may have been the result of a fire and flash flood event in 1989 that introduced a substantial volume of fine substrates into the stream channel.

Current status of large woody debris-The amount of large woody debris in resurveyed streams varied widely, ranging from 1.0 to 66.0 pieces/km (table 10), with large woody debris generally lacking. In addition, current Forest Service surveys indicate that streams in managed watersheds throughout the upper Grande Ronde have a low frequency of large woody debris, but unmanaged portions of the basin have much higher frequencies (P. Boehne, pers. comm.). The frequency of large woody debris in the upper Grande Ronde is similar to other managed river basins we surveyed on the eastside, but far less than that found in unmanaged systems.

Table 10. Current levels of large woody debris (LWD, ≥ 0.1 m diameter and ≥ 2.0 m length) in selected streams of the Upper Grande Ronde River Basin.

Managed Streams			
NAME	**LENGTH (KM)**	**LWD (#/KM)**	**LWD COMPLEXES (#/KM)**
Jordan Creek	3.1	1.0	0.6
Rock Creek	2.2	6.0	1.3
McCoy Creek	4.7	6.2	1.4
Grande Ronde River	73.4	14.6	1.9
Five Points Creek	2.8	23.3	3.6
Catherine Creek	30.7	52.0	8.0
Beaver Creek	3.3	59.0	10.1
N Fk Catherine Creek	6.6	65.6	13.4
Meadow Creek	18.6	65.8	
S Fk Catherine Creek	3.3	66.0	12.5
TOTAL	**148.7**	**MEAN 40.0**	**5.9**

Changes in streamflow and climate over time in the Grande Ronde River basin: introduction-To provide context for the changes in anadromous fish habitat in the Upper Grande Ronde River basin, McIntosh (1992) examined the available long-term stream discharge and climate records for the basin. In a given basin, the pattern of runoff can influence the availability and quality of fish habitat. The natural discharge regimes of a watershed, and their interaction with the riparian/stream channel complex, are the processes that create and maintain fish habitat. Changes to these discharge regimes can affect fish habitat and populations adversely. Of particular concern are peak flows, the timing of peak flows, and low summer flow.

Analysis of long-term stream discharge records-Discharge records from the La Grande, Union, and Rondowa gauging stations were analyzed for the period of record to determine trends in annual, peak, and base discharge, along with the timing of peak discharges (McIntosh 1992). The La Grande and Union gauges measure primarily undiverted, natural streamflows, while the Rondowa gauge is influenced by irrigation withdrawals upstream.

Annual discharge was based on mean annual discharge. The instantaneous annual peak discharge was determined from peak flow files provided by the U.S. Geological Survey. These values represent the single largest event in each water year. Base discharge was calculated from the mean of the 10 lowest continuous days for the water year. The timing of peak discharge was based on the Julian day on which the largest peak occurred. Linear regression was used to determine temporal trends in the stream discharge record.

Our analysis showed that base discharge had increased in both the Upper Grande Ronde River (La Grande gauge) and Catherine Creek (Union gauge). The trend line suggests a near doubling in base discharge for the Upper Grande Ronde River (0.4 to 0.75 m^3/s (cms), fig. 10), and a 25 percent increase in Catherine Creek (0.56 to 0.70 cms, fig. 11). The timing of peak flows appears to have shifted to earlier in the year in the Upper Grande Ronde River by as many as 30 days (fig. 12, April 10 to March 11). No significant changes were found in the magnitude of peak flows and annual discharge at either gauge.

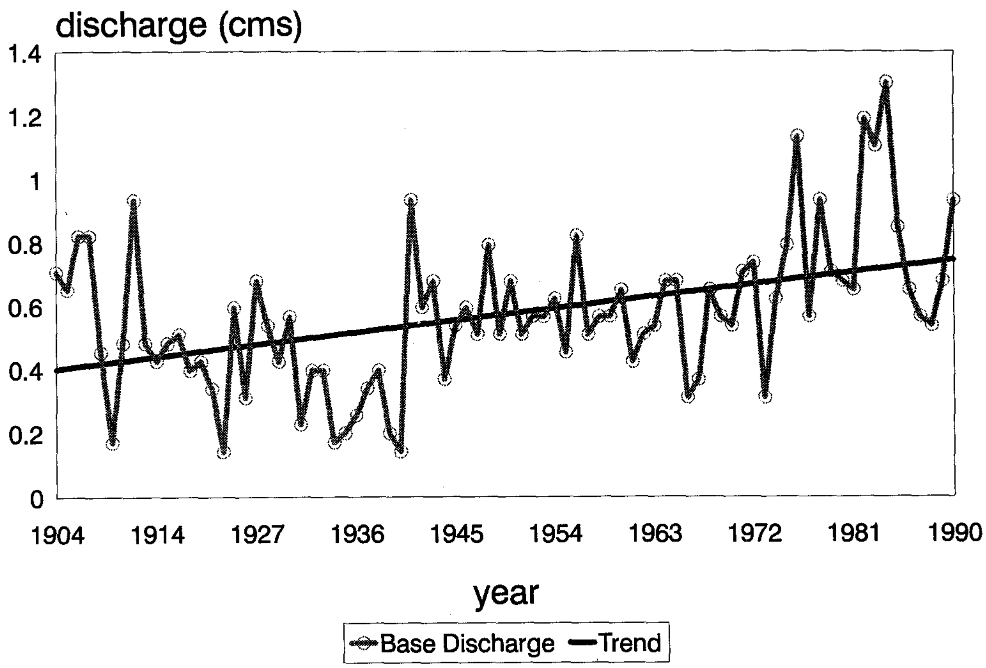


Figure 10. Trend in base discharge for the Upper Grande Ronde River, 1904 to 1990.

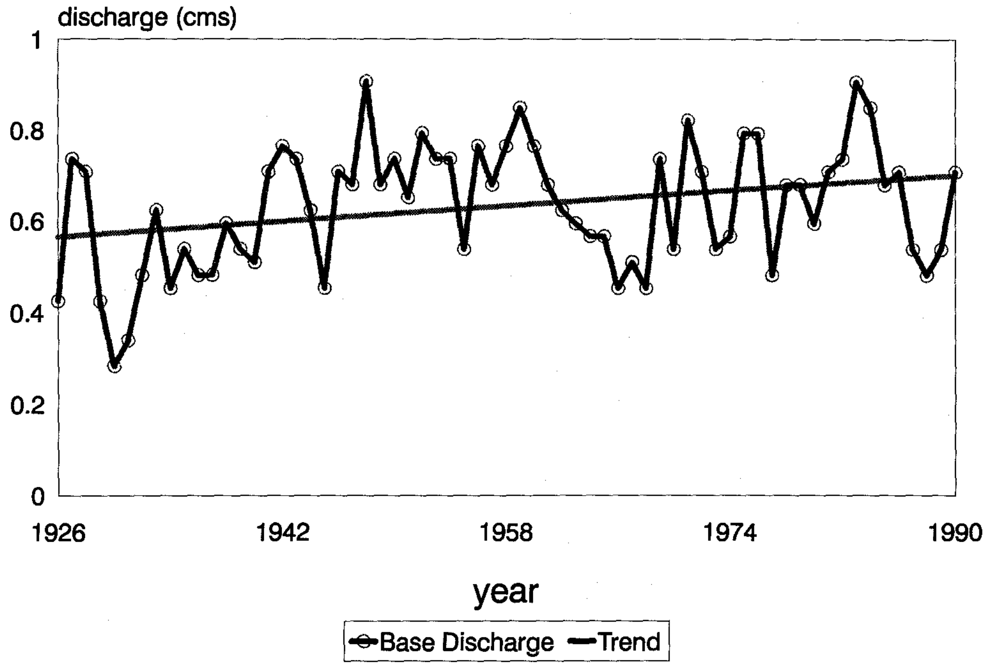


Figure 11. Trend in base discharge for Catherine Creek, 1926 to 1990.

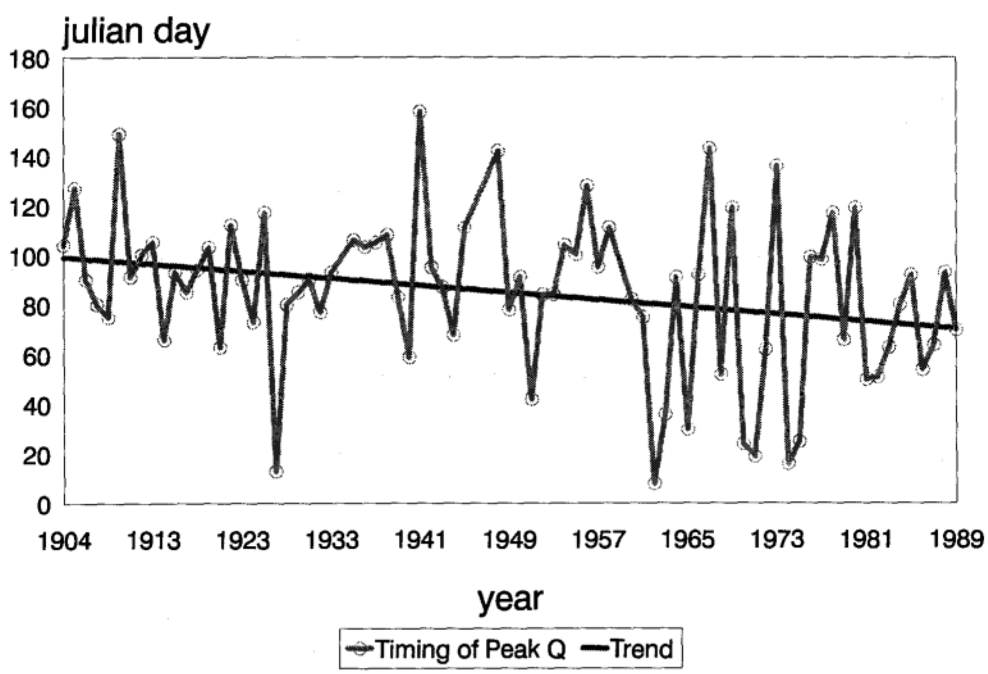


Figure 12. Trend in the timing of peak discharge based on Julian day for the Upper Grande Ronde River, 1904 to 1989.

At the Rondowa gauge, no significant trends appeared in any discharge variables, which would indicate that the changing discharge regimes evident in the Upper Grande Ronde River and Catherine Creek subbasins are unique to that portion of the basin. The data from the Rondowa gauge are influenced by upstream irrigation withdrawals, to what extent this affects the analysis is unknown.

Analysis of long-term climate records-The climate record was examined by using data from all available stations. From these data, mean annual, summer (May-September), and winter (December-May) precipitation, along with snowpack and annual temperature, were calculated. In northeastern Oregon most precipitation comes from winter snowpack, with little precipitation falling during the summer months (Higgins and others 1989).

In the Upper Grande Ronde River basin, mean annual precipitation declined 15 percent and mean annual winter precipitation declined 20 percent over the period of record (figs. 13, 14). Winter snowpack also decreased over 25 percent for the available record (1938 to 1990, fig. 15). No significant changes in summer precipitation or annual temperature were recorded. For the Catherine Creek basin, no significant changes were found in any of the climate variables.

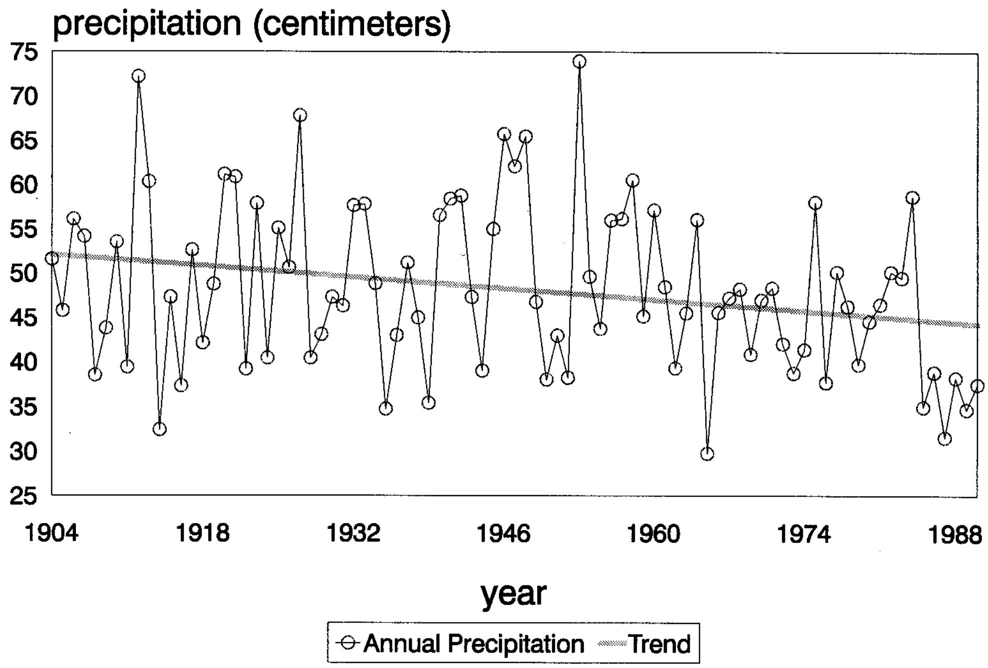


Figure 13. Trend in mean annual precipitation at La Grande, 1904 to 1990.

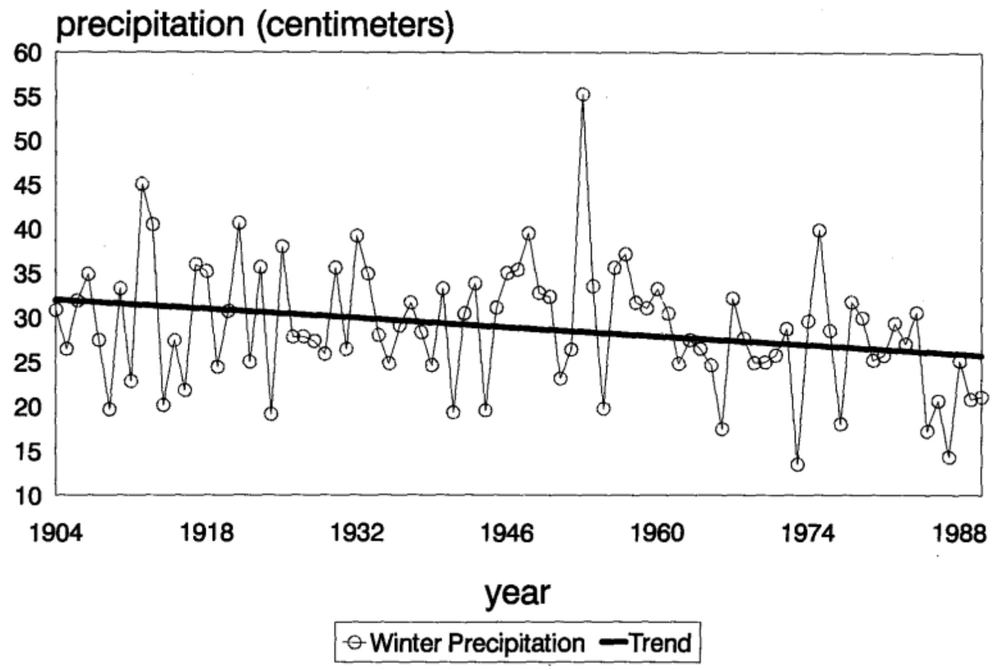


Figure 14. - Trend in winter precipitation (December-May) at La Grande, Oregon, 1904 to 1990.

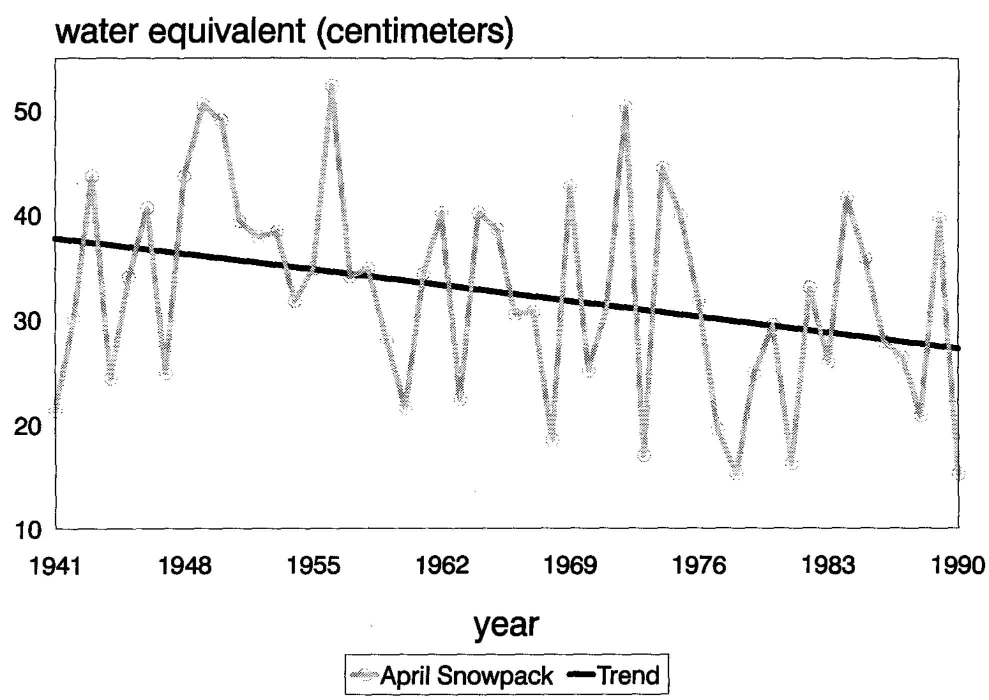


Figure 15. Trend in snowpack (April 1 water equivalent) for Upper Grande Ronde River watershed, at Beaver Creek, 1941 to 1990.

Conclusion-Temporal analysis of streamflow and climate records indicate significant changes in these parameters since 1904. Base discharge has increased, and both annual and winter precipitation, along with snowpack, have decreased. The timing of peak discharge appears to have shifted to earlier in the year.

The near doubling in base discharge, while precipitation has declined, suggests that the increases are not due to climate. The altered base-discharge regime may be the result of reduced evapotranspiration, caused by extensive defoliation from insect infestations and timber harvest. The reduction in moisture lost to transpiration caused by decreased leaf area from insect defoliation and timber harvest could result in more precipitation being retained as soil moisture, eventually being released to the stream channel through subsurface flow. The higher base discharge did not translate into increased annual discharges, but still showed a significant increase during a critical bottleneck in anadromous salmonid life history. Base flow may be more sensitive to increased subsurface flow than annual discharge because base flow is less than 3 percent of the annual water yield.

Change in the timing of peak discharge to earlier in the year could also be a result of land use practices. Research in western Oregon has shown that snowfall accumulations are greater in clearcuts and that they melt earlier because of increased exposure to solar radiation (Harr 1983). The high rate of timber harvest in the Upper Grande Ronde River basin may have created similar conditions.

The shift in timing of peak flows may have implications for the emigration of smolts from the basin, since their migration is timed largely to peak flows. If the smolts are forced to migrate earlier, they may not be physiologically ready, or if they do not migrate early, they risk being stranded by low flows. The migration of smolts is a highly evolved process that represents a critical juncture in the life history of anadromous salmonids.

Conventional wisdom holds that the rearing capacity of streams in eastern Oregon is limited by base discharge. A similar analysis of long-term base flow trends for the John Day River basin indicates that base flows have also increased in all river basins with gauging stations except one (PNW, unpublished data). The exception was Strawberry Creek, draining the Strawberry Mountains wilderness area, which showed no change in base flow. Preliminary analysis of other major river basins in eastern Oregon and Washington have shown no increase in base flow. This phenomenon appears to be limited to the Blue Mountain region.

The increased base discharge in the Upper Grande Ronde River may indicate sufficient summer flow, but both in-channel (pools) and floodplain (riparian vegetation), habitats necessary to store and release these increased base flows over the summer are not functional (Elmore and Beschta 1987, Sedell and Beschta 1991).

Summary-From this historical perspective on how anadromous fish habitat has changed, we can begin to identify desired conditions and opportunities for restoration. Pools are not distributed evenly along the stream network, but tend to occur in patches. Most pool habitat, both historical and current, is in unconstrained reaches, providing the geomorphic context to habitat distribution. Unconstrained reaches are defined as having a valley floor width greater than two active stream channel widths. For example, 40 percent of the Grande Ronde River is unconstrained. In 1941, these reaches contained 69 percent of the pool habitat, declining to 48 percent by 1990.

Unconstrained reaches are the most dynamic, complex, and productive portions of the riverine environment (Gregory and others 1991, Sedell and others 1990.). These habitats are the result of highly dynamic interaction between the stream channel and the associated floodplain and riparian vegetation. Research in western Oregon has shown that unconstrained reaches have the highest biotic productivity (Gregory and others 1989, Lamberti and others 1989, Moore and Gregory 1989).

To expedite recovery of stream and riparian habitat, thus improving anadromous fish habitat, recovery efforts for the near-term should be focused on unconstrained reaches. These areas will recover fastest, with accompanying increases in biological productivity. Efforts should focus on restoring and enhancing the natural processes that cause these reaches to be so highly dynamic, complex, and productive.

Restoring stream and riparian habitat in the Grande Ronde River basin requires changes in land management practices and a long-term commitment to good watershed stewardship. A framework for restoration has been developed in the Upper Grande Ronde River Anadromous Fish Habitat Protection, Restoration, and Monitoring Plan (Anderson 1992). In the near-term, anadromous fish stocks need relief from highly unfavorable rearing and spawning conditions. Management should emphasize accelerating recovery through sound and biologically defensible methods. These efforts should concentrate on areas most important to rearing and spawning and should in no way forestall the long-term recovery of the Upper Grande Ronde River.

Changes in Fish Habitat-Yakima River Basin, Washington

From 1990 to 92, the Pacific Northwest Research Station cooperated with the University of Washington and the Wenatchee National Forest to resurvey over 80 km of historically surveyed streams in the Yakima River basin. Three streams within the Naches River basin, and one tributary of the upper Yakima River were resurveyed. Pool habitats have increased in both managed and unmanaged drainages over the past 50 years. Of the four streams we surveyed, only the American River had a decrease in pool habitat.

Study area-The Yakima River basin, in south-central Washington, drains an area of 15,942 km^2 (fig. 16). It is the largest tributary of the Columbia River in Washington. The Yakima River’s headwaters are near the crest of the Cascades above Keechelus Lake; the river flows 344 km to the southeast, emptying into the Columbia River. Six major reservoirs and several major diversion dams are on the Yakima and Naches Rivers (Northwest Power Planning Council 1989). More than 60 percent of the land in the Yakima basin is publicly owned, with the remainder in private ownership. The Yakima Indian Reservation, in the southwest portion of the basin, comprises 25 percent of the land base. Irrigated agriculture is the economic base of the basin, with livestock production and forestry also contributing to the local economies (Northwest Power Planning Council 1989).

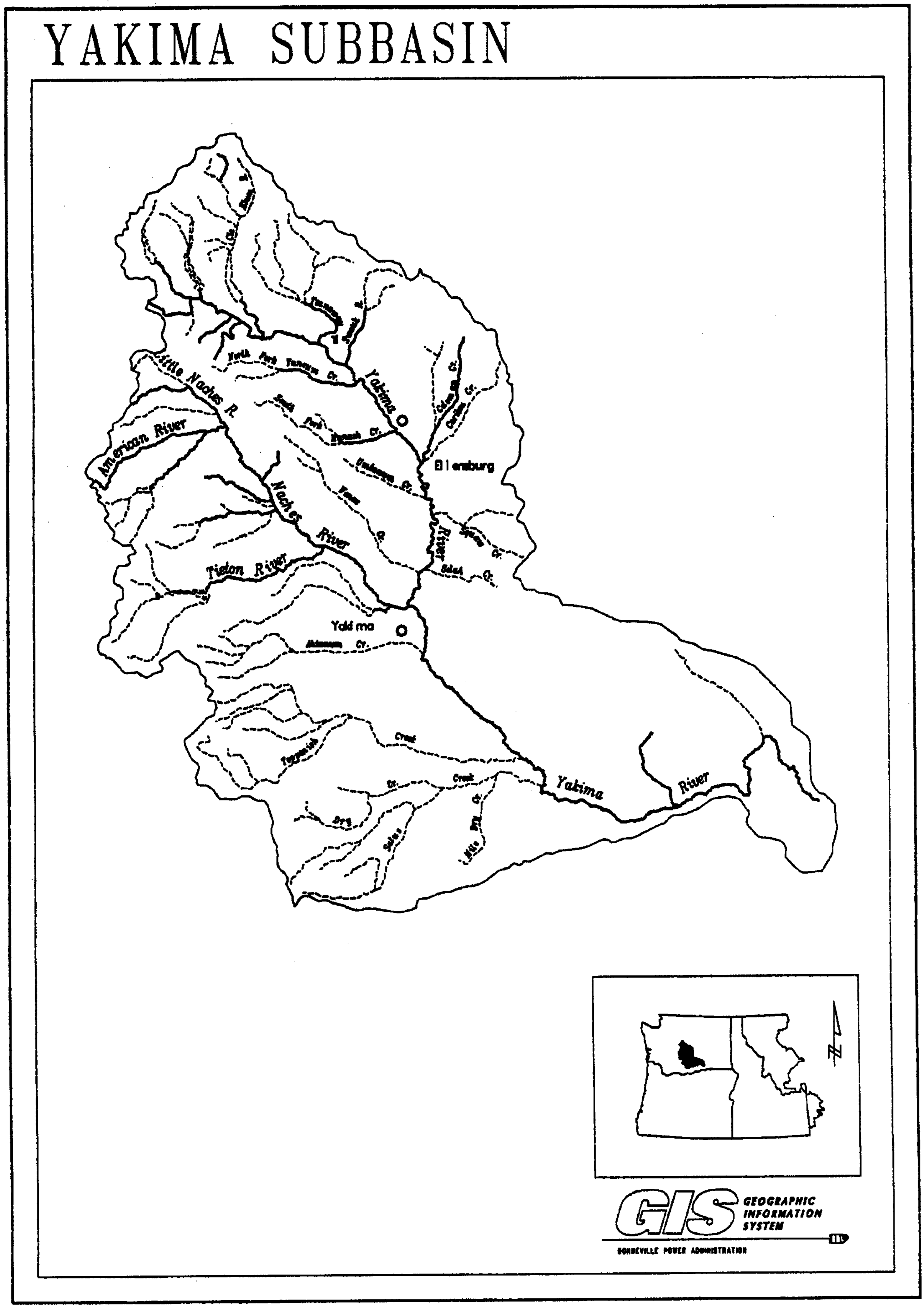


Figure 16. Yakima River basin, Washington

The Yakima basin once supported spring, summer/fall Chinook, summer steelhead, coho (*O. kisutsh*), and sockeye salmon. Historic runs have been estimated at 790,000 adults before the 1870s (Northwest Power Planning Council 1989, table 11). By the turn of the century, more than 90 percent of the runs were believed to be depleted, with coho and sockeye runs nearly extinct (Uebelacker 1980). The primary causes were dams and irrigation canals without adequate fish ladders and screens, along with log drives that affected stream habitat, and local overfishing (Fast and others 1991). These declines were not taken seriously by management agencies until the 1950s. In addition, resident trout and bull trout were also declining.

Table 11. Historical estimates of salmon and steelhead runs in the Yakima River basin (NPPC 1989).

Species/race	Historic Run Size	Present Run Size [a]
Spring Chinook	200,000	
Fall & Summer Chinook	200,000	
Coho	110,000	
Summer Steelhead	80,000	
Sockeye	200,000	
Total	790,000	7,018

[a] - based on mean run size for all anadromous salmonids in the Yakima Basin, from 1983-87 (NPPC, 1989). Sockeye and summer chinook are extinct, with coho at severely depressed populations.

Within the basin, the major constraints currently limiting increased anadromous fish runs are believed to be inappropriate instream flows (too low or too high), upstream/downstream passage at irrigation diversions, degraded riparian and stream habitat, and excessive temperatures in the lower river (Northwest Power Planning Council 1989).

Land-use history-The early development of the Yakima River basin followed a pattern similar to that of the Grande Ronde. Cattle and sheep grazing began in the mid-1800s, with cattle use peaking in the 1880s and sheep use peaking at the turn of the century and again during World War I. By 1907, the public had already recognized that portions of the basin were overgrazed, notably along ridgetops, which served as travel corridors, and on alluvial flats where livestock were grazed. In 1909, because of overgrazing, several drainages such as the Wenas and the Manastash, had greatly deteriorated (Cooperative Western Range Study 1938, Wissmar and others 1993). By the 1930s, sheep numbers were less than 10 percent of their historical peaks.

Before 1890, livestock grazing was concentrated on the Yakima Plateau, the surrounding foothills, and lower tributary valleys. The development of irrigation, and a subsequent boom in agriculture in the main Yakima valley forced the livestock industry to expand their summer and fall range into the tributary and headwater portion of the basin. Rapid expansion of irrigated agriculture was the turning point for economic development in the Yakima basin.

In the upper Yakima, near Cle Elum and Roslyn, coal mining and development of the Snoqualmie pass route were probably as important in altering the landscape as grazing and irrigation. The earliest timber harvest occurred along the lower slopes of the Teanaway, Menastash, Taneum, and the upper Yakima basins, from 1890 to 1900 (Plummer 1902).

Until the 1950s, timber harvest was largely limited to the harvest of large trees from the valley bottoms and adjacent hillslopes (Smith 1993), with little harvest on public lands until the 1960s. Through the 1970s this was largely limited to selective harvesting. From the mid-1970s to the present, clearcutting became a common practice, with the volume of timber harvest increasing significantly. Accompanying these practices were substantial increases in road building.

Naches River basin-The Naches River drainage is the largest tributary of the Yakima River. The upper reaches of the Naches provide summer and fall rearing habitat for more than 30 percent of the juvenile anadromous salmonids in the Yakima basin (Fast and others 1991); in addition, it contains about 60 percent of the remaining harvestable timber in the Yakima basin (U.S. Department of Agriculture, Forest Service 1990).

Little Naches River-The Little Naches River is a fifth-order basin with a drainage area of 398 km^2. Most of the basin lies within the Wenatchee National Forest, with portions of the upper basin under checkerboard ownership with Plum Creek Timber Co. Before 1960, land use in the Little Naches consisted of intensive livestock grazing from 1880 to 1930, small scale selective harvest in the valley bottoms, and considerable recreational use.

Before 1900, no developed roads were built in the Little Naches basin, only a few wagon trails. Until 1962, only 30 to 40 km of roads were in the basin, but between 1962 and 1990, over 450 km were constructed. Road densities in 1990 range from 1.0 to 3.1 km/km^2 (B. Ehinger, pers. comm.). Before 1963, timber harvest was minimal. Between 1963 and 1975, 17 percent of the available harvestable acres in the basin were cut. In 1975, clearcut harvest began in the lower basin. Clearcutting on the private checkerboard lands in the head-waters started in 1985. By 1985, 26 percent of the harvestable acres in the basin had been cut, increasing to 35 percent by 1992.

American River-The American River originates in the William O. Douglas wilderness area, along the border of Mount Rainier National Park. It flows east more than 30 km, where it meets the Naches River, draining an area of 205 km^2. The river is surrounded by two wilderness areas, with State Highway 410 following it for most of its course. The major effects to the American River have been caused by road construction and maintenance along with recreational development and use.

Rattlesnake Creek-Rattlesnake Creek begins in the William O. Douglas wilderness area, flowing 30 km to the east where it joins the Naches River. The upper 16 km are in the wilderness area; the lower portions of the basin are managed by the Forest Service, with some private lands near the mouth. Historically, livestock have grazed throughout the basin, with most allotments currently vacant or minimally used (J. Smith, pers. comm.). In the lower portions of the basin, timber has been harvested on both private and public land.

Upper Yakima River basin: Taneum Creek-Taneum Creek is a fifth-order tributary to the upper Yakima River, located near Thorp, Washington. The Taneum drainage extends east-southeast about 40 km to its confluence with the Yakima River. It has a drainage area of 214 km^2 and two major tributaries, the north and south forks.

Taneum Creek was not settled until about 1868, when several homesteads were established. Taneum Ditch was completed in 1873 to provide irrigation for the croplands along Taneum Creek and the lower Yakima Valley. Since then, the pastureland has been under continuous cultivation or grazed by livestock. Sheep were grazed along the ridgetops and riparian meadows from early summer to fall from the 1870s to the 1930s. A major sheep driveway was established up and over Cle Elum ridge into Easton.

Until the turn of the century, logging had been limited to selective cutting for homes and firewood. Shortly after the railroad arrived in 1903, Cascade Lumber Company began more intensive logging operations in the surrounding area. Several sawmills and boxmills were established along the creek, and logs were skidded out for railroad ties. A spur track of the railroad was built up the Taneum in 1928, but it was only operated through the mid-1930s. Large-scale timber harvest did not begin until the mid-1950s. By 1986, about 30 percent of the basin had been harvested, with more intensive partial and clearcut harvesting in the upper watershed since then.

Changes in fish habitat in the Yakima River basin from 1935 to 1990-The results of resurveys, conducted from 1990 to 1992, indicate that pools have increased in both managed and unmanaged portions of the Yakima River basin, with the exception of the American River, where pools decreased (table 12). These surveys also indicate that substrate composition has become coarser in the Little Naches River and Taneum Creek, but remained the same in Rattlesnake Creek (table 13). In the following sections, the results of these surveys will be examined in more detail.

Table 12. Changes in the frequency of large pools for selected managed and unmanaged streams in the Yakima River basin, 1935-36 to 1990-92.

Managed Watersheds	Kilometers Surveyed	1935-1936 #/km	1990-1992 #/km	Percent Change
Taneum Creek	17.3	0.5	3.4	580%
Little Naches River	15.6	1.7	4.6	171%
Rattlesnake Creek	8.1	1.9	4.6	142%
American River	24.5	3.3	2.4	-27%
TOTAL	**65.4**	**1.8**	**3.8**	**111%**
Unmanaged Watersheds	**Kilometers Surveyed**	**1935-1945 #/km**	**1987-1992 #/km**	**Percent Change**
Rattlesnake Creek	18.8	1.6	3.9	144%

Table 13. Changes in dominant substrate in the Yakima River Basin, 1935-36 to 1990-92.

Managed Streams	1935-1936 Dominant Substrate	1990-1992 Dominant Substrate	Change
Taneum Creek	SR (39%)	MR (43%)	+
Little Naches River	SR (37%)	LR (47%)	+
Rattlesnake Creek	LR (33%)	LR (63%)	NC
Unmanaged Streams			
Rattlesnake Creek	LR (48%)	LR (57%)	NC

Naches River basin-Three tributaries to the Naches River drainage were resurveyed from 1990 to 1992: the Little Naches and American River, along with managed and unmanaged portions of Rattlesnake Creek. The resurveys indicated that pool habitat had increased in the Little Naches and Rattlesnake Creek, but decreased in the American River (table 12).

Little Naches River-In 1990, the University of Washington began a study to examine changes in stream and riparian habitat in the Little Naches River basin (Smith 1993). The initial hypothesis, based on current observations of stream habitat, was that pool habitat had declined since the 1935 survey, but the 1990 resurvey indicated that the frequency of pool habitat had increased and that substrate composition had changed.

Anecdotal information from the 1935 survey suggests that pool habitat had already been significantly degraded by human disturbance by 1935. Although pool habitat has increased over the past 55 years, the frequency of pools is still far below any accepted standards, such as those in the Wenatchee National Forest Plan (1990) and Pacific Northwest Region, Forest Service, Standards and Guidelines (U.S. Department of Agriculture Forest Service 1991).

Pool habitat-Smith (1993) found that the frequency of large pools had increased from 1.7 to 4.6/km for the 15.6 km of stream surveyed. The increase in large pools appears to be the result of repeated scouring of the channel around areas that have been riprapped. About 80 percent of the main channel has been constrained by roads and riprap, increasing stream energy, magnifying the effects of scour at high flows, displacing smaller particles, and shifting large particles. The 1990 survey indicated that most pools were bedform scour pools controlled by large substrate and bedrock. Smith (1993) has suggested that the frequency of extreme high-flow events (40- to 100-year floods) has increased from 0.6 events/decade before 1966, to 2 events/ decade after 1966. This change in peak flows coincided with increased harvest and road densities.

Substrate composition-For the Little Naches River, substrate composition changed significantly from 1935 to 1990 (table 14). In 1935, small rubble dominated the surface substrate (38 percent), with large rubble (30 percent) and medium rubble (29 percent) making up equal portions of the bottom. Both fine sediment (1.0 percent) and bedrock (2.0 percent) were small portions of the surface substrate. By 1990, the channel surface had coarsened and small rubble was replaced by large rubble. Large rubble dominates surface substrate (47 percent) with small rubble decreasing to 15 percent. Minor increases in fine sediment and bedrock also occurred but medium rubble stayed the same.

Table 14. Substrate composition of the Little Naches River in 1935 and 1990.

Substrate Class	1935 mean (%)	1990 mean (%)
Large Rubble (LR)	30.0	47.0
Medium Rubble (MR)	29.0	28.0
Small Rubble (SR)	38.0	15.0
Mud and Sand (MS)	1.0	6.0
Bedrock (BR)	2.0	4.0

The increase in percent fines (MS) in the Little Naches, along with the high degree of embeddedness, suggests that the input of fine sediment has increased since 1935. At the same time, large rubble has increased significantly, now comprising almost 50 percent of the surface substrate. Large rubble can be an important component of rearing habitat if it is not embedded. Juvenile fish use the interstitial spaces for thermal cover in winter and hiding cover in summer (Bjornn and Reiser 1991). Aquatic insects also use interstitial spaces, providing a food source for fish.

Large woody debris-Comparisons of the frequency of large woody debris from aerial photographs (1962 and 1990) indicate a lack of wood in the lower reaches of the Little Naches. Although large woody debris increased from 1962 to 1990, the frequency still remains far below the Forest Plan standard of 62 pieces/km (U.S. Department of Agriculture, Forest Service 1990). The upper reaches have twice the frequency of the lower reaches, but little of this wood was associated with pools; most of the wood was in a few debris jams. Even though the association of large woody debris with pool habitat was weak, the increased may contribute to pool formation and increased habitat complexity in the future.

Conclusion-The historical survey indicates that pool habitat was not abundant in the 1935 survey. Although pools had increased by 1990, the frequency of pool habitat was still below current standards. With most of the mainstem now constrained by roads and riprap, the potential of the stream to create pool habitat may be severely reduced, especially in the lower reaches. Constrained channels typically have more high-gradient habitats, such as riffles, rapids, and cascades (Grant 1986), except at meander bends where large pools may form and persist (Lisle 1986). Current standards may need to be revised for streams of this nature, and efforts at rehabilitation may need to be rethought.

For example, alternative types of rearing habitat may need to be considered for restoration efforts. Side-channel areas that were cutoff from the main channel through road construction could be reconnected to provide highly productive refuge areas. Also, instead of trying to create large pools from riffle areas, riffle areas can be made more complex. Pocket pools and step-pool cascades can be established in riffles with large and small boulders combined with large woody debris. Besides providing cover, these structures lower stream energy and reduce the scour and erosive power that removes the structural components.

Even though pools increased over time, other habitat components critical to abundant and high quality spawning and rearing habitat have been reduced over the last 55 years. Off-channel habitat, channel complexity, riparian cover, and spawning gravels all have decreased over time. In addition, substrate embeddedness, percentage of fines, and water temperatures are above currently accepted values for fish.

Rattlesnake Creek-Our resurvey results indicated that pool habitat increased in both the managed and unmanaged portions of the basin by the same magnitude (table 12). Current pool frequencies remain quite low compared to current standards. A possible explanation for the improving trend may be recovery from intensive grazing in the early part of the century, followed by wilderness protection for the headwaters, and relatively little management activities in the lower portions (J. Smith, pers. comm.). No changes were observed in dominant substrate in either the managed or unmanaged portions of the basin (table 13).

American River-Survey results indicated that pool habitat has decreased by over 25 percent (table 12), with pools becoming shallower. The river has been altered over time by the continuous maintenance and realignment of the highway, along with heavy recreational use along the limited floodplain. These activities are likely to have influenced pool habitat by increased sediment loads which could result in the filling of pools (J. Smith, pers. comm.). In addition, debris removal for road and bridge maintenance is likely to have reduced channel complexity (for example, large woody debris), further reducing pool habitat. Road construction and maintenance, along with recreational development, have probably provided chronic and persistent sediment sources.

Upper Yakima River: Taneum Creek pool habitat-The frequency of large pools increased from 0.5/km to 3.4/km from 1936 to 1990 in Taneum Creek (table 12). Although the frequency of pools increased seven-fold, current frequencies are quite low for a stream of this size, indicating a general lack of pool habitat.

Substrate composition-In 1936, substrate was dominated by small and medium rubble (40 and 39 percent overall, table 15). By 1990, medium rubble (43 percent) was the dominant substrate, with a subsequent decrease in small rubble (26 percent) and increase in fine sediments (18 percent). The current level of fine sediments is approaching Forest Plan standards (< 20 percent fines). Furthermore, the most upstream reach exceeds the forest standard by 5 percent. The increase in percentage of fines, along with the embedded condition of the bed throughout most reaches, indicates that fine sediments have increased over the past 50 years. The ability of the stream to export fines has been exceeded.

Table 15. Substrate composition of Taneum Creek in 1935 and 1990.		
Substrate Class	**1935 mean (%)**	**1990 mean (%)**
Large Rubble (LR)	14.0	13.0
Medium Rubble (MR)	39.0	43.0
Small Rubble (SR)	40.0	26.0
Mud and Sand (MS)	7.0	18.0
Bedrock (BR)	0.0	0.0

Conclusion-The historical record indicates that grazing pressure had greatly diminished in Taneum Creek by the 1930s. From that period until the 1970s, land-use effects were largely limited to agriculture in the lower reaches, with some selective timber harvest along the mainstem of the creek. This period of relative inactivity may have provided a window over which stream habitat began to show some recovery from past effects. From the 1970s to the present, the basin has experienced greatly accelerated road construction and timber harvest.

The effects of intensive logging over the past 20 years are likely to curtail further recovery in pool habitat, as evidenced by increased fine sediments and high embeddedness, and may result in further declines in habitat conditions in the future. With accelerated harvest in the steep headwaters areas, along with chronic surface erosion from sparsely vegetated upland meadows, fine sediments are likely to persist for some time. This condition may result in decreased pool habitat through sedimentation, accompanied by a reduction in fish productivity from the direct effects of fine sediments on salmonid reproduction.

Summary-Recent research (Mullan and others 1992, Wissmar and others 1993, this volume) indicates that the land-use history in the mid-Columbia region may be quite different from patterns seen west of the Cascades and in the Snake River basin, thus influencing the effects to riverine ecosystems. Generally, streams were heavily affected by livestock grazing from about 1860 to 1920. After that point, development pressures were concentrated in the larger river valleys, while the headwater and tributary portions of the basins had a period of relative inactivity. This pattern changed in the late 1950s, as timber harvest and road construction began in the upper portions of the basins. Harvest practices changed over time from selective harvest to clearcutting. Since the 1970s, timber harvest has accelerated dramatically throughout the mid-Columbia region (Wissmar and others 1993).

The period of relative inactivity in the tributary portions of the Yakima basin, followed by much later entry for timber harvest, may explain the trend in increased pool habitat. These trends must be viewed in the perspective of current standards for pool habitat. None of the streams we have surveyed meet current Forest Service standards for pool habitat (table 4). Although the trend in improving habitat is encouraging, the stream habitats we surveyed are still in poor condition. Given the late entry for timber harvest, stream habitats may not be expressing the full cumulative effects of harvest activities. Management priorities for stream protection should emphasize continuing these improving trends.

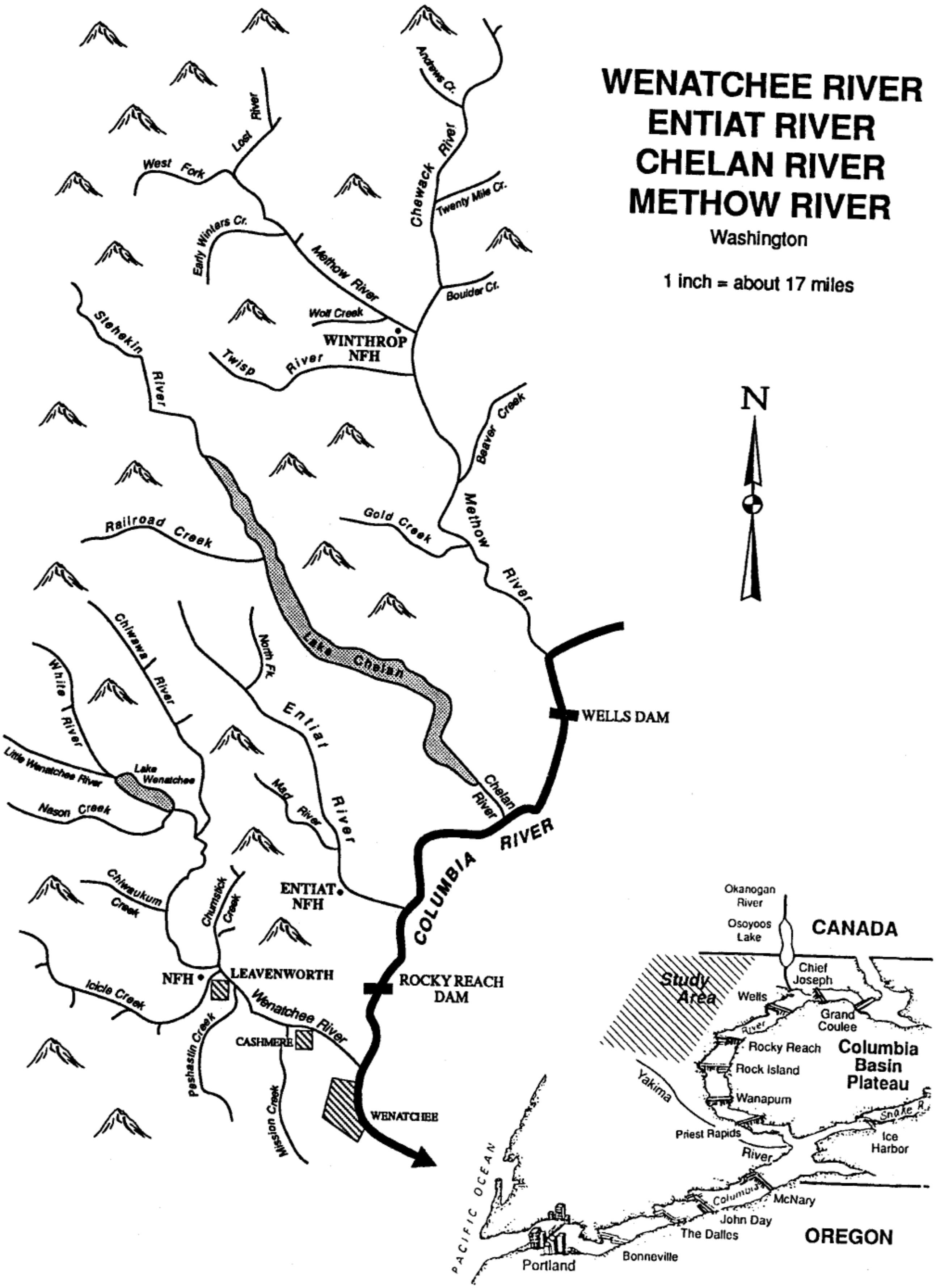


Figure 17. Wenatchee and Methow River basins, Washington

Changes in Fish Habitat -Wenatchee River Basin, Washington

Study area-The Wenatchee River basin is located in north-central Washington, draining an area of 3437 km^2 (fig. 17). It flows to the southeast from glacial outflow in the Cascade Range, through mountainous, heavily forested reaches, to a broader, more arid valley at its confluence with the Columbia. The basins climate is strongly influenced by the orographic effects of the Cascades; the region is in the coldest of 24 western climate zones (Mullan and others 1992). Precipitation is primarily winter snowpack, with little falling from April to September.

Irrigated agriculture, primarily fruit orchards along the lower river, has been the economic base of the Wenatchee basin. Livestock production and forestry are also important components of the economy. The basin is about 80 percent public land, mostly in the mountainous, forested regions.

Historically, the Wenatchee had large runs of spring/summer/fall Chinook, coho salmon, sockeye salmon, and steelhead. Coho runs were probably a minor component of the population, and these small runs became extinct sometime after the 1940s Recent research (Mullan and others 1992) suggests that current wild runs appear to be similar in size to historical runs (table 16). Although total run sizes are about the same, the species composition of the runs has shifted substantially-coho are extinct and sockeye reduced. The majority of the run is now spring Chinook. Summer steelhead were listed as a species of special concern by Nehlsen and others (1991), primarily because of the effects of hatchery introgression.

Table 16. Historical and current run sizes of naturally produced salmon and steelhead in the Wenatchee River basin (from Mullan and others 1992).

Species	1850s	1967-87
Chinook Salmon	41,300	204,800
Coho Salmon	3,900	0
Sockeye Salmon	228,100	93,700
Steelhead	7,300	8,200 [a]
TOTAL	**280,600**	**306,700**

[a] - for years 1987-1989.

Land use history-The historical pattern of land use in the Wenatchee basin follows a familiar pattern in the Pacific Northwest. Mining was probably the first activity during the settlement era, beginning in the 1870s The records indicate that mineral production was minor, with effects being mostly local and short lived (Mullan and others 1992, Wissmar and others 1993).

After the advent of mining was a period of intense livestock grazing, similar to what has been documented for other river basins. Grazing pressure was highest from the late 1800s to the 1930s, with subsequent reductions as allotment systems replaced the open range (Carter 1990). Currently, the Wenatchee National Forest lists no rangelands in unsatisfactory condition, with most considered to be improving (U.S. Department of Agriculture, Forest Service 1990).

As with the Yakima basin, timber harvest came later to the Wenatchee. Up until 1955, selective harvest or “high grading” was the primary harvest method. Since then, partial cutting and clearcutting have been the predominant practices. The 1980s represent the period of most intense harvest (Mullan 1992, U.S. Department of Agriculture, Forest Service 1990). Even with increased harvest in the past decade, about 65 percent of the Wenatchee National Forest is currently designated as wilderness or roadless areas (U.S. Department of Agriculture, Forest Service 1990).

Although the basin has been affected by stream channelization, irrigation, and pollution, these effects are not nearly as extensive as those found in the Yakima basin. A major effect early in the century were dams and irrigation diversions with inadequate bypass or screening facilities. Overfishing by Euro-Americans was also a problem during the settlement period.

Fires have been an important part of the natural disturbance regime in the Wenatchee River basin. Variations in the pattern, magnitude, and frequency of fire are complex throughout the Wenatchee. In the presettlement era, Native Americans used fire to maintain and enhance their hunting and berry producing areas (Mullan and others 1992). With the initiation of fire suppression, fuels have accumulated and vegetative composition has changed, from open stands of fire-tolerant species to dense stands of less fire-tolerant species. These changes have increased fire frequencies, and the risk of catastrophic fires are much greater.

Changes in fish habitat in the Wenatchee River basin from 1935 to 1991: pool habitat- During 1991, the Pacific Northwest Research Station surveyed four streams in the Wenatchee River basin, covering more than 70 km of streams. Three of the streams were in unmanaged basins, and one was in a managed watershed. Pool habitat increased in both the managed and unmanaged portions of the basin (table 17), with both having similar pool frequencies in the resurveys. Compared to Nason Creek, which is the stream in the managed area, the increase was twice as great in the unmanaged portions of the basin.

Table 17. Change in the frequency of large pools for selected streams in the Wenatchee River Basin, 1935-37 to 1991.

Managed Watersheds	Kilometers Surveyed	1935-1937 #/km	1991 #/km	Percent Change
Nason Creek	33.6	4.9	7.7	57%
Unmanaged Watersheds	**Kilometers Surveyed**	**1935-1945 #/km**	**1987-1992 #/km**	**Percent Change**
Jack Creek	6.8	1.9	8.1	326%
Icicle Creek	14.1	3.8	10.3	171%
Chiwawa River	59.1	1.8	4.2	133%
TOTAL	**80.0**	**2.5**	**7.5**	**200%**

The reasons for the increases in pool habitat are largely unknown at this point, but several explanations are possible. We know that the Wenatchee has had several large flood events (return interval 40 to 100 years) since the surveys in the 1930s; the most recent was in 1990. Our 1991 surveys indicated that the 1990 flood was probably a major pool-forming event in the Wenatchee systems. In some systems, such as the Chiwawa River, evidence of debris flows, which brought large woody debris and boulders to the stream channel, was extensive. In addition, the interaction of the flood with the Chiwawa's large, intact riparian floodplain greatly increased channel complexity.

A contrast to this would be Nason Creek, which has an extensive management history. In the lower portions, Nason Creek has a fairly broad floodplain that has been significantly altered and constrained by a railroad grade and a State highway. The historical record indicates that timber resources had been significantly reduced by the turn of the century, because of the demands of the railroad (Plummer 1902). In addition, the railroad right-of-way has been burned repeatedly to maintain passage, which undoubtedly had a large effect on riparian vegetation (Mullan and others 1992). Although Nason Creek showed an increase in pool habitat from the 1930s survey, the increase was considerably less than what we found in the unmanaged systems. This finding suggests that unmanaged systems with intact, fully functional floodplains, were further enhanced by the interaction with large flood events, which are a key to shaping and maintaining high-quality fish habitat.

Substrate composition-Changes in dominant substrate varied for surveyed streams in the Wenatchee River basin (table 18). Of the unmanaged streams, two did not change, and Icicle Creek shifted to a finer dominant substrate. Nason Creek, the managed stream, also had a shift to finer substrate.

Table 18. Changes in dominant substrate in the Wenatchee River basin, 1935-36 to 1991.

Managed Streams	1935-1936 Dominant Substrate	1991 Dominant Substrate	Change
Nason Creek	LR (33%)	MR (34%)	--
Unmanaged Streams			
Jack Creek	LR (76%)	LR (45%)	NC
Icicle Creek	LR (48%)	SR (26%)	--
Chiwawa River	LR (46%)	LR (33%)	NC

MR = medium rubble, SR = small rubble, NC = no change, - = decrease

Large woody debris-As the general trends for eastside river basins have indicated, large woody debris is much more prevalent in unmanaged than in managed streams in the Wenatchee River basin (table 19). From the unmanaged (72.5 pieces/km) to the managed streams (26.7 pieces/km) there was nearly a threefold increase in large woody debris. Also, the frequency of large woody debris complexes was much higher in the unmanaged streams. As an example, the Chiwawa River has a very complex stream channel, with numerous debris jams and multiple channels throughout its course and is representative of the potential of these systems to create highly diverse stream habitat.

Table 19. Current amounts of large woody debris (LWD > 0.1 m diameter and > 2.0 m length) in selected managed and unmanaged streams in the Wenatchee River basin.

Managed Streams Name	LENGTH (KM)	LWD (#/KM)	LWD COMPLEXES (#/KM)
Nason Creek	33.6	26.7	3.5
Unmanaged Streams Name	**LENGTH (KM)**	**LWD (#/KM)**	**LWD COMPLEXES (#/KM)**
Jack Creek	6.8	73.3	10.7
Icicle Creek	14.1	81.9	11.2
Chiwawa River	59.1	62.4	13.9
TOTAL	**80.0**	**MEAN 72.5**	**11.9**

Summary-The historical resurveys, along with Mullan and others (1992), indicate that fish habitat is in good condition in the Wenatchee River basin. The primary effects to anadromous salmonids appear to be irrigation diversions and low flows in the mainstem Wenatchee River. Some tributaries, such as Mission Creek, are in poor condition, but they represent a small portion of the total habitat.

The data from this case history strongly imply that the stability of anadromous fish runs in the Wenatchee River basin are tied to the abundance of high-quality habitat. This condition is largely because most of the Wenatchee National Forest is in wilderness or roadless designation. Having a wealth of intact headwater and floodplain areas has helped shape and maintain productive fish habitat. To maintain the productivity of the Wenatchee River basin, these features of the landscape must be maintained.

Changes in Fish Habitat-Methow Diver Basin, Washington

We resurveyed 176 km of streams in the Methow River basin during the summer of 1992, including most of the mainstem Methow, along with the two major drainages, the Chewack and Twisp Rivers. The survey results indicated that the frequency of large pools had increased significantly in both managed and unmanaged systems over the past 50 years.

Summary documents from the historical survey indicate that pools were infrequent at the time of the survey, with no suggestion as to a cause. Although current pool frequencies have more than doubled, the cause is not obvious. Whether the reason is natural geomorphic constraints or is an artifact of past disturbance, natural or human, is unknown. Using the historical record, we will examine potential reasons for the improvement in pool habitat.

Study area-The Methow River basin is in north-central Washington, just south of the Canadian border (fig. 17). It drains an area of 4641 km^2 as it flows about 140 km from the crest of the Cascades to the Columbia River. About 80 percent of the basin is public land managed by the Forest Service, with the lower 100 km of the river in private ownership. Logging and livestock production are the economic base of this sparsely populated basin, with orchards also a significant part of the local economy.

The basin is characterized by a wide alluvial valley and forested uplands. Glaciers have provided extensive alluvium throughout the valley, often several hundred meters deep, which has allowed for development of significant groundwater storage in the floodplain (Wissmar and others 1993). Many reaches of streams in the upper basin naturally de-water during periods of low flow because of this. Like the Wenatchee, the Methow is located in the coldest of 24 western climate zones (Mullan and others 1992).

Before settlement by Euro-Americans, the Methow supported significant runs of spring/summer Chinook salmon, coho salmon, and steelhead, with coho being the most abundant (Mullan and others 1992, table 20). By 1941, coho were at or near extinction because of impassable dams, unscreened irrigation diversions, overharvest, and the indiscriminate use of coho eggs for early hatchery programs. Currently, anadromous salmonid stocks are supported by Chinook salmon and steelhead in the Methow. Recent research suggests that current runs exceed the historical runs in the Methow River basin, with Chinook replacing coho (Mullan and others 1992). Wild steelhead were listed as having a high risk of extinction by Nehlsen and others (1991), primarily because of the effects of irrigation and hatchery introgression.

Table 20. Historical and current run sizes of naturally produced salmon and steelhead in the Methow River basin (from Mullan and others 1992).

Species	1850s	1967-87
Chinook Salmon	24,200	86,100
Coho Salmon	36,000	0
Steelhead	3,600	5,000 [a]
TOTAL	**63,800**	**91,100**

[a] - for years 1987-1989

Land use history-The land-use history of the Methow River basin is similar to the other river basins of central Washington. Unlike the other basins, though, the Methow remains very sparsely populated. The first settlers in the basin were miners and livestock grazers. With its extensive floodplain and gentle uplands, the Methow provided excellent summer range for livestock. The heyday of grazing was from the late 1800s, continuing until after the turn of the century, with subsequent declines. As with the other river basins in the Pacific Northwest, sheep grazing came first, followed by cattle grazing. Undoubtedly, stream and riparian habitats suffered under this intensive grazing pressure, providing a legacy that continues today in many places.

As the basin was settled, fruit orchards became prominent on terraces throughout the floodplain, although not as extensively as in the Wenatchee. To support a growing fruit business, extensive irrigation was developed throughout the lower reaches of the Methow. As noted previously, dams and irrigation diversions greatly contributed to the decline of anadromous salmonids in the Methow early in the century.

Timber harvest and road construction of any significance began in the 1970s in the Methow (J. Spotts, pers. comm.). The current Forest Plan (1989) indicates that about 75 percent of the forest is designated as wilderness or roadless areas. Before the 1970s, timber harvest was limited to the riparian zone and adjacent hillslopes. The Twisp basin has had the most management activities over the development period (J. Spotts, pers. comm.).

Changes in fish habitat in the Methow River basin from 1935 to 1992: pool habitat-During the summer of 1992, the Pacific Northwest Research Station resurveyed the three major drainages of the Methow River basin, namely the Chewack and Twisp Rivers, along with the upper 70 km of the Methow River. Our surveys indicated that pool frequencies doubled in the managed portions of the basin, and increased more than three-fold in the unmanaged portion (table 21).

Table 21. Change in the frequency of large pools for selected streams in the Methow River basin, 1935-37 to 1991.

Managed Watersheds	Kilometers Surveyed	1935-1937 #/km	1991 #/km	Percent Change
Chewack River	33.9	1.0	3.5	250%
Methow River	69.6	1.4	3.0	114%
Twisp River	42.5	2.8	3.9	37%
TOTAL	**146.0**	**1.7**	**3.4**	**100%**
Unmanaged Watersheds	**Kilometers Surveyed**	**1935-1945 #/km**	**1987-1992 #/km**	**Percent Change**
Chewack River	30.3	1.0	3.4	40%

The low pool frequencies indicated by the 1930s survey suggest that stream habitat was in poor condition at the time. The period of declining grazing coupled with late entry for timber harvest may have allowed some time for stream habitat to recover. The important point is not the size of the change, but the direction. Both the Chewack and the Methow are near current Forest Service standards for large pools, with the Twisp still below them.

Substrate composition-Comparisons of substrate composition in the Methow River basin indicated no significant trends (table 22). The exception was the Methow River, where the dominant substrate shifted from medium rubble to small rubble.

Table 22. Changes in dominant substrate in the Methow River basin, 1934-38 to 1992.

Managed Streams	1934-1938 Dominant Substrate	1992 Dominant Substrate	Change
Methow River	MR (44%)	SR (39%)	--
Twisp River	MR (35%)	MR (33%)	NC
Chewack River	MR (34%)	MR (35%)	NC
Chewack River (unmanaged)	LR (35%)	LR (49%)	NC

MR = medium rubble, SR = small rubble, NC = no change, - = decrease

Large woody debris-The frequency of large woody debris in the Methow basin was the reverse of what was detected in the other river basins (table 23). About 50 percent more large woody debris and debris complexes were found in the managed portions of the basin than in the unmanaged portion. This distribution may be an anomaly, the result of a large fire in the headwaters of the Chewack River in 1929, described below. The apparent high-intensity of this fire may have eliminated much of the large woody debris and set back future recruitment, which later became evident in the current survey.

Table 23. Current levels of large woody debris (LWD > 0.1 m diameter and > 2.0 m length) in selected managed and unmanaged streams of eastern Oregon and Washington.

Managed Streams Names	LENGTH (KM)	LWD (#/KM)	LWD COMPLEXES #/KM
CHEWACK RIVER	33.9	71.5	12.5
METHOW RIVER	69.6	50.6	7.8
TWISP RIVER	42.5	85.6	16.7
TOTAL	**146.0**	**MEAN 69.2**	**12.3**
Unmanaged Streams Name	**LENGTH (KM)**	**LWD (#/KM)**	**LWD COMPLEXES #/KM**
CHEWACK RIVER	30.3	40.2	8.1

Summary-As examples of different disturbance regimes and how these systems have changed over the past 50 years, we will examine the Twisp and Chewack Rivers. When the Chewack was surveyed in 1935, the surveyors noted that:

> *the hillsides are covered by a good growth in the lower and upper reaches with the exception of the last three miles of stream surveyed. This area was burnt over by a fire in 1929 which killed the timber and killed the under-brush. At the time of the survey, there was [sic] little or no protected stretches along the stream banks.*

Based on this description, the low frequency of pools in 1935 is likely explained by the effects of the 1929 fire. Also, this portion of the basin has not been affected by human activities and is currently a wilderness area, thus raising the likelihood of this explanation.

In contrast, the Twisp river has been a managed river basin since settlement. At the time of the 1935 survey, extensive irrigation development to support fruit orchards was noted in the lower 20 km of the river. The upper portions of the basin had been grazed, but no extensive burns were reported. In the historical survey, the Twisp River had a pool frequency three times greater than the Chewack-most likely explained by its relatively undisturbed state as compared to the Chewack, which had experienced the 1929 fire. Since 1935, the Twisp has had the most intensive timber harvest of all the drainages in the Methow River basin (J. Spotts, pers. comm.). The management history of the Twisp may explain why it shows the least improvement in pool habitat of the streams resurveyed.

IDENTIFICATION OF KEY WATERSHEDS WITH HIGH QUALITY FISH HABITAT AND THOSE WITH THE GREATEST POTENTIAL FOR RESTORATION

Fishery and aquatic specialists generally recognize that conservation and restoration efforts for aquatic resources need to be focused at the watershed scale (Johnson and others 1991, Meehan 1991, Reeves and Sedell 1992, Sheldon 1988, Williams and others 1989, Wissmar and others 1993). This section identifies key watersheds in eastern Oregon and Washington that can serve as cornerstones to regional protection and restoration efforts for aquatic systems (table 24a, b; figs. 18, 19).

The criteria for selection were based on Johnson and others (1991) and Reeves and Sedell (1992). Key watersheds were larger than 15 km^2 and contained relatively high-quality water and fish habitat, or had the potential to provide high-quality habitat with appropriate restoration efforts; and contained habitat for threatened or potentially threatened anadromous and resident fish species. These watersheds were determined by Federal, State, and Tribal fish biologists from across the region.

Table 24a. List of key watersheds for anadromous and resident fish in Washington.

Forest/Watershed	Steelhead/		Coho	Chinook				Sea run cutthroat trout	Bull trout	West slope cutthroat trout	Other
	Sum	Win		Spr	Sum	Fall	Win				
OKANOGAN NF											
COLUMBIA R.											
METHOW R.											
20 Twisp R.	X			P	X						C2
21 Early Winters Cr.	X			P					X		C2
21 Upper Methow R.	X			P					X		C2
22 Chewack R. [1]	X			P							
WENATCHEE NF											
COLUMBIA R.											
YAKIMA R.											
11 Teiton R.									X		
12 Rattlesnake Cr.	P			P					X		
13 Bumping-American R.				P					X		
14 Cle Elum R.									X		P(9)
WENATCHEE NF											
15 Ingalls Cr.	X								X		C2
16 Mission Cr.	X										C2
17 Icicle Cr.									X		C1,C2
18 Upper Wenatchee R. [2]	X			P					X		P(9)
19 Entiat. R.	X			P					X		

Table 24b. List of key watersheds for anadromous and resident fish in eastern Oregon.											
Forest/Watershed	Steelhead/ Trout		Coho	Chinook				Sea run cutthroat trout	Bull trout	West slope cutthroat trout	Other
	Sum	Win		Spr	Sum	Fall	Win				
WINEMA NF											
KLAMATH R.											
19 Clover Cr.											C2
20 Rainbow Cr.											C2
21 Pelican Butte											C1,C2
22 Cherry Cr.									X		
23 Seven Mile Cr.									X		
24 Evening Cr.									X		
DESCHUTES NF											
COLUMBIA R.											
DESCHUTES R.											
52 Big Marsh Cr.									X		
53 Odell Cr.									X		C2
54 Deschutes R. Corridor, Lava Lake to Crane Prairie [1]									X		C2
55 Cultus Cr.											C2
56 Duschutes R. Corridor, Dilman Meadows to La Pine Rec. Area [1]											C2
57 Deschutes R. Corridor, Benhan Falls Camp to Dillon Falls [1]											C2
58 Tumalo Cr.											C2
59 Squaw Cr.											C2
61 Metolius R.									X		C2
60 Three Creeks Meadows & Creek [1]											C2
MT. HOOD NF											
COLUMBIA R.											
DESCHUTES R.											
69 White R. [3]	P										X(5),C2
70 Fifteen Mile Cr./Ramsey Cr.	X	X									
72 W. Fork Hood R.	X	X	X	X				X			
67 Eagle Cr.		P	P	P							C2
71 Mill Cr./Five Mile Cr./Eight Mile Cr.		X									C2

Table 24b. List of key watersheds for anadromous and resident fish in eastern Oregon (continued).											
Forest/Watershed	Steelhead/ Trout		Coho	Chinook				Sea run cutthroat trout	Bull trout	West slope cutthroat trout	Other
	Sum	Win		Spr	Sum	Fall	Win				
<u>OCHOCO NF</u>											
COLUMBIA R.											
JOHN DAY R.											
73 Rock Cr.	P										X(5)
74 Black Canyon Cr.	P										X(5)
75 Cottonwood Cr.	P										X(5)
DESCHUTES R.											
76 Trout Cr.	P										X(5)
<u>MALHEUR NF</u>											
COLUMBIA R.											
JOHN DAY R.											
77 Fields Cr.	P									P	
CANYON CR.											
78 E. Fork Canyon Cr.	P									P	
79 M. Fork Canyon Cr./Canyon Cr.	P									P	
80 Reynolds Cr./Deardorf Cr.	P			X					X	P	
John Day R. Headwaters											
MIDDLE FORK JOHN DAY R.											
81 M. Fork John Day R. Corridor, Galena to Phipps Meadow [1]	P			X							
83 Camp Cr.	P			X					X		
84 Big Boulder Cr.	P			X					X		
84 Granite Boulder Cr.	P			X					X		
84 Beaver Cr./Little Boulder Cr./Caribou Cr./Vincent Cr./Vinegar Cr.	P										
85 Davis Cr.	P								X		
86 Clear Cr.	P			X					X		
82 Big Cr.	P			X					X	P	
SOUTH FORK JOHN DAY R.											
87 Murderers Cr.	P										

Table 24b. List of key watersheds for anadromous and resident fish in eastern Oregon (continued).											
Forest/Watershed	Steelhead/ Trout		Coho	Chinook				Sea run cutthroat trout	Bull trout	West slope cutthroat trout	Other
	Sum	Win		Spr	Sum	Fall	Win				
WALLOWA-WHITMAN NF											
COLUMBIA R.											
JOHN DAY R.											
N. FORK JOHN DAY R.											
88A Upper N. Fork John Day R.	P			X					X		
89A Granite Cr./Bull Run Cr./Beaver Cr.	P			X					X		
SNAKE R.											
GRANDE RONDE R.											
90 Meadow Cr.	P										
91 Beaver Cr.	P										
92 Upper Grand Ronde R.	P			X					X		
93 Upper Catherine Cr.	P			X							
94 Minam R.	P			X					X		
95 Wallowa R./Lostine R.	P			X							
96 Joseph Cr.	P										X(5)
96 Cottonwood Cr.											X(5)
97 Imnaha R.	X			X		X			X		
98 Cherry Cr.											X(5)
UMATILLA NF											
COLUMBIA R.											
JOHN DAY R.											
88B Upper N. Fork John Day R.	P			X					X		C2
89B Granite Cr.	P			X							C2
89B Clear Cr.	P			X							
99 Desolation Cr.	P			X					X		C2
100 Camas Cr.	P										
101 Fivemile Cr.	P										
102 Potamus Cr.	P										C2
103 Wall Cr.	P										

Table 24b. List of key watersheds for anadromous and resident fish in eastern Oregon (continued).											
Forest/Watershed	Steelhead/ Trout		Coho	Chinook				Sea run cutthroat trout	Bull trout	West slope cutthroat trout	Other
	Sum	Win		Spr	Sum	Fall	Win				
SNAKE R.											
GRAND RONDE R.											
104 Looking Glass Cr.	P			X					X		C2
105 Wenaha R. [4]	P			X					X		C2
106 Wenatchee Cr. [4]	X			X					X		C2
107 Asotin Cr. [4]	X			X					X		
108 Tucannon R. [4]	X			X					X		
WALLA WALLA R.											
109 N. Fork Walla Walla R.	X								X		C2
110 S. Fork Walla Walla R.	X								X		C2
111 Touchet R. [4]	X								X		
112 Umatilla R.	P								X		C2

P	Present in streams of watershed
X	Identified as at risk or declining by the Endangered Fish Committee of the American Fisheries Society
C1	High-Quality water source
C2	Unique or high-value resident trout populations

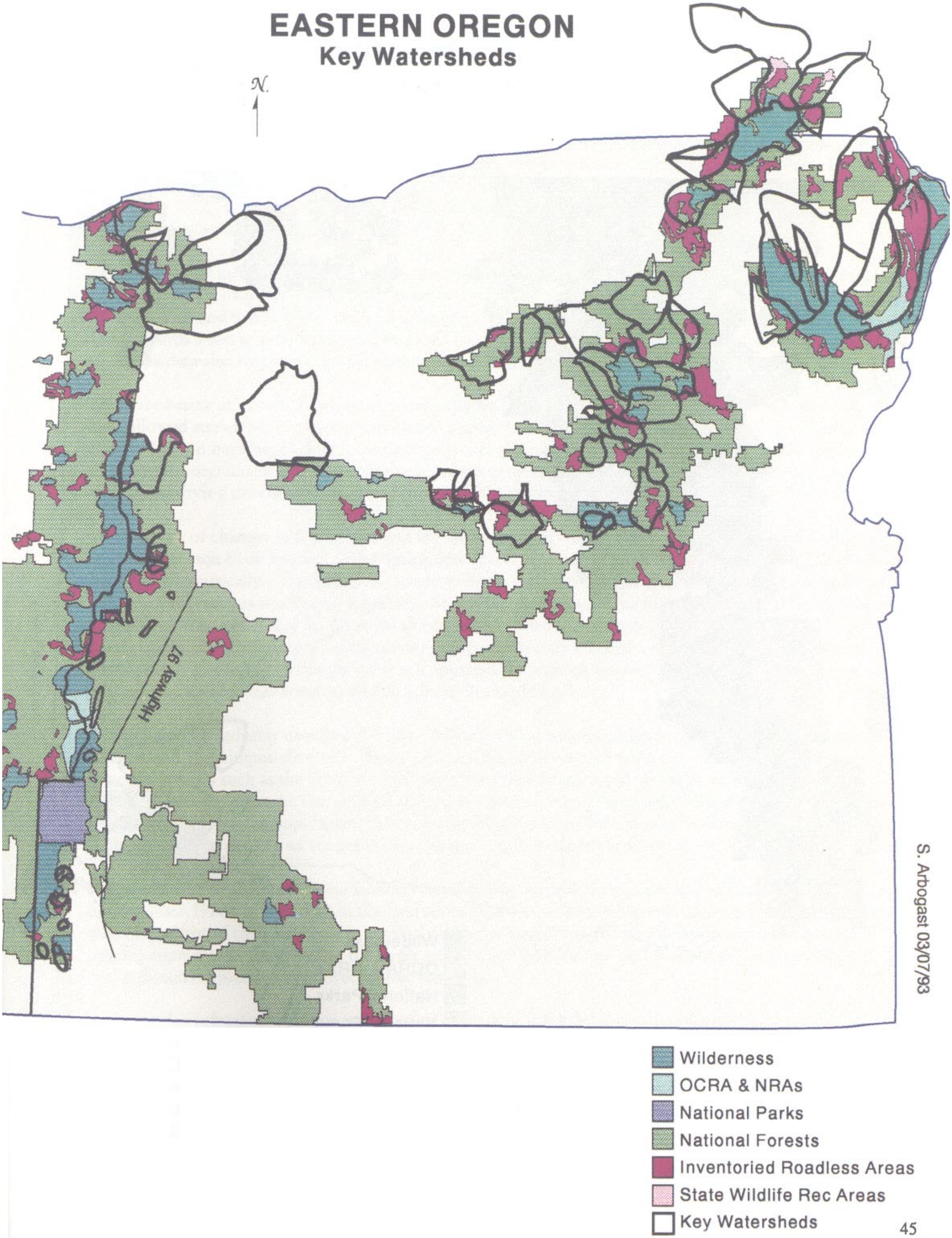
5	Red-band trout	Spr	Spring race
6	Chum salmon	Sum	Summer race
7	Oregon chub	Fal	Fall race
8	Pink salmon	Win	Winter race
9	Sockeye salmon		
10	Olympic mudminnow		

Common name	Scientific name
Chinook salmon	*Oncorhynchus tshawytscha*
Coho salmon	*O. kisutch*
Steelhead trout	*O. mykiss*
Sea-run cutthroat trout	*O. clarki clarki*
West-slope cutthroat trout	*O. clarki lewisi*
Sockeye salmon	*O. nerka*
Chum salmon	*O. keta*
Pink salmon	*O. gorbuscha*
Red-band trout	*O. mykiss gibbsi*
Bull trout	*Salvelinus confluentus*
Oregon chub	*Oregonichthys crmeri*
Olympic mudminnow	*Novumbra hubbsi*

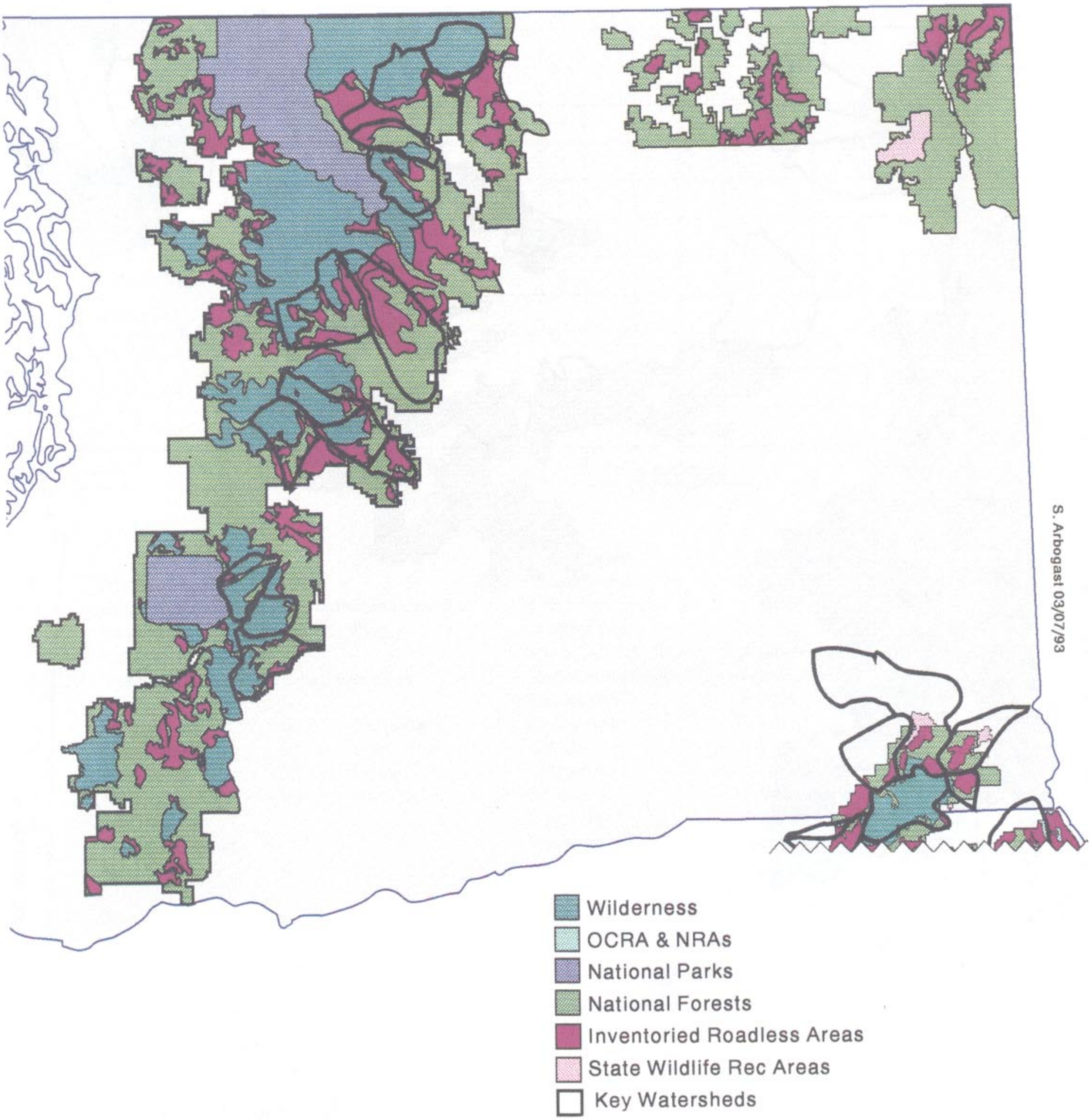
[1] 1/4 mile no-harvest area on each side of stream.
[2] Includes Wenatchee R., White R., Nepeequa R., and Chiwawa R.
[3] Includes Rock Cr., badger Cr., Tygh Cr., and Jordan Cr.
[4] Administered by Umatilla NF (Oregon), but located in Washington.

Figure 18 (next page). Key watersheds for eastern Oregon.

Figure 19 (following page). Key watersheds for eastern Washington.


EASTERN OREGON
Key Watersheds
N.
Highway 97
S. Arbogast 03/07/93
Wilderness
OCRA & NRAs
National Parks
National Forests
Inventoried Roadless Areas
State Wildlife Rec Areas
Key Watersheds

EASTERN WASHINGTON
Key Watersheds



DISCUSSION

In this paper, we have examined how fish habitat has changed in select river basins of eastern Oregon and Washington over the past 50 years. These snapshots over time show considerable variability in how fish habitats have been affected by natural and human-induced disturbance. Although quantifiable relations between land-use practices and long-term trends in fish abundance have been difficult to obtain (Bisson and others 1992), the body of literature concludes that land-use practices have simplified fish habitat (Bisson and others 1992, Hicks and others 1991, Meehan 1991).

"Simplification" means a loss in the frequency and diversity of habitat types-pools, riffles, side-channels-decreased large woody debris and other structural elements, and declining water quality (higher temperatures) (Reeves and Sedell 1993). Although the general trend throughout the Columbia River basin has been towards a loss in pool habitat on managed lands and stable or improving conditions on unmanaged lands, the data also suggest a regional pattern to this change.

The river basins of eastern Washington apparently had a period of recovery after World War I, which may have allowed stream habitat to show moderate improvement since then. In contrast, the river basins of eastern Oregon have been affected continuously over the entire settlement period (1850-1930), explaining their current degraded state. The cumulative effects of these impacts have operated collectively, exacerbating or magnifying the effect of any one factor operating in isolation.

Our analysis of changes in fish habitat and the chronology of settlement and land use suggests a different response for each basin because of the timing and duration of human disturbance events, acting individually and synergistically. The historical records indicate that during the settlement era, the major influence on stream ecosystems was livestock grazing. Sheep and cattle grazed the high meadows and floodplains year-round in numbers that far exceeded the capacity of the range (Platts 1991, U.S. EPA 1990). Anecdotal reports and photographs depict summer ranges so heavily stocked with sheep, they appear to be snow drifts. The legacy of this period is still apparent throughout the eastside as evidenced by the terraced hillslopes caused by near constant trodding by millions of hoofs.

As the livestock industry declined after World War I, this similarity in land-use histories for eastern Oregon and Washington diverged. While eastern Oregon developed more rapidly, being along the main migration routes such as the Oregon Trail, most of eastern Washington was relatively isolated. As the livestock industry declined, the timber industry in eastern Oregon expanded to supply the railroads and support the burgeoning population. After World War II, the timber industry boomed, and it has been increasing since then. As an economic base, timber has dominated the forested regions of eastern Oregon.

In eastern Washington, the timber industry developed at a much more moderate pace, not really booming until the late 1970s, as is evident in the land allocations of the Wenatchee and Okanogan National Forests: over 65 percent of their land base is currently under wilderness or roadless designation. Most human development was concentrated in the larger river valleys (the Yakima and Wenatchee), where irrigated orchards and croplands were the economic base.

Based on this information, along with data on changes in fish habitat and the relative health of fish runs in these two regions, fish habitat appears to be in far better condition in eastern Washington than in eastern Oregon. This argument is further strengthened by the stable condition of anadromous runs in eastern Washington, with the exception of the Yakima system; anadromous species in eastern Oregon are listed as threatened species or of special concern (see Nehlsen and others 1991). Anadromous runs to these regions are affected both by fishing and by 8 to 10 mainstem Columbia River dams.

These generalizations must be viewed with caution. A broad regional overview of this nature will fail to identify particular known areas of concern. Clearly, fish stocks in the Yakima basin are imperiled, but primarily because of mainstem flow issues and irrigation diversions (Fast and others 1991). On the other hand, anadromous runs to the Wenatchee and Methow River basins appear to be stable, with the exception of summer steelhead. In eastern Oregon, we know of no anadromous runs that are stable. All are declining.

Strategies to protect and restore anadromous and resident fish populations and their habitat must be based on a watershed approach that protects remaining habitat and restores historical habitats (Johnson and others 1991, Reeves and Sedell 1992). Currently, the Forest Service is developing a strategy (PACFISH) to be applied across the range of anadromous salmonids throughout the west (U.S. Department of Agriculture, Forest Service 1992). Restoration activities that deal with issues of forest health must incorporate a watershed strategy that recognizes the critical linkages between the uplands, riparian zones, and fish habitat. Active restoration and protection of eastern Oregon and Washington watersheds is critical if high-quality fish habitat is to be restored and maintained.

ACKNOWLEDGMENTS

The authors thank the fine people who assisted in completing this project: The field crews, who worked long hours under difficult circumstances to collect the data-Eric Brown, Kelly Christiansen, Mark Garner, Lisa Heigh, Luke Hunt, Janet Hutson, Andy Johnson, Kerry Lundsten, Chris Moyer, Todd Reeves, and Kirstin Schumaker; Mark Chambers, Kelly Christiansen, and Mark Garner, who provided assistance with data analysis; the staff of the Aquatic/Lands Interaction Project at the Pacific Northwest Research Station in Corvallis, Oregon, whose support made our jobs easier-Kelly Burnett, Jon Grunbaum, Bruce Hansen, Dave Price, and Linda Yung; and the many National Forest system people, who helped us along the way-Wenatchee National Forest: Ken MacDonald, Dan Rife, and Kent Russell; Okanogan National Forest Jim Spotts; and the Wallowa-Whitman National Forest John Anderson and Paul Boehne.

REFERENCES

Anderson, J. Personal Communication. U.S. Department of Agriculture, Forest Service, Wallowa-Whitman National Forest.

Anderson, J.W. 1992. Upper Grande Ronde River-anadromous fish habitat protection, restoration, and monitoring plan. [Location of publisher unknown]: [Publisher unknown]. 22 p. In cooperation with: Wallowa-Whitman National Forest, Pacific Northwest Research Station, Oregon Department of Wildlife, Columbia River Inter-Tribal Fish Commission, Confederated Tribes of the Umatilla Indian Reservation, Nez Perce Tribe, and Oregon State University.

Bisson, P.A.; Bilby, R.E.; Bryant, M.D. [and others]. 1987. Large woody debris in forested streams in the Pacific Northwest: past, present, and future. In: Salo, E.O.; Cundy, T.W., eds. Streamside management: forestry and fishery interactions: proceedings of a symposium: [dates of meeting unknown]; [location of meeting unknown]. Seattle, WA: University of Washington, Institute of Forest Resources: 143-190.

Bisson, P.A.; Quinn, T.P.; Reeves, G.H.; Gregory S.V. 1992. Best management practices, cumulative effects, and long-term trends in fish abundance in Pacific Northwest river systems. In: Naiman, R.J., ed. Watershed management: balancing sustainability and environmental change. Seattle, WA: [Publisher unknown]: 189-232.

Bisson, P.A.; Sedell, J.R. 1984. Salmonid populations in streams in clear-cut vs. old-growth forests of western Washington. In: Meehan, W.R.; Merrell, T.R.; Hanley, T.A., eds. Fish and wildlife relationships in old-growth forests. Proceedings of a symposium; 1982 April 12-15; Juneau, AK. [Location of publisher unknown]: American Institute of Fishery Research Biologists: 121-129

Bjornn, T.C.; Reiser, D.W. 1991. Habitat requirements of salmonids in streams. American Fisheries Society Special Publication 19: 83-138.

Boehne, P. Personal Communication. U.S. Department of Agriculture, Forest Service, Wallowa-Whitman National Forest, La Grande, OR.

Bryant, F.G. 1949. A survey, of the Columbia River and its tributaries with special reference to its fishery resources. No. 2: Washington streams from the mouth of the Columbia River to and including the Klickitat River (area I). Spec. Scien. Rep. 62. [Location of publisher unknown]: U.S. Fish and Wildlife Service. 110 p.

Bryant, F.G.; Parkhurst, Z.E. 1950. Survey of the Columbia River and its tributaries. No. 4: area III, Washington streams from the Klickitat and Snake Rivers to Grande Coulee Dam, with notes on the Columbia and its tributaries above Grande Coulee Dam. Spec. Scien. Rep. Fish. 37. [Location of publisher unknown]: U.S. Fish and Wildlife Service. 108 p.

Carter, S. 1990. A history of livestock grazing on the Wenatchee National Forest. Unpublished report for the Supervisors Office, Wenatchee National Forest. 23 p.

Chapman, D.W. 1988. Critical review of variables used to define effects of fine in redds of large salmonids. Transactions of the American Fisheries Society. 115: 662-670.

Cooperative Western Range Study. 1938. An analysis of range problems in Kittitas county, WA and a plan for their solutions. [Location of publisher unknown]: [Publisher unknown].

Ehinger, B. Personal Communication. U.S. Department of Agriculture, Forest Service, Wenatchee National Forest, Wenatchee, WA.

Elmore, W.; Beschta, R.L. 1987. Riparian areas: perceptions in management. Rangelands. 9(6): 260-265.

Everest, F.H.; Armantrout, N.B.; Keller, S.M. [and others]. 1985. Salmonids. In: Brown, E.R. ed. Management of wildlife and fish habitats in forests of western Oregon and Washington. Part 1: Chapter narratives. Portland, OR: U.S. Department of Agriculture, Forest Service, Pacific Northwest Region. p. 199-230.

Everest, F.H., Beschta, R.L.; Scrivener, J.C.; Koski, K.V. [and others]. 1987. Fine sediment and salinonid production: a paradox. In: Salo E.O.; Cundy, T.W., eds. Streamside Management: forestry and fishery interactions: Proceedings of a symposium; [dates of meeting unknown]: [location of meeting unknown]. Seattle, WA: University of Washington Institute of Forest Resources; 98-142.

Farnell, J.E. 1979. Grande Ronde navigability study. Salem, OR: Division of State Lands. 39 p.

Fast, D.; Hubble, J.; Kohn, M.; Watson, B. 1991. Yakima River spring Chinook enhancement study. [Location of publisher unknown]: [Preparer unknown]; final report; DOE/BP39461-9. 345 p.

Frissell, C.A. 1990. Draft list of threatened and endangered fishes of the Pacific Northwest and California, arranged by drainage basin. [Location of file unknown]. 60 p.

Fulton, L.A. 1968. Spawning areas and abundance of Chinook salmon (*Oncorhynchus tshawytscha*) in the Columbia River basin-past and present. Spec. Scien. Rep. Fish. 571. [Location of publisher unknown]: U.S. Fish and Wildlife Service. 26 p.

Fulton, L.A. 1970. Spawning areas and abundance of steelhead trout and coho, sockeye, and chum salmon in the Columbia River basin--past and present. Spec. Scien. Rep. Fish. 618. [Location of publisher unknown]: National Oceanic and Atmospheric Administration. 37 p.

Grant, G.E. 1986. Downstream effects of timber harvest activities on the channel and valley floor morphology of western Cascade streams. Baltimore, MD: Johns Hopkins University. 364 p. Ph.D. dissertation.

Gregory, S.; Ashkenas, L. 1990. Riparian management guide: Willamette National Forest. [Location of publisher unknown]: U.S. Department of Agriculture, Forest Service, Pacific Northwest Region. 120 p.

Gregory, S.V.; Lamberti, G.A.; Moore. K.S. 1989. Influence of valley landforms on stream ecosystems. In: Proceedings of the California riparian systems conference: protection, management, and restoration for the 1990; 1988 September 22-24; Davis, CA. Gen. Tech. Rep. PSW-110. Berkeley, CA: Pacific Southwest Forest and Range Experiment Station, Forest Service, U.S. Department of Agriculture: 3-8.

Gregory, S.V.; Swanson, F.J.; McKee, W.A.; Cummins, K.W. 1991. An ecosystem perspective of riparian zones. BioScience.41(8):540-550.

Harr, R.D. 1983. Potential for augmenting water yield through forest practices in western Washington and western Oregon. Water Resources Bulletin. 19(3): 383-393.

Heede, B. 1980. Stream dynamics: an overview for land managers. Gen. Tech. Rep. RM-72. Fort Collins, CO: U.S. Department of Agriculture, Forest Service. 26 p.

Heimann, D.C. 1988. Recruitment trends and physical characteristics of coarse woody debris in Oregon Coast Range streams. Corvallis, OR: Oregon State University. M.S. thesis.

Hicks, B.J.; Hall, J.D.; Bisson, P.A.; Sedell, J.R. 1991. Responses of salmonids to habitat change. American Fisheries Society Special Publication. 19: 483-518.

Higgins, D.A.; Tiedemann, A.R.; Quigley, T.M.; Marx, D.B. 1989. Streamflow characteristics of small watersheds in the Blue Mountains of Oregon. Water Resources Bulletin. 25(6) 1131-1149.

Howell, P.J.; Buchanan, D.V., eds. 1992. Proceedings of the Gearheart Mountain bull trout workshop; [dates of meeting unknown]; [location of meeting unknown]. [Location of publisher unknown]: Oregon Chapter of the American Fisheries Society. 67 p.

James, G. 1984. Grande Ronde River basin: recommended salmon and steelhead habitat improvement measures. Pendleton, OR: Confederated Tribes of the Umatilla Indian Reservation. 59 p.

Johnson, K.N.; Franklin, J.F.; Thomas, J.W.; Gordon, J. 1991. Alternatives for management of late-successional forests of the Pacific Northwest. A Report to the Agricultural Committee and the Merchant Marine and Fisheries Committee of the U.S. House of Representatives. 59 p.

Lamberti, G.A.; Gregory, S.V.; Ashkenas, L.R.; Wildman, R.C. [and others]. 1989. Influence of channel morphology on retention of dissolved and particulate matter in a Cascade mountain stream. In: Proceedings of the California riparian systems conference: protection, management, and restoration for the 1990; 1988 September 22-24; Davis, CA. Gen. Tech. Rep. PSW-110. Berkeley, CA: Pacific Southwest Forest and Range Experiment Station, Forest Service, U.S. Department of Agriculture: 256-261.

Lisle, T.E. 1986. Stabilization of a gravel channel by large streamside obstructions and bedrock bends, Jacoby Creek, northwestern, California. Geological Society of America Bulletin. 87: 999-1011.

MacDonald, L.A.; Smart A.; Wissmar R.C. 1991. Monitoring guidelines to evaluate effects of forestry activities on streamsain the Pacific Northwest and Alaska. EPA/910/9-91-001. Ann Arbor, MI: Edwards Brothers Press. 166 p.

McIntosh, B.A. 1992. Historical changes in anadromous fish habitat in the upper Grande Ronde River, Oregon, 1941-1990. Corvallis, OR: Oregon State University. 88 p. M.S. thesis.

Meehan, W.R., ed. 1991. Influences of forest and rangeland management on salmonid fishes and their habitat. Spec. Publ. 19. [Location of publisher unknown]: American Fisheries Society. 751 p.

Moore, K.S.; Gregory, S.V. 1989. Geomorphic and riparian influences on the distribution and abundance of salmoriids in a Cascade mountain stream. In: Proceedings of the California riparian systems conference: protection, management, and restoration for the 1990; 1988 September 22-24; Davis, CA. Gen. Tech. Rep. PSW-110. Berkeley, CA: Pacific Southwest Forest and Range Experiment Station, Forest Service, U.S. Department of Agriculture: 256-261.

Mullan, J.W.; Williams, K.R.; Rhodus, T.; Hillman, W. [and others]. 1992. Production and habitat of salmonids in mid-Columbia River tributary streams. Monogr. I. [Location of publisher unknown]: U.S. Fish and Wildlife Service. 489 p.

Naiman, R.J. [and others]. 1992. Fundamental elements of ecologically healthy watersheds in the Pacific Northwest coastal ecoregion. In: Naiman, R.J., ed. Watershed management: balancing sustainability and environmental change. Seattle, WA: 127-188.

Nehlsen, W.; Williams, J.E.; Lichatowich, J.A. 1991. Pacific salmon at the crossroads: stocks at risk from California, Oregon, Idaho, and Washington. Fisheries. 16(2) 4-21.

Northwest Power Planning Council. 1986. Council staff compilation of information on salmon and steelhead losses in the Columbia River basin. Portland, OR. 252 p.

Northwest Power Planning Council. 1989. Yakima River subbasin salmon and steelhead plan: draft report. Portland, OR. 212 p.

Northwest Power Planning Council. 1990. Grande Ronde River subbasin salmon and steelhead production plan: draft report. Portland, OR. 129 p.

Oregon Department of Fish and Wildlife. 1987. Grande Ronde River basin fish habitat improvement plan. Portland, OR. 29 p.

Oregon Department of Forestry. 1992. Water classification and protection project: draft Report. [Location of publisher unknown]: 150 p.

Parkhurst, Z.E. 1950a. Survey of the Columbia River and its tributaries, part 6, area V: Snake River from the mouth through the Grande Ronde River. Spec. Scien. Rep. Fish. 39. [Location of publisher unknown]: U.S. Fish and Wildlife Service. 58 p.

Parkhurst, Z.E. 1950b. Survey of the Columbia River and its tributaries, part 7, area VI. Snake River from above the Grande Ronde River through the Payette River. Spec. Scien. Rep. Fish, 40. [Location of publisher unknown]: U.S. Fish and Wildlife Service. 95 p.

Parkhurst, Z.E. 1950c. Survey of the Columbia River and its tributaries, part 8, area VIII: Snake River above Payette River to upper Salmon Falls. Spec. Scien. Rep. Fish. 57. [Location of publisher unknown]: U.S. Fish and Wildlife Service. 19 p.

Parkhurst, Z.E.; Bryant, F.G Nelson, R.S. 1950. Survey of the Columbia River and its tributaries, part 3. Spec. Scien. Rep. Fish. 36. [Location of publisher unknown]: U.S. Fish and Wildlife Service. 103 p.

Platts, W.S. 1991. Livestock grazing. American Fisheries Society Special Publication. 19: 389-424.

Plummer, F.G. 1902. Forest conditions in the Cascade range, Washington. Prof. Pap. No. 6, Series H, For. 3. [Location of publisher unknown]: U.S. Geological Survey. 41 p.

Reeves, G.H.; Everest, F.H.; Sedell, J.R. [In press]. Diversity of juvenile anadromous salmonid communities in basins in coastal Oregon with different levels of timber harvest. Transaction of the American Fisheries Society.

Reeves, G.H.; Sedell, J.R. 1992. An ecosystem approach to the conservation and management of freshwater habitat for anadromous salmonids in the Pacific Northwest. Transactions of the 57th North American Wildlife and Natural Resource Conference. [Issue unknown]: 408-415.

Rich, W.H. 1948. A survey of the Columbia River and its tributaries with special reference to the management of its fishery resources. Spec. Scien. Rep. 51. [Location of publisher unknown]: U.S. Fish and Wildlife Service. 25 p.

Sedell, J.R.; Beschta, L. 1991. Bringing back the "bio" in bioengineering. American Fisheries Society Symposium. 10: 160-175.

Sedell, J.R.; Everest, F.H. 1990. Historic changes in habitat for Columbia River basin salmon under study for TES listing: draft report. On file with: Pacific Northwest Research Station, U.S. Department of Agriculture, Forest Service, Corvallis, OR.

Sedell, J.R.; Leone, F.N.; Duval, W.S. 1991. Water transportation and storage of logs. American Fisheries Society Special Publication. 19: 325-367.

Sedell, J.R.; Reeves, G.H.; Hauer, F.R.; Stanford, J.A.; Hawkins, C.P. 1990. Role of refugia in recovery from disturbances: modern fragmented and disconnected river systems. Environmental Management 14: 711-724.

Sheldon, A.I. 1988. Conservation of stream fishes: patterns of diversity, rarity, and risk. Conservation Biology. 2: 149-156.

Skovlin, J.M. 1991. Fifty years of research progress: a historical document on the Starkey Experimental Forest and Range. Gen. Tech. Rep. PNW-GTR-266. Portland, OR: U.S. Department of Agriculture, Forest Service, Pacific Northwest Research Station. 58 p.

Smith, J. Personal Communication. University of Washington, Seattle, WA.

Smith, J.E. 1993. Changes in stream and riparian habitat characteristics between 1935 and 1990 in two eastern Cascade streams. Seattle, WA: University of Washington. M.S. thesis.

Spotts, J. Personal Communication. U.S. Department of Agriculture, Forest Service, Okanogan National Forest, Okanogan, WA.

Thompson, K. 1976. Columbia basin fisheries; past, present, and future. Columbia River Fisheries Project Report. [Location of publisher unknown]: Pacific Northwest Regional Commission. 41 p.

Uebelacker, M.L. 1980. Land and life in the Naches River basin: a cultural resource overview. [Location of publisher unknown]: [Publisher unknown]; report to the Wenatchee National Forest; contract 00--5GG9-00450. 390 p.

U.S. Department of Agriculture, Forest Service. 1989. Final environmental impact statement; land and resource management plan; Okanogan National Forest. Okanogan, WA. [Publisher unknown]. 4 Vol.

U.S. Department of Agriculture, Forest Service. 1990. Final environmental impact statement; land and resource management plan; Wenatchee National Forest. Wenatchee, WA. [Publisher unknown].4 Vol.

U.S. Department of Agriculture, Forest Service. 1991. Columbia river basin anadromous fish habitat management policy and implementation guide. [Location of publisher unknown]. U.S. Department of Agriculture, Forest Service, Regions 1, 4, and 6. 30 p.

U.S. Department of Agriculture, Forest Service. 1992. Background report for development of the Forest Service management strategy for Pacific salmon and steelhead habitat. [Location of publisher unknown]. Pacific Salmon Work Group and Field Team. 41 p.

U.S. Environmental Protection Agency. 1990. Livestock grazing on western riparian areas. 1990-775-443/ 21/661. [Location of publisher unknown]: Region 8. 45 p.

Wickman, B.E. 1991. Forest health in the Blue Mountains: insects and diseases: draft report. U.S. Forest Service, Pacific Northwest Research Station, La Grande, OR.

Williams, J.E.; Johnson, J.E.; Hendrickson, D.A. [and others]. 1989. Fishes of North America endangered, threatened, or of special concern: 1989. Fisheries. 14(6): 2-20.

Wissmar, R.C.; Smith, J.E.; McIntosh, B.A. [and others]. 1993. Ecological health of river basins in forested regions of eastern Washington and Oregon. In: Hessburg, P.F., tech. ed. Eastside forest ecosystem health assessment--Volume III: Assessment. Portland, OR: U.S. Department of Agriculture, Forest Service, Pacific Northwest Research Station.

GLOSSARY[1]

Animal Unit Month (AUM)-Amount of feed or forage required by one animal-unit grazing on a pasture for 1 month; an "animal-unit" is one mature (454-kg) cow or the equivalent of other animals, based on an average daily forage consumption of 12 kg dry matter; an AUM is also defined as 1-month tenure of one animal-unit.

Channelization-Human-caused alterations to the stream channel that cause the channel to be fixed in place, such as levees, dikes, trenching, and rip-rap.

Cover-Any feature that provides protective concealment for fish and wildlife; cover may consist of live or dead vegetation, or geomorphic features such as boulders and undercut banks; cover may be used for escape from predators, feeding, or resting.

Geomorphology-The geological study of land-form evolution and configuration.

Headwater (headwall)-Steep slope at the head of a valley.

Large woody debris (LWD)-Any piece of woody material that intrudes into a stream channel, the smallest diameter of which is greater than 10 cm, and has a length greater than 1 m.

Orographic-Pertaining to mountains, especially as the affect precipitation that results when moisture-laden air encounters mountains and is forced to rise over them.

Reach-Section of stream between two specified points.

Refugia-Areas where animals or plants can survive catastrophic disturbance events.

Resting Habitat-Areas used by adult fish during their migration to spawning habitat.

Roughness-Features found in stream channels that interact with streamflow to reduce flow, cause channel scour, or both. Examples include boulders, large woody debris, vegetation, and meander bends.

Salmonids-Fish of the family Salmonidae, including salmon, trout, chars, whitefish, ciscoes, and grayling; in general usage, the term often refers to salmon, trout, and chars.

Salvage-The cutting of trees that are dead, dying, or deteriorating (because they are "overmature," or materially damaged by fire, wind, insects, fungi, or other injurious agencies) before they lose their commercial timber value.

Scour-Local removal of material from streambeds by flowing water.

Smolt-Juvenile salmonid 1 or more years old that has undergone physiological changes to cope with marine environment; the seaward migrant stage of an anadromous salmonid.

Spawning Habitat-Areas used for spawning by adult fish.

Streamflow (discharge; instream flow)-A measure of the volume of water flowing past a reference point per unit time (such as cubic meters^3 per second).

Watershed (also catchment area, basin, drainage area)-Total land area draining to any point in a stream, as measured on a map, aerial photo, or other horizontal, two-dimensional projection.

[1] After Meehan (1991) and Gregory and Ashkenas (1990).

McIntosh, Bruce A.; Sedell James R.; Smith, Jeanette E.; Wissmar, Robert C.; Clarke, Sharon E.; Reeves, Gordon H.; Brown, Lisa A. 1994. Management history of eastside ecosystems; changes in fish habitat over 50 years, 1935 to 1992. Gen. Tech. Rep. PNW-GTR-321. Portland, OR: U.S. Department of Agriculture, Forest Service, Pacific Northwest Research Station. 55 p. (Everett, Richard L., assessment team leader; Eastside forest ecosystem health assessment; Hessburg, Paul F., science team leader and tech. ed., Volume II I: assessment.)

From 1934 to 1942, the Bureau of Fisheries surveyed over 8000 km of streams in the Columbia River basin to determine the condition of fish habitat. To evaluate changes in stream habitat over time, a portion of the historically surveyed streams in the Grande Ronde, Methow, Wenatchee, and Yakima River basins were resurveyed from 1990 to 1992. It is clear from the data gathered that land-use practices have degraded fish habitat throughout eastern Washington and Oregon. Strategies to protect, restore, and maintain anadromous and resident fish populations and their habitat, must be based on a watershed approach that protects the remaining habitat and restores historical habitats.

Keywords: Anadromous fish, fish habitat, historical changes, land-use practices, pools, restoration, stream-flow.

Pacific Northwest Research Station
333 S.W. First Avenue
P.O. Box 3890
Portland, Oregon 97208-3890

U.S. Department of Agriculture
Pacific Northwest Research Station
333 S.W. First Avenue
P.O. Box 3890
Portland, OR 97208