Historical Changes in Pool Habitats in the Columbia River Basin

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By

Bruce A. McIntosh
James R. Sedell
Russell F. Thurow
Sharon E. Clarke
Gwynn L. Chandler

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This research is the culmination of the efforts of many fine people. It is to them that we owe our eternal gratitude for their help in making this project a success. This research is dedicated to all the individuals that worked on the original Bureau of Fisheries Survey. They toiled many long hours under difficult circumstances to complete this study, only to have the data sit in boxes for 50 years, unknown to the rest of the world. We are very proud to follow in their footsteps and bring their efforts to life. A special thanks to Dr. David Frey, for coming to Corvallis and reliving his memories of working on the survey. It is our hope this work is some small consolation for your fine efforts so many years ago.

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ABSTRACT

Knowledge of how stream habitats change over time in natural and human-influenced ecosystems at large, regional scales is currently limited.' A historical stream survey (1934-1945) was compared to current surveys to assess changes in pool habitats in the Columbia River, basin. Streams from across the basin, representing a wide range of geologies, stream sizes and land-use histories, were used to evaluate habitat change. We classified streams as managed or unmanaged, based on their land-use histories. Managed basins were watersheds managed predominantly for multiple-use (e.g., timber harvest, livestock grazing) and unmanaged basins were minimally affected by human disturbance (e.g., wilderness/roadless areas). The quantity and quality of pool habitats increased or remained the same in unmanaged streams, and decreased in managed streams since the 1930s. Despite differences in stream size and land-use history, the magnitude and direction of these changes were consistent. In addition, the decrease in pool habitats did not differ between public and private lands. Only where entire watersheds, or at least the headwaters, were designated roadless/wilderness areas did pool habitats consistently remain unchanged or increase. Ecoregions were used to assess regional patterns to these changes. Our analysis showed that pool habitats decreased in all Ecoregions except the North Cascades Ecoregion. Regional land-use histories were developed for the study streams. The overgrazing of most rangelands had been documented by 1900. Grazing practices began to change after 1930, but current information suggests that. while uplands have improved, riparian areas have not. By World War II, stream habitats had been affected by the loss of riparian vegetation, large woody debris, and aquatic habitats due to splash dams, log drives, and riparian timber harvest. Timber harvest expanded to the uplands after World War II, as the demand for timber expanded. Rapidly developing road networks increased runoff and sedimentation,

which continued the impact of timber harvest on already damaged stream ecosystems. Almost 90% of managed streams had roads along the channel or within the floodplain. "Stream improvements," such as channelization and stream cleaning, also affected stream ecosystems. We concluded that the chronic and persistent effects of land-use practices had simplified stream channels and reduced habitat complexity in most managed watersheds in the Columbia River basin.

INTRODUCTION

The widespread declines in the native fish fauna of the Pacific Northwest since Euro-American settlement have been well documented (Frissell, 1993; National Research Council, 1995; Nehlsen et al., 1991; The Wilderness Society, 1993; Williams et al., 1989). While dams, hatchery practices, and over-exploitation by sport and commercial fisheries have contributed to these declines, the common denominator for both anadromous and non-anadromous species is 'the degradation of aquatic habitats. The most cited cause for the decline of aquatic ecosystems in the western United States is the cumulative effect of land-use practices (Henjum et al., 1994; Nehlsen et al., 1991; U.S. Department of Agriculture, Forest Service, 1993; Williams et al., 1989). This conclusion has been based on many studies of paired watersheds and before-and- after studies that have generally evaluated the effects of one or a few practices on aquatic ecosystems. Ralph et al. (1994) concluded that such studies have suffered from limited scope (i.e., small spatial scales), lack of historical baselines, and replicable measures to compare streams. The study reported on in this paper provides the first published report quantifying changes in stream habitats across large spatial and temporal scales.

Clear examples of the cumulative effects of land-use practices on aquatic ecosystems have only been shown in the most degraded rivers (Bisson et al., 1992). Examples include the South Fork Salmon River (Megahan et al., 1992) and the Alsea River (Hall et al., 1987). Land-use practices affect aquatic ecosystems by altering sediment supply, channel morphology, large woody debris, riparian vegetation, and water quality. The effects are often similar, whether they are the result of logging, mining, livestock grazing, agriculture, or urbanization (Hicks et al., 1991). Where these effects have been studied, simplification of stream channels and loss of habitat complexity has been the trend (Bisson et al., 1992). Fish habitat simplification was defined by Reeves et al. (1993) as "a decrease in the range and variety of hydraulic conditions (Kaufmann, 1987) and reductions in structural elements (Bisson et al., 1987), frequency of habitats, and diversity of substrates (Sullivan et al., 1987)."

To evaluate the effects of natural and anthropogenic disturbances on aquatic ecosystems, long-term monitoring data are essential (Sedell and Luchessa, 1982). Research by Sedell and others (Sedell et al., 1988; Sedell and Duvall, 1985; Sedell and Froggatt, 1984; Sedell and Luchessa, 1982) pioneered the use of historical records to document the effects of Euro-American development on aquatic ecosystems. They documented the extent of splash dams and log drives in the Pacific Northwest, removal of debris from stream channels, and the loss of riparian forest and channel complexity in the Willamette River basin. More recent efforts have used aerial photography to quantify changes in aquatic characteristics and relate them to natural and human-caused disturbances (Beschta, 1983a and b; Grant, 1988; Lyons and Beschta, 1983; Minear, 1994; Ryan and Grant, 1991; Smith, 1993).

In 1987, the Pacific Northwest Research Station (U.S. Department of Agriculture, Forest Service) discovered a historical stream habitat survey collected by the Bureau of Fisheries (now National Marine Fisheries Service) from 'throughout the Columbia River basin. The Bureau of Fisheries survey inventoried more than 6,400 km of streams from 1934 to 1945. Their surveys were initiated to determine the condition of streams in the Columbia River basin that provided, or had provided, spawning and rearing habitat for anadromous salmonids (*Oncorhynchus* spp.). Spring chinook salmon (*Oncorhynchus tshawytscha*) was an emphasis of the surveys (Rich, 1948). These records are the earliest and most comprehensive documentation of the condition and extent of anadromous fish habitat available. Unlike most other historical surveys, these data were collected systematically, with replicable variables (e.g., pool and substrate classes), which enable a direct comparison to recent surveys (Bisson et al., 1992; McIntosh et al., 1994a,b).

Since 1987, the Pacific Northwest and Intermountain Research Stations (collectively called Forest Service Research for remainder of report) have been resurveying streams surveyed in the Bureau of Fisheries survey. Our objectives were: (1) to quantify changes in pool habitat in the Columbia River basin since the Bureau of Fisheries surveys, (2) to quantify where the change has occurred, and (3) to characterize, and quantify where possible, the disturbance history in the basin. Disturbance histories were analyzed to identify potential causal mechanisms for changes in pool habitat. The results from individual watersheds and select regions of the Columbia River basin have been published previously (McIntosh, 1992; McIntosh et al., 1994a, b; Minear, 1994; Peets, 1993; Smith, 1993). This paper summarizes the changes that have occurred throughout the Columbia River basin.

These surveys allow us to evaluate changes in pool habitats in large basins, across a diverse region, with different land management histories, in a consistent, replicable manner. We acknowledge that many study streams had already been affected by land use practices at the time of the Bureau of Fisheries survey. In addition, wilderness -and roadless areas have been affected by grazing, mining and fire suppression. Despite these concerns, the key question remains, have pool habitats changed over the past fifty to sixty years?

Pool habitats are the preferred habitat for most stream fishes (Beschta and Platts, 1986; Elser, 1968; Lewis, 1969). We do not mean to imply that pools are the only habitats necessary for fish. Clearly stream fishes have a variety of habitat requirements, depending on species, season, and life stage (Bisson et al., 1992; Sullivan et al., 1987). Nonetheless, pools are a critical habitat component for stream fishes. Pools provide rearing habitat for juvenile fish, resting habitat for adults (Bjornn and Reiser, 1991), and refugia from natural disturbances, such as drought, fire and winter icing (Sedell et al., **1990)**. Several studies have shown fish using cool pools to behaviorally thermoregulate during periods of thermal stress (Berman and Quinn, **1991;** Matthews et al., 1994; Nakamoto et al., 1994, Nielsen et al., 1994, Torgerson et al., 1995). Pool habitats also influence the diversity of stream fish communities (Bisson and Sedell, 1984).. As the volume and complexity (i.e., diversity of cover, hydraulic, and substrate conditions) of pools increases, the capacity to support a diversity of species and life stages also increases (Bisson et al., 1992; Bjornn and Reiser, 1991; Fausch and Northcote, 1992). In addition, complex pools produce greater biomasses of fish (Fausch and Northcote, 1992).

Our survey data provides information on the quantity and quality of fish habitat, both historically and present. We used large pools as indicators of the quantity of pool habitat and deep pools as indicators of habitat quality. Factors that 'affect habitat qualities include velocity, depth, substrate, and overhead cover (Bjornn and Reiser, 1991). Most pools in streams of the Pacific Northwest are formed by local obstructions (Sullivan et al., 1987), which create complex pool habitats (i.e., heterogeneity in depth, cover, substrate, and velocity). Deeper pools contribute to higher quality habitat, by providing refuge from terrestrial predators (Bisson et al., 1987) and summer low flows (Beschta and Platts, 1986). In addition, deeper pools increase fish community diversity, by allowing fish species and age classes to "layer" in the water column (Allee, 1982, in Bisson et al., 1987; Fraser, 1969).

In the 1990's, natural resource management in the United States is in the throes of a paradigm shift, attempting.to transition from an emphasis on resource extraction to a more holistic perspective based on ecosystem management. While the concepts of ecosystem management, sustainable development, adaptive management, and restoration ecology are being defined, an emphasis on the restoration of ecosystem connectivity and function to natural conditions is emerging. To undertake a more ecologically-based approach to natural resource management, Wissmar et al. (1994b) concluded that a key question to address was, "How have historical ecosystems functioned and how have human actions changed them?" We believe our research begins to answer some of these questions.

MATERIALS AND METHODS

We compared Bureau of Fisheries stream surveys to current stream surveys to assess changes in pool habitat in the Columbia River basin. The Forest Service Research study, conducted from 1987 to 1994, examined streams throughout the Columbia River basin, representing a broad range of geologic conditions, land ownerships, and land-use histories. In conducting the resurveys, we attempted to examine streams across the Pacific Northwest, to encompass as much variation as possible. We also assessed, where possible, the disturbance history, both natural and anthropogenic, of the study basins, to develop potential causal mechanisms for change.

Study Area

The Columbia River basin encompasses parts of seven states and one Canadian province, draining an area of 667,000 km^2. It is the second largest river in the United States in terms of discharge. Before Euro-American development, 23,598 km of streams were accessible to anadromous fish (Thompson, 1976). By 1976, dams had blocked access to 7,390 km of streams, decreasing available habitat by 31% (Pacific Northwest Regional Commission, 1976). In addition, much of the remaining habitat had been degraded by land-use practices (Northwest Power Planning Council, 1986).

We analyzed one hundred twenty streams in twenty-one river basins for changes in pool habitat (Figure 1). Stream segments ranged from 0.8 to 122.1 km in length (mean = 18.8 km, SD = 19.5) and stream size ranged from small headwater streams (drainage area < 50 km^2) to large rivers (drainage area > 4700 km^2). These river basins occur throughout the range of habitat available to

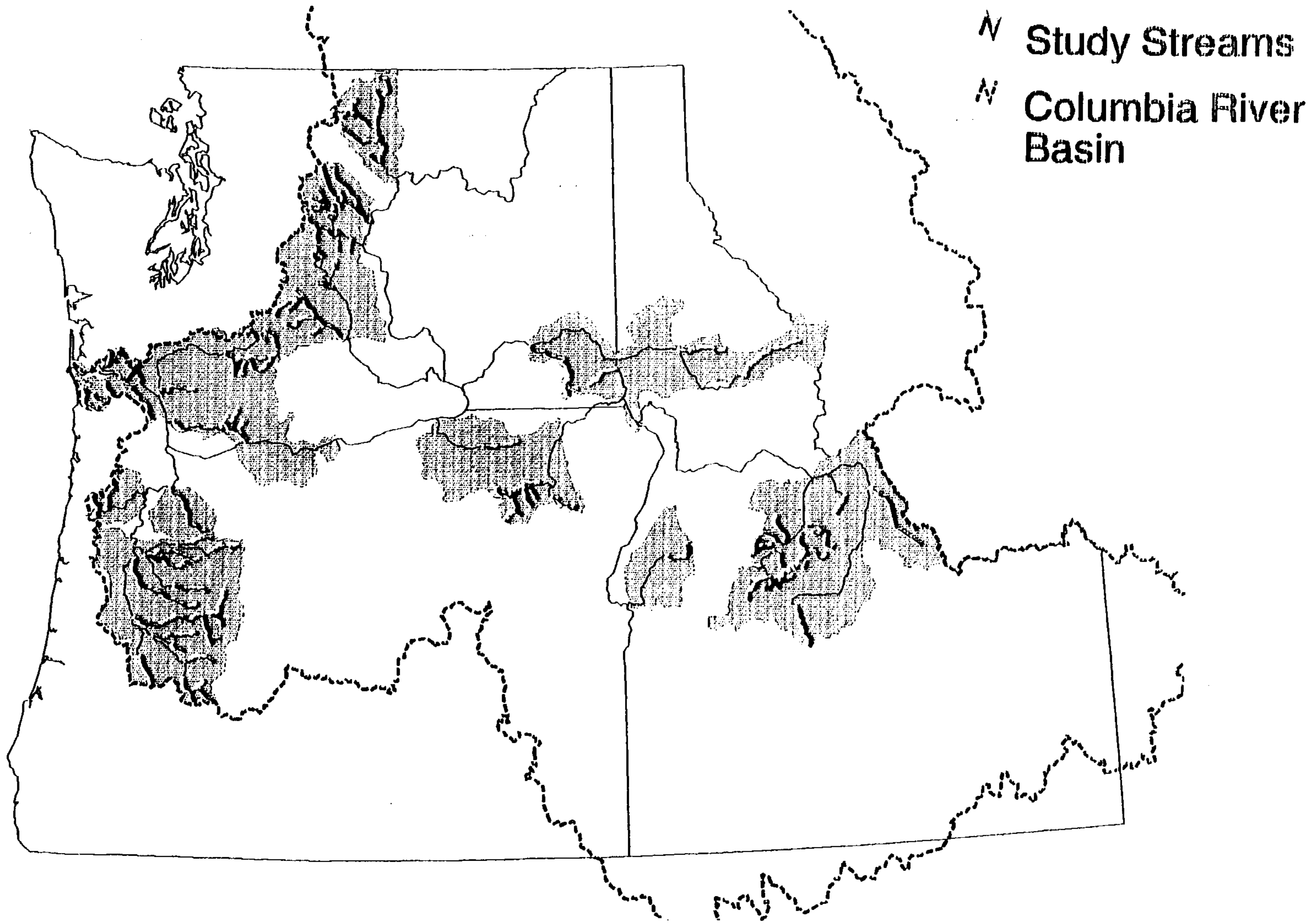


Figure 1. Map of Columbia River basin showing study basins and streams.

anadromous fish. Two large river basins, the Deschutes and John Day, were not surveyed in the Bureau of Fisheries survey.

Fish Habitat Surveys

The Bureau of Fisheries surveys were initiated to determine the condition of streams in the Columbia River basin that provided, or had provided, spawning and rearing habitat for anadromous salmonids (*Oncorhynchus* spp.) . Habitats for spring chinook salmon (*Oncorhynchus tshawytscha*) were emphasized in the surveys (Rich, 1948). These records are the earliest and most comprehensive documentation of the historical condition and extent of anadromous fish habitat available. The Bureau of Fisheries survey inventoried more than 6,400 km of streams in the Columbia River basin from 1934 to 1945.

Rich (1948) provided a detailed description of methods used in the Bureau of Fisheries survey. Data for the Bureau of Fisheries survey were systematically collected at continuous 91-m (100-yard) intervals for the entire section surveyed, generally from the mouth to the upstream extent of anadromy. Within each 91-m unit, the surveyors visually estimated channel width, bottom substrate composition by size-classes and percentage per class, and the number of pools based on size-classes (Table 3.1).

Historically surveyed streams were resurveyed using the Hankin-Reeves method (Hankin and Reeves, 1988) for stream inventories. This sampling technique stratifies streams according to geomorphic channel units (e.g., pools, riffles, glides; after Bisson et al., 1982). In the resurveys, morphological characteristics decided channel units, rather than on an arbitrary length, as in the Bureau of Fisheries survey. We have concluded that the pool classes in the Bureau of Fisheries surveys would have met the criteria for geomorphically defined pools. These pools were the large, deep, low velocity areas (i.e., "resting pools") in streams that geomorphologists and

Table 1. Pool classes used in the Bureau of Fisheries stream habitat surveys (Rich, 1948). SX, S=size class, X=l,...,n, denotes size class.

Class	Area/Depth Criteria
S1:	>40-m^2 area and > 1.8-m depth
s2:	≥20- to 40-m^2 area and ≥0.9- to 1.8-m depth
s3:	≥20- to 40-m' area and ≥0.7- to 0.9-m depth
s4:	≥20- to 40-m' and > 1.8-m depth
s5:	>40-m^2 area and ≥0.7- to 0.9-m depth
S6:	small pools in cascades and behind boulders

fisheries biologists typically call pools. It is our conclusion that the Hankin-Reeves method provides data that are comparable to the Bureau of Fisheries surveys.

Analysis of Pool Habitats

The Bureau of Fisheries pool classes were combined into two categories for the Forest Service Research study. These categories were large pools (220-m' area and 20.9-m depth; all S1, s2, and S4 pools) and deep pools (220-m' area and 21.8-m depth; all S1 and S4 pools). The S3, S5, and S6 pool classes were not used in this study due to narrower depth criteria (S3 and S5, ≥0.7- to 0.9-m depth) and no objective criteria for S6 pools. Eliminating these size classes reduced the potential for introducing observer bias and increased our confidence in duplicating the historical surveys. We felt that potential surveyor bias in the Bureau of Fisheries surveys were small when the larger, broader size classes were used.

Potential observer bias between surveys was addressed in two ways. First, we assumed that the broad size-classes in the Bureau of Fisheries surveys (S1, S2, and S4 pools) reduced observer error. The personnel who worked on the Bureau of

Fisheries surveys were seasoned fish biologists with extensive field experience. Most had surveyed hundreds of kilometers of streams over the duration of the study. In the summer of 1990, we brought the last living member from the Bureau of Fisheries study to Corvallis and interviewed him regarding the survey methodology. He is Professor David Frey, a world-renowned limnologist from the University of Indiana. He brought extensive diaries, along with sharp memories, of his two years with the Bureau of Fisheries, which included the surveys of the Grande Ronde, Salmon, and Willamette basins. Dr. Frey verified the methods they used, leaving us confident the data was replicable. Secondly, in the resurveys, habitat areas were calculated using the Hankin-Reeves method (Hankin and Reeves, 1988) and the maximum depth of each pool was measured. These methods reduced observer error in the resurveys.

Nonetheless, we attempted to account for hydrologic variability and any potential observer bias by imposing an intentional bias on the two surveys. Marginal pools were discarded in the Bureau of Fisheries survey but included in the resurveys. In the Bureau of Fisheries surveys, marginal pools were those noted as shallow or small by the surveyors. Marginal pools added to the resurveys were large pools 10.8-m depth and deep pools 21.6-m depth. In effect, the data represents a bias for fewer pools historically and more pools in the resurveys. While the bias for the resurveys is arbitrary, we believe this provides a consistent and conservative estimate (i.e., magnitude of change from Bureau of Fisheries to Forest Service Research surveys less) of changes in pool frequencies.

The frequency at which pools occur is a fundamental principle of fluvial geomorphology (Montgomery et al., 1995). In free-formed pool-riffle reaches, pools tend to occur every 5-7 channel widths (Keller and Melhorn, 1978; Leopold et al., 1964) and every 1-4 channel widths in steeper, step-pool reaches (Grant et al., 1990). Pools may be freely formed by the interaction of sediment and flow, or forced by local obstructions, such as large woody debris, bedrock, root masses, and debris jams, which cause local'scour (Beschta and Platts, 1986; Montgomery et al., 1995). Forced pool morphologies can increase the natural variability in pool spacing (Beschta and Platts, 1986), often reducing the distance between pools (Montgomery et al., 1995).

Our current knowledge indicates that most pools formed in forested streams are the result of structural elements (Sullivan et al., 1987), especially large woody debris (Montgomery et al., 1995). In addition, large woody debris loading, channel type, slope, and width control pool spacing in forested mountain streams (Montgomery et al., 1995). Less is known about pool formation in non-forested streams, such as the rangelands of the interior Columbia. We hypothesize that while some pools are free-formed, pool formation is largely forced by local obstructions. While large woody debris has a dominant role in forested streams, it is likely to be less important in non-forested streams. Riparian vegetation, such as willows, alders, and sedges are probably the dominant pool-forming elements in non-forested streams.

We attempted to account for the effect of stream size by stratifying the study streams using several surrogates for stream size. These included drainage basin characteristics (drainage area, Strahler (1964) stream order), hydrology (mean annual discharge), and channel characteristics (mean wetted channel width). Drainage area and stream order were derived from 1:100,000-scale U.S. Geological Survey (USGS) topographic maps and discharge data were obtained from USGS gauging stations. We calculated mean wetted channel widths from the Bureau of Fisheries survey to quantify channel width. No significant relationships were found between pool frequency and any of the measures of stream size.

This analysis may be incomplete, either due to inadequate measures of stream size, availability of data, or a poor understanding'of the processes that determine pool formation across such a wide range of stream sizes: For example, Montgomery and Buffington (1993) concluded stream order was a useful tool for describing channels within a watershed, but inadequate for comparing watersheds. This is due to differences in drainage densities between watersheds and inconsistencies in mapping of stream channels. We suspect measures of bankfull-width and channel gradient might be more appropriate, but were either unavailable or beyond the scope of this study. Despite the problems with using stream orders, we use stream order as a relative indicator of stream size for our study streams.

To analyze changes in large and deep pool.habitats, the pool data were standardized by calculating mean values (number of pools/kilometer surveyed) for each stream. These values were then used to calculate the grand mean (mean of the stream means), 25^{th} and 75^{th} quartiles of the grand mean, and range for the Bureau of Fisheries and PNW surveys. A paired two-sample t-test was used to test for differences in pool frequencies between the Bureau of Fisheries and Forest Service Research surveys. Before analysis, pool data were examined for possible violations of the assumptions of the Student's t-test (e.g., sample from a normal distribution) . The data were transformed using square root or log functions when the samples were not normally distributed.

We used 95% confidence intervals to classify which streams had increased, decreased, or shown no change in pool frequencies. Confidence intervals (CI) were calculated from the net change in pool frequencies between the two surveys and positioned around zero (no change). When the net change in pool frequencies from the Bureau of Fisheries to the resurveys was greater than the 95% CI, we concluded the change was statistically significant.

Stream Classification

Classification of Land Use and Ownership

To examine changes in fish habitat over time, individual streams were classified according to the land management history of the basin and ownership. We classified basins as either managed or unmanaged. Managed basins were watersheds managed predominantly for multiple-use (e.g., timber harvest, livestock grazing, agriculture, and mining). Unmanaged basins were minimally affected by human disturbance (e.g., wilderness and roadless areas, limited entry). We recognize that many unmanaged basins were affected by grazing and mining historically and have been influenced by fire suppression. Without suitable data, we submit that human perturbations have been less in unmanaged basins. We assume unmanaged streams tend to have higher gradients than managed streams, due to their position in watersheds. The unmanaged streams in this study tend to be located in the headwaters of drainage basins, while the managed streams flow from headwaters to lower gradient, valley reaches. This is likely to affect pool frequencies, as pool frequencies tend to increase with increasing gradient (Grant et al., 1990).

Ecoreaions

To assess regional patterns in pool habitats, we used Aquatic Ecoregions of the Pacific Northwest (Omernik and Gallant, 1986). These Ecoregions are based on regional differences in landforms, potential natural vegetation, soils, and land use. A one-way ANOVA and, if significant differences ($\alpha < 0.05$) were found, a Tukey test was done to detect differences between Ecoregions. The data were transformed using square root or log functions where the assumptions of one-way ANOVA were not met.

Past research has shown significant relationships between Ecoregions and spatial patterns in stream ecosystems in the Pacific Northwest (Hughes et al., 1987; Whittier et al., 1988). Our study streams were located in the Coast Range, Cascades, North Cascades, Blue Mountains, and Northern Rockies Ecoregions (Figure 2). The Cascades Ecoregion is divided into two distinct physiographic regions. They are the High Cascades, which consists of the range east of the Cascade crest, and the western Cascades, which are geologically older and more highly dissected (Omernik and Gallant, 1986). The ecoregions are described as follows from Omernik and Gallant (1986):

Coast Range

This Ecoregion consists of the Pacific Coast Range, extending from the north Washington coast to southern Oregon. The topography is characterized by low elevation (450 to 600-m), highly dissected hillslopes which abruptly transition to short, low gradient, estuarine lowlands. Most streams are perennial, with stream densities being relatively high (1.2 to 1.9 km/km^2). Climate is maritime, with highly variable precipitation (1400 to 3175 mm) due to high topographic relief. Streamflows are dominated by winter rainfall with lowflows occurring during the summer. The dominant vegetation is coniferous forest, consisting of Douglas-fir ***(Pseudotsuga menziesii),*** western hemlock (*Tsuga heterophylla*), Sitka spruce (*Picea* ***sitchensis),*** and western red cedar (*Thuja plicata*).

Disturbance patterns in the region are dominated by winter floods, landslides, fire, and windthrow. High winter precipitation results in peak flows that can affect channel morphology, aquatic habitats, and riparian forests on a relatively frequent basis (Beschta et al., 1995). Landslides occur frequently and tend to be small in volume. They tend to occur when non-cohesive soils on steep slopes become saturated

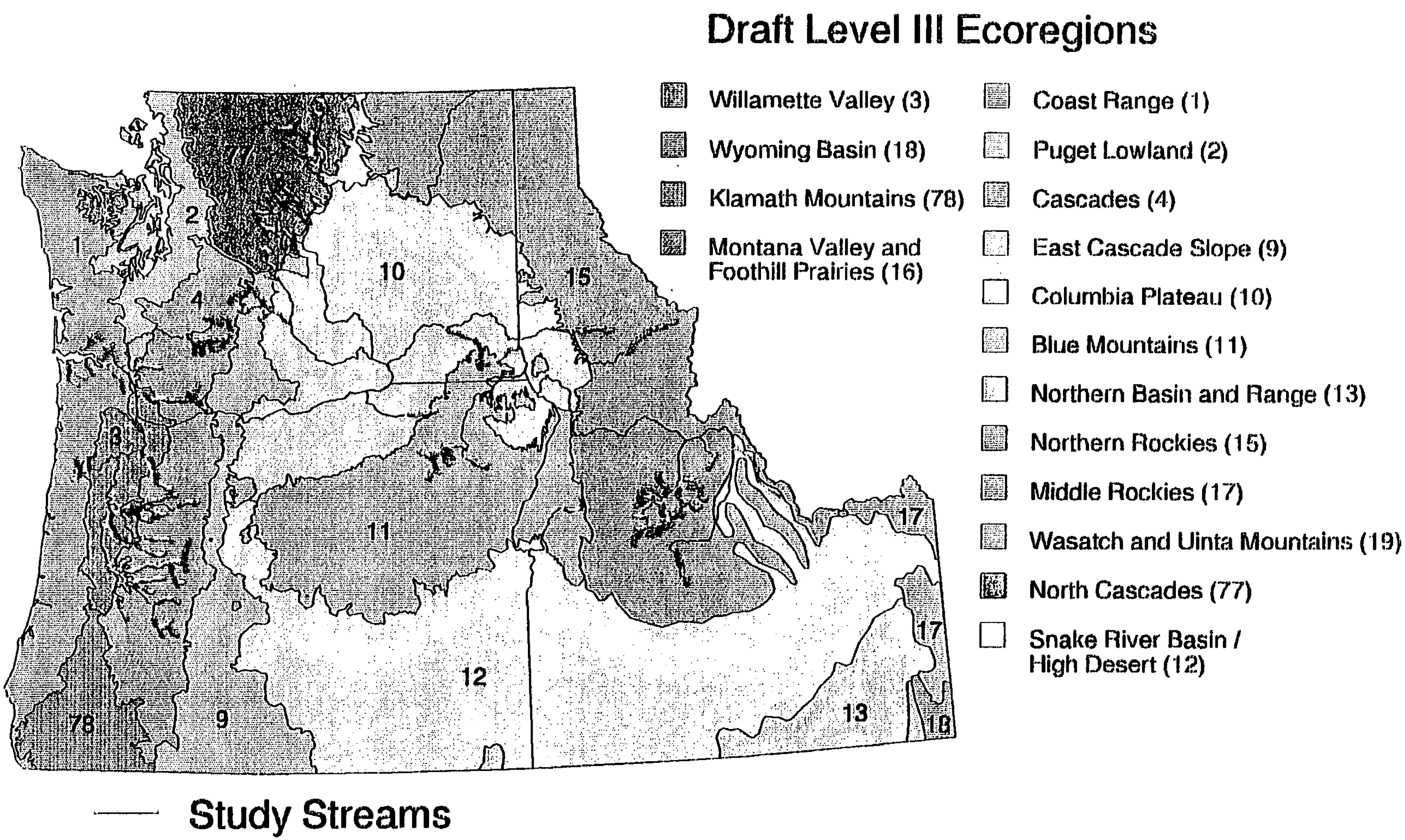


Figure 2. Draft Ecoregions of the Pacific Northwest and study streams.

with precipitation, resulting in rapid, shallow slope failures. Fire in the Coast Range is infrequent (> 100-year return interval), but tends to be severe, stand-replacement fires (Agee, 1990). Forests in the Coast Range are also susceptible to wind damage. Summer droughts occur periodically. Forest management is the predominant land use in the region, with larger river valleys used for cultivation and dairy operations.

Cascades

The Cascades Ecoregion occurs along the Cascade range of Oregon and Washington and the Olympic Mountains of Washington. This region consists of the western Cascades, which occur west of the Cascade crest, and the High Cascades, which occur east of the crest (Franklin and Dyrness, 1969). Regional topography is dominated by high mountains and deeply dissected valleys. Perennial stream densities are relatively high (0.9 to 1.2 km/km*) , although less than the Coast Range. Small watersheds commonly support perennial streams. The climate is highly variable (1270 to 2540 mm annual precipitation), with winter rainfall common at lower elevations, and snow at higher elevations. Streamflows are similar to the Coast Range, with high flows during the winter and lowflows during the summer. Runoff can also be extended by winter snowpack. Dense coniferous forests are the predominant vegetation. The two subregions, Western and High Cascades, are distinguished by precipitation and vegetation patterns. Vegetation in the Western Cascades tends to be more mesic, while the High Cascades is more xeric due to the rainshadow effect of the Cascade range. Precipitation in the High Cascades also tends to be snow-dominated, versus rain and snow in the Western Cascades.

Disturbance patterns also vary between the two subregions. In the Western Cascades, winter floods and fire have been the dominant disturbances. Winter rainfall, along with rain-on-snow events, can produce high flows at a relatively high frequency. The fire regime is similar to the Coast Range, typified by infrequent (> 100 year return intervals) and severe stand-replacement fires (Agee, 1990). Windthrow can also occur, along with landslides, although they are less frequent than the Coast Range due to a more stable geology. In the High Cascades, floods, fires, insects, and disease dominate the natural disturbance regime. Floods can occur due to winter rainstorms, spring runoff, and summer convective storms. The fire regime tends to be low severity (few overstory effects), but more frequent (< 25 year return intervals) (Agee, 1990). Insects and disease outbreaks are also more associated with forests east of the Cascade crest. Summer droughts also occur periodically. Timber harvest tends to be the predominant land-use, with livestock grazing common in the High Cascades.

North Cascades (Draft)

The Environmental Protection Agency Environmental Research Lab, Corvallis, Oregon is currently revising Ecoregions of the Pacific Northwest (J. Omernik, Environmental Protection Agency Environmental Research Lab, Corvallis, Oregon, pers. comm.). In this revised classification, the North Cascades Ecoregion has been split out from the Cascades Ecoregion. A description of the North Cascades Ecoregion is presently in draft form, unavailable for this publication. According to Jim Omernik (Environmental Protection Agency Environmental Research Lab, Corvallis, Oregon, pers. comm.), the North Cascades was classified based on distinct differences in geology, landforms, and vegetation from the Cascades Ecoregion. The North Cascades Ecoregion is characterized by sedimentary geology, while the Cascades Ecoregion tends to be volcanic. Landform in the North Cascades Ecoregion is typically high peaks with large glacial valleys. The Cascades Ecoregion contains a few high, volcanic peaks and deep highly dissected valleys. The mean elevation in the North Cascades Ecoregion is higher than the Cascades Ecoregion, resulting in vegetation and climatic differences.

Blue Mountains

The Blue Mountains Ecoregion comprises several mountain ranges located in central/northeast Oregon and southeast Washington. High mountain ranges and large lower valleys typify regional topography. Perennial stream densities range from 0.9 to 1.2 km/km^2 in wet areas, to no perennial streamflow in drier areas. This Ecoregion is much drier than the Cascades or Coast Range. Annual precipitation ranges from 254 to 508 mm in the lower valleys and reaches 1,016 mm in the mountains. Most precipitation comes as winter snowfall. Streamflows are dominated by spring snowmelt runoff, with peaks coming later than Westside ecoregions. Lowflows tend to occur in late summer. The higher elevation forested regions are typically in the ponderosa pine (*Pinus ponderosa*) and grand fir (*Abies grandis*) zones, while the lower elevations are typified by juniper (*Juniperus occidentalis*) and sagebrush/wheatgrass steppe.

Disturbance patterns are dominated by winter, spring, and summer floods, along with drought, fire, insects, and disease. Peak flows can occur as winter rainstorms, spring snowmelt runoff, and summer convective storms (Beschta et al., 1995). Summer convective storms have produced some of the largest floods in eastern Oregon (Hubbard, 1991). Drought occurs periodically, like in the other regions. It may be a more significant factor in this region, due to lower annual precipitation. Droughts, along with silvicultural practices, are often cited as major factors affecting the size and frequency of insect, disease, and fire in the Blue Mountains (Wickman, 1992). The fire regime is typified by frequent (< 25 year return intervals), low intensity groundfires that have little overstory effects (Agee, 1990).

Insects and disease are also a common disturbance in the Blue Mountains Ecoregion. Land-use in the Ecoregion is characterized by timber production and livestock grazing in the forested areas, and livestock grazing and irrigated croplands in the lower valleys. Streams throughout the region were historically mined for metals, typically gold.

Northern Rockies Ecoregion

This region occurs in central to northern Idaho and is characterized by high mountains and narrow valley bottoms. Annual precipitation is highly variable (508 to 1,524 mm) and is dominated by winter snowpack. Streamflows are typified by spring snowmelt runoff and late summer lowflows. Perennial stream densities are highly variable, ranging from less than 0.5 to 1.9 km/km^2. Vegetation is predominantly coniferous forest, such as Douglas-fir, western white pine (*Pinus monticola*), western red cedar, western hemlock, western larch (*Larix **occidentalis***), subalpine fir (*Abies lasiocarpa*), and Englemann spruce (*Picea englemannii*).

The disturbance regime is characterized by floods, landslides and surface erosion, fire, insects and disease. Floods can occur as snowmelt runoff or summer convective storms. Due to high local relief and a highly erosive geology (Idaho batholith), landslides and surface erosion are common. Fires tend to be relatively frequent (25 to 100 year return intervals) and of moderate severity. Partial stand-replacement fires with large areas of low and high severity burns are common. Insect and disease outbreaks occur periodically over large areas. Land-use is dominated by timber harvest and livestock grazing, with many streams historically mined for metals.

Disturbance History

The available records of land-use history for the study basins, along with more general regional records, were examined to characterize the land management history before and after the Bureau of Fisheries survey. We analyzed the disturbance history to provide context and to identify potential causal mechanisms for changes in fish habitat. Land-uses that were examined included timber harvest, road construction, splash dams and log drives, livestock grazing, mining, stream channelization, agriculture, and stream improvement. Where quantitative records were available we attempted to match the records to the study basins by counties or national forests. Records were not available by basin.

Timber harvest records were available annually, by county, for Oregon and Washington from 1925 to 1993. In Idaho, harvest volumes were available annually from 1948 to 1993 for only the Nez Perce and Clearwater National Forests. Livestock numbers were derived from U.S. Bureau of Census data at-5 to 10 year intervals, by county, from 1860 to 1992.

RESULTS

Since 1987, Forest Service Research, with the support of many cooperators (Appendix A), have resurveyed 31% (120/390) of the streams surveyed by the Bureau of Fisheries (Figure 3). This represents 35 percent (2259/6454 km) of the stream lengths surveyed historically. Our resurveyed streams were from across the Columbia River basin, representing a broad range of stream types and disturbance histories. Of the major river basins surveyed historically, only the Kalama, Klickitat, Walla Walla, Washougal, and Payette had no data for the resurveys. The streams we used for comparison were not randomly or systematically selected from the Bureau of Fisheries dataset. Instead, we were forced to be opportunistic in the streams compared, due to funding constraints or the availability of data. Only 58% (69/120 streams) of the streams were resurveyed specifically for this study. The remainder of the data came from comparable surveys collected by other agencies and institutions for other purposes.

A two-sample t-test was used to test whether the sub-sample of streams from the Bureau of Fisheries survey used in this study were representative of the entire Bureau of Fisheries dataset. We found no significant differences ($p > 0.05$) in large pool frequencies, but significant differences ($p < 0.05$) in deep pool frequencies. Therefore, our sub-sample of streams was comparable for large pools, but was slightly higher for deep pools.

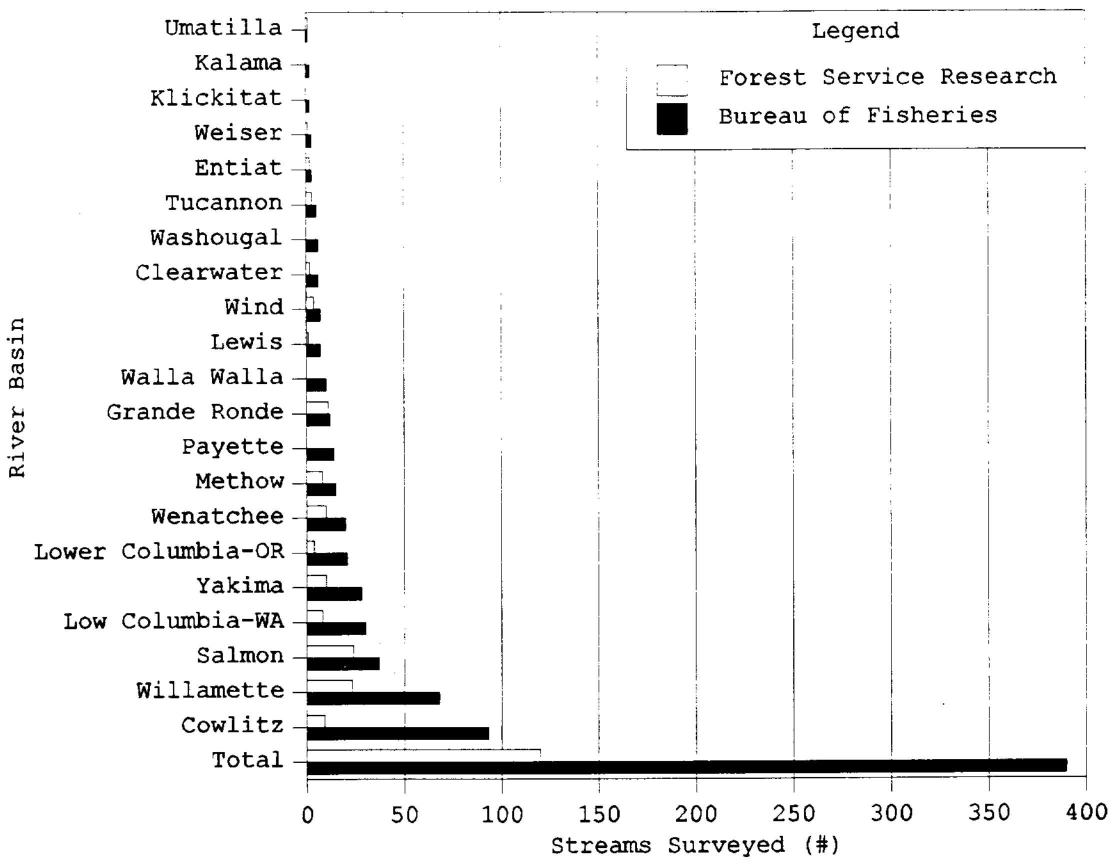


Figure 3. Streams surveyed in the Bureau of Fisheries and Forest Service Research surveys, by river basin.

Chanses in Pool Habitats in the Columbia River Basin

Our data show that the quantity and quality of pool habitats in the Columbia River basin have decreased significantly (p c 0.01) since the Bureau of Fisheries survey. Large pools decreased by 24% (7.1 to 5.4 large pools/km), while deep pools decreased 65% (2.3 to 0.8 deep pools/km) (Figure 4). In addition, the variability and range in pool frequencies were much greater in the Bureau of Fisheries surveys as compared to the Forest Service Research surveys.

To illustrate the magnitude and variability of change for the surveyed streams, we plotted the net change in pool frequencies for each stream on a histogram (Figure 5). As is readily discernible, the magnitude and frequency of pool'loss, especially deep pools, are apparent. Large pools increased in 34%, remained unchanged in 20%, and decreased in 46% of the study streams. Deep pools increased in 6%, remained unchanged in 48%, and decreased in 46% of the study streams. In addition, deep pools were a much larger component of pool habitats in the Bureau of Fisheries survey, comprising 36% of the total pool habitat, while declining to 17% of the total pool habitat in the resurveys.

Chancres in Pool Habitats Based on Land-Use

Our analysis of changes in pool habitats based on land-use was limited by the availability of streams that have been minimally influenced by human disturbance (e.g., wilderness or roadless areas, limited entry). Despite historical human influences (e.g., mining, grazing) and a policy of fire suppression over the past century, streams in unmanaged

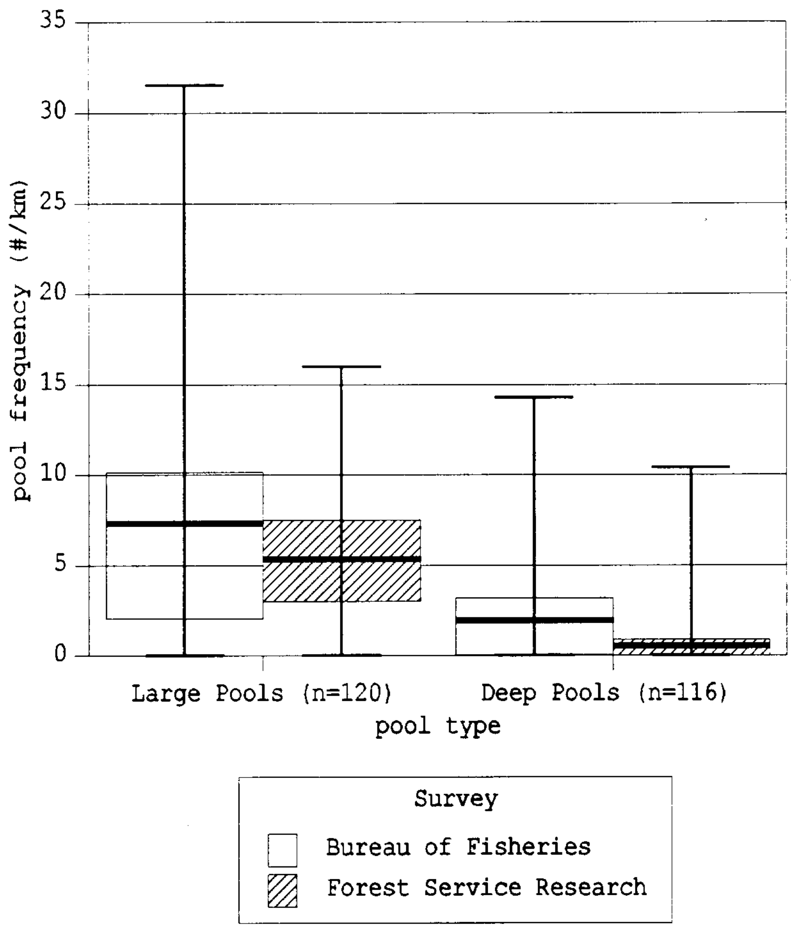


Figure 4. Frequency of large and deep pools in the Bureau of Fisheries and Forest Service Research surveys. The vertical line inside the box represents the mean and the vertical ends of the box represent the 25th and 75th percentiles, whiskers represent range.

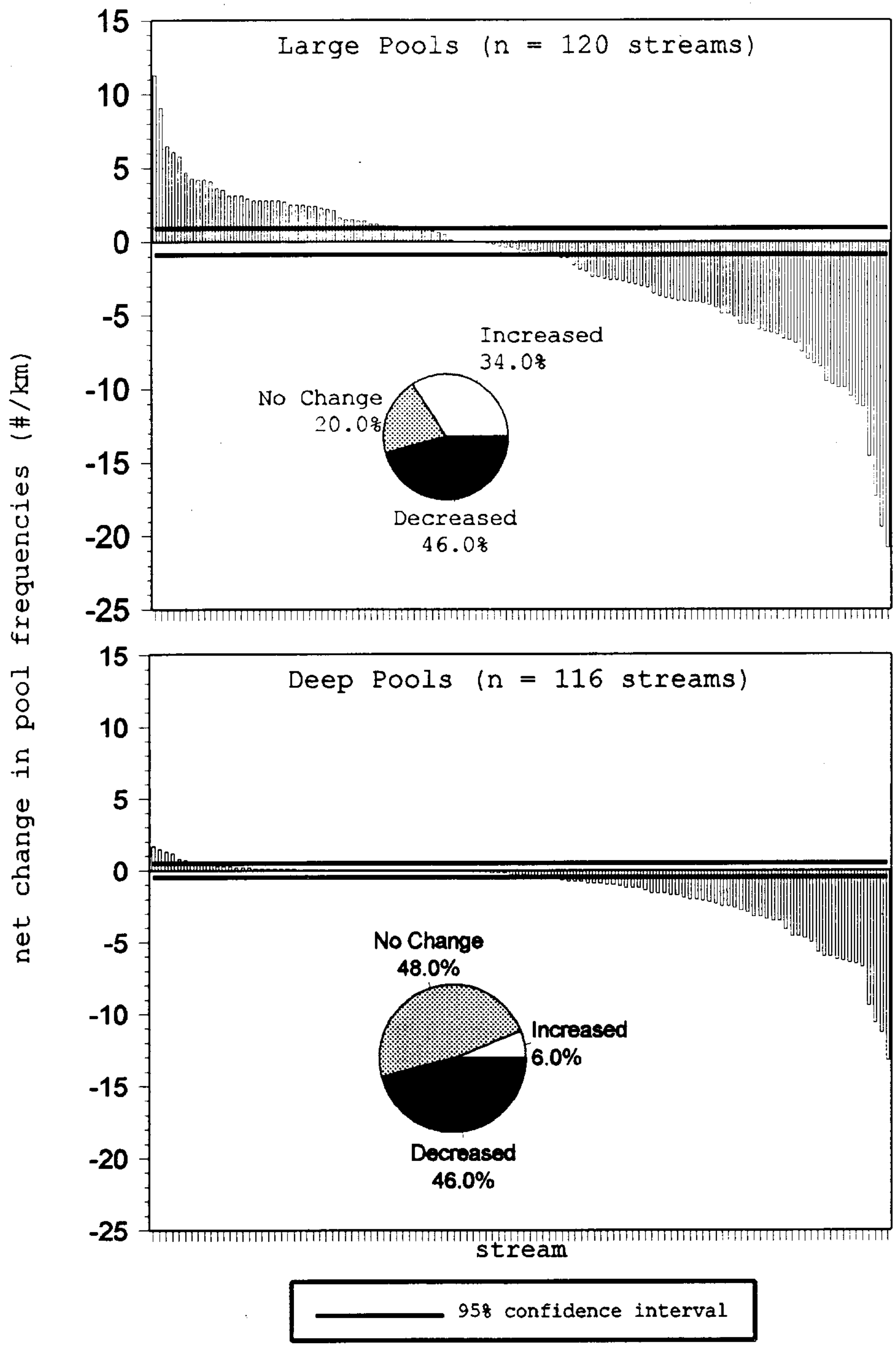


Figure 5. Change in large and deep pool frequencies, by stream, from the Bureau of Fisheries to the Forest Service Research survey.

watersheds provide a relative baseline of natural change. Stream orders were similar between managed and unmanaged streams, although the ranges were greater for managed streams. Unmanaged streams ranged from 3rd to 5th order (median = 4, SD = 0.5) and managed streams ranged from 2nd to 6th order (median = 4, SD = 0.9). For both classes of streams, 3rd and 4th order streams were the dominant stream orders (Figure 6).

Analyses of changes in pool habitats based on land-use classification show that the quantity and quality of pools increased in unmanaged watersheds and decreased in managed watersheds (Figure 7). The mean frequency of large pools increased by 81%, from 3.1 to 5.6/km in unmanaged watersheds ($p < 0.01$, Figure 7) and decreased by 31%, from 7.8 to 5.4/km in managed watersheds ($p < 0.01$, Figure 7). Deep pools increased by 67% (0.3 to 0.5/km) in unmanaged watersheds ($p < 0.05$, Figure 7) and decreased by 69% (2.6 to 0.8/km) in managed watersheds ($p < 0.01$, Figure 7).

Historically, large and deep pool frequencies were significantly higher in managed streams as compared to unmanaged streams (two-sample *t*-test, $p < 0.05$, Figure 7). In the resurveys there were no significant differences in large pool frequencies (two-sample *t*-test, $p > 0.05$, Figure 7) between managed and unmanaged streams. The fact that historical large pool frequencies were greater in managed streams contradicts our assumption that pool frequencies increase with increasing gradient (i.e., unmanaged streams are steeper, headwater steams). Deep pool frequencies were significantly higher (two-sample *t*-test, $p < 0.05$) in managed streams historically and in the resurveys (Figure 7). The difference in the resurveys is much smaller. In addition, the variance and range about the mean decreased in managed streams, while remaining unchanged in unmanaged streams.

Land-use classification shows the striking contrast in the magnitude and variability in pool habitats changes. In unmanaged watersheds, large pools increased in 56% of the streams surveyed,

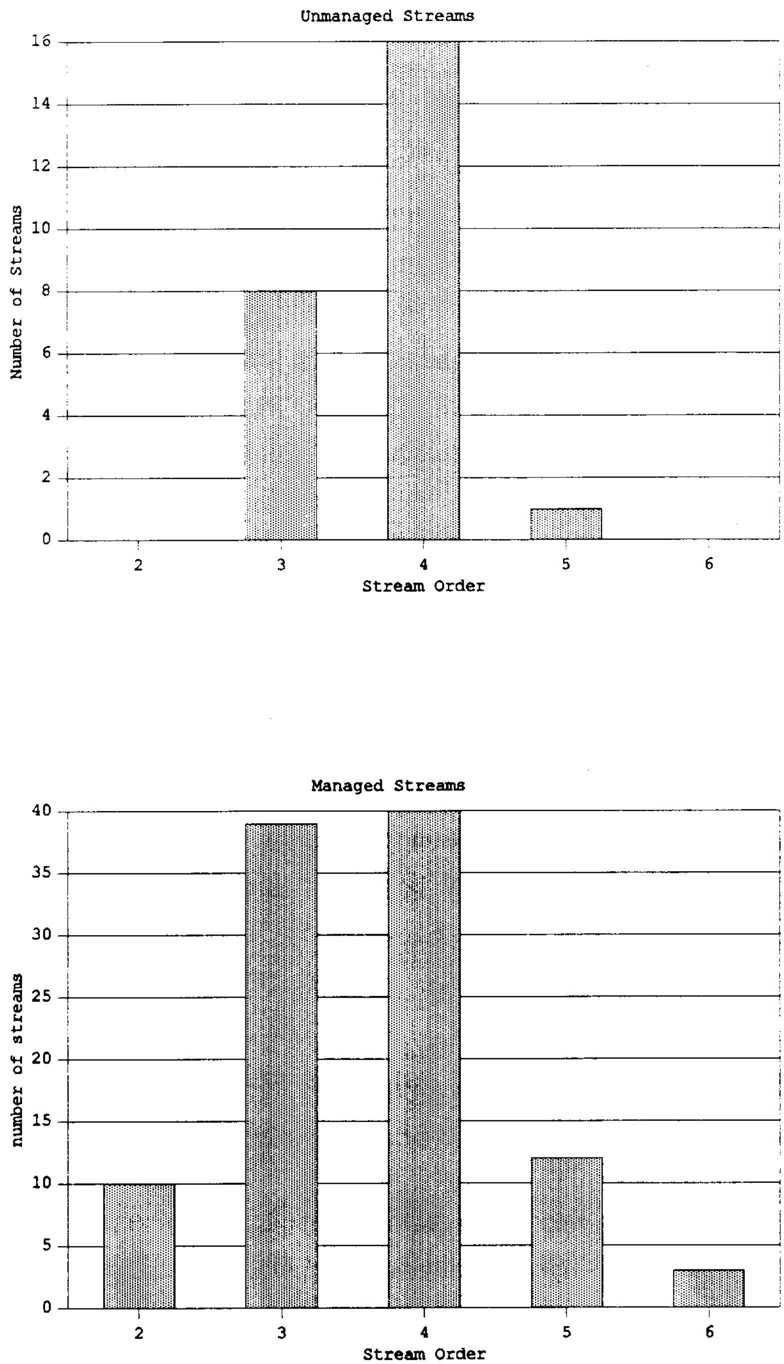


Figure 6. Distribution of streams by stream order for unmanaged and managed streams.

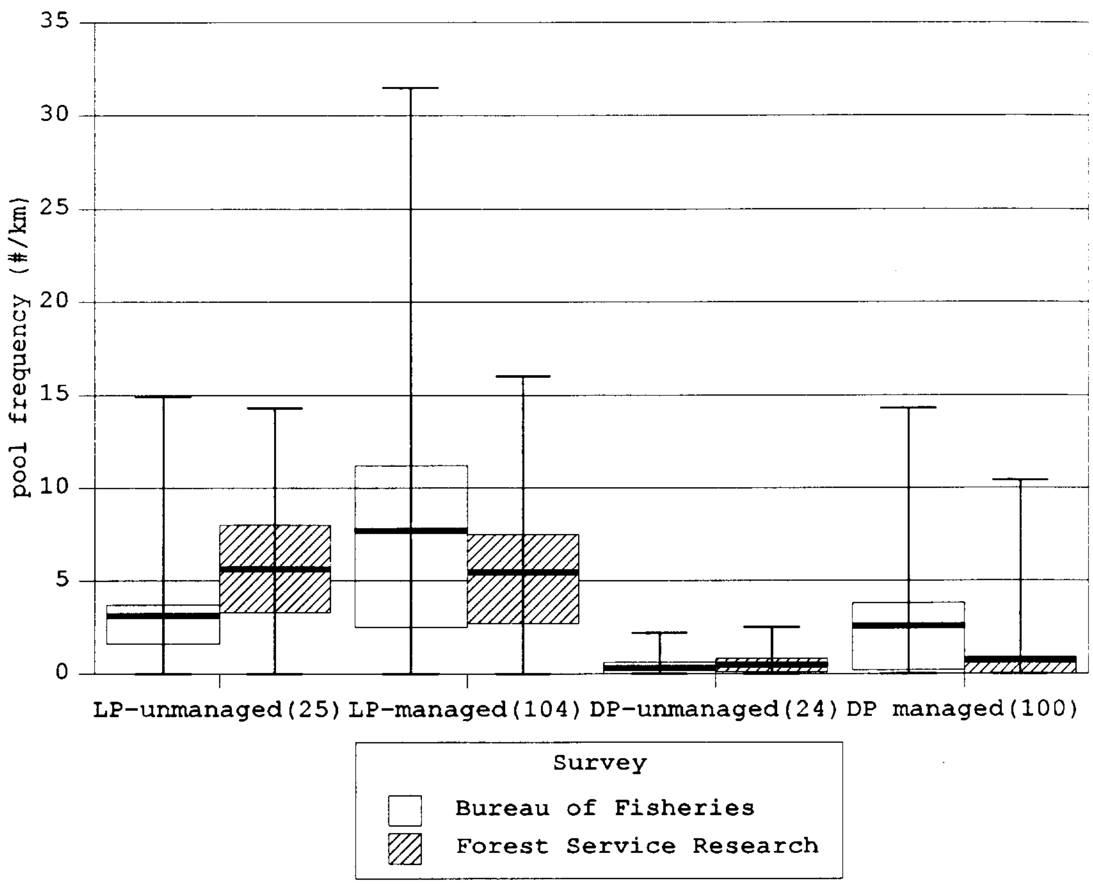


Figure 7. Frequency of large (LP) and deep pools (DP) in managed and unmanaged streams from the Bureau of Fisheries and the Forest Service Research surveys. The vertical lines inside the boxes represent the mean and the vertical ends to the boxes represent the 25th and 75th quartiles, whiskers represent the range. Number in parentheses is sample size.

while large pools in managed watersheds decreased in 51% of the streams surveyed (Figure 8a). The frequency of deep pools in unmanaged streams increased in 33% of the unmanaged streams surveyed, whereas in managed watersheds, deep pools decreased in 54% of the streams surveyed (Figure 9b). The decreases in deep pool frequencies in managed streams were even more pervasive than the decrease in large pools.

Decreases in pool frequency and depth in managed streams support the generalization that land-use practices have simplified and homogenized stream channels and habitat complexity throughout the Columbia River basin. Our assumption that pool frequencies would be higher in unmanaged versus managed streams, due to higher gradients, appears false. The data from this study shows that the highest quantity and quality of pool habitats were historically in managed streams and have been reduced significantly due to land-use over the past 50-60 years.

We also attempted to look at streams that had shown the largest increases (≥ 5 pools/km) and decreases (≥ 5 pools/km) to see whether they had commonalities. There were no similarities in our grouping of the "best" and "worst" streams. The streams were from different Ecoregions, covered a range of stream orders, and had varied land-use histories. This implies that land management practices can degrade pool habitats regardless of where they occur.

Changes in Pool Habitats Based on Land Ownership

We also examined whether changes in pool frequencies were different between public and private lands. Stream orders ranged from 2nd to 6th (median = 4, SD = 1.1) on private lands and 2nd to 5th (median = 4, SD = 0.7) on public lands. Third through fifth order streams were the dominant orders for both ownerships (Figure 10). Streams on public lands probably have steeper

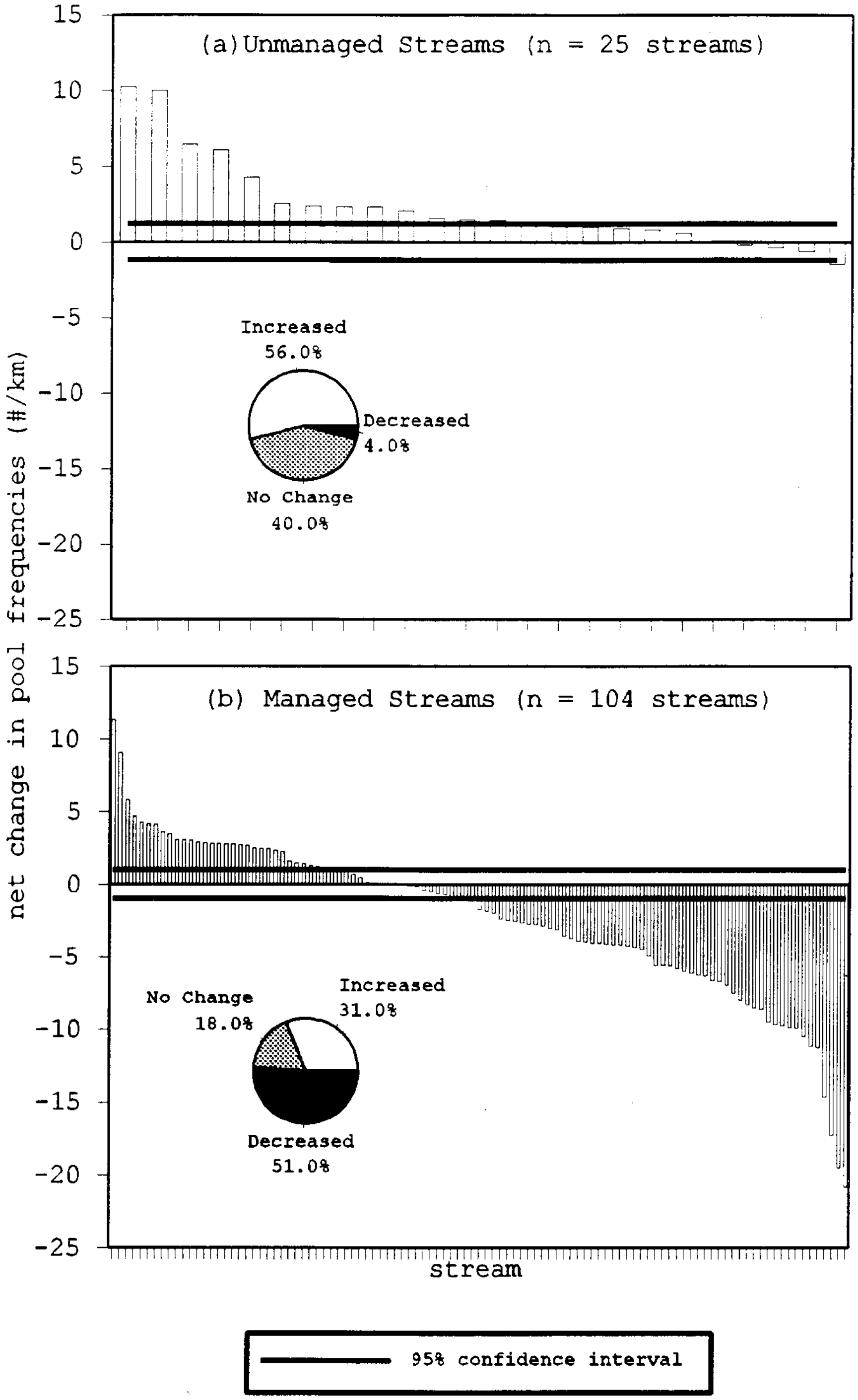


Figure 8. Changes in large pools in (a) unmanaged and (b) managed streams, from the Bureau of Fisheries to Forest Service Research surveys.

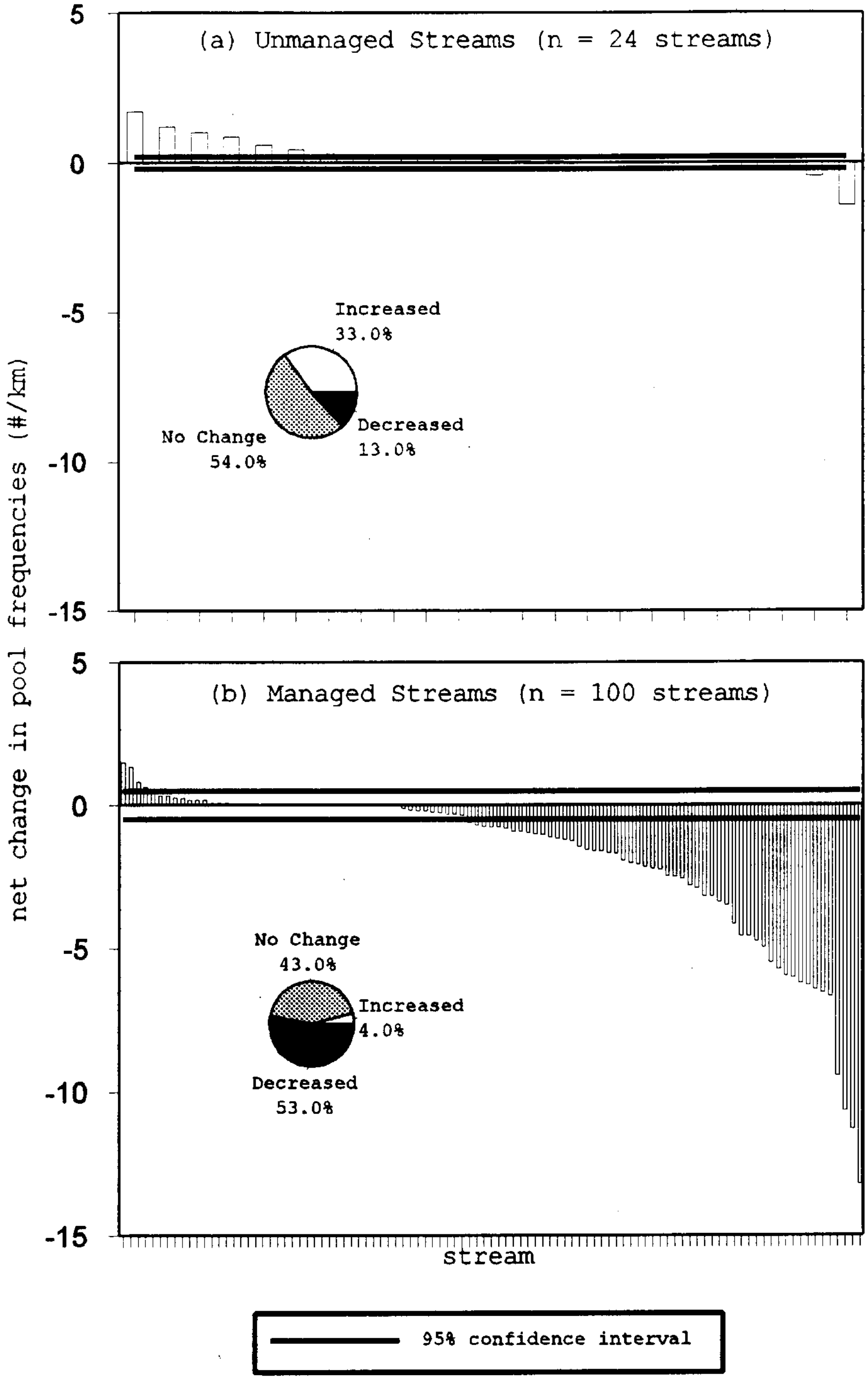
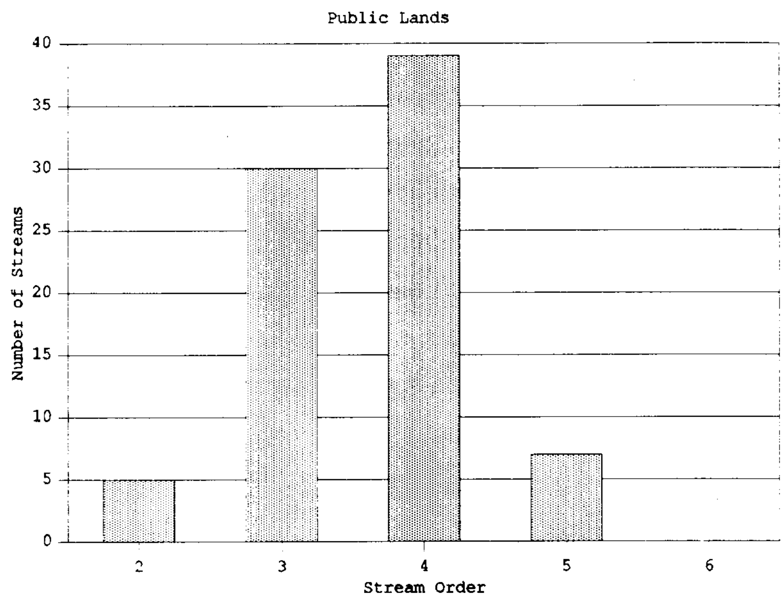


Figure 9. Changes in deep pools in (a) unmanaged and (b) managed streams, from the Bureau of Fisheries to the Forest Service Research surveys.



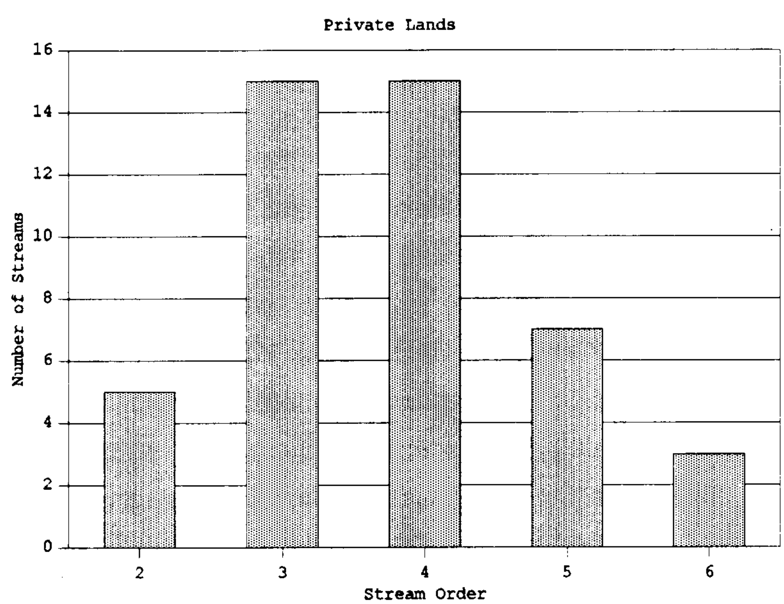


Figure 10. Distribution of streams by stream order for public and private lands.

gradients than streams on private lands, due to their location higher in the watershed. There were no significant differences in pool frequencies based on ownership for the Bureau of Fisheries or Forest Service Research surveys. Large and deep pool frequencies decreased significantly on both private ($p < 0.01$) and public ($p < 0.01$) lands (Figure 11). In addition, the variability in pool frequencies was much greater in the Bureau of Fisheries surveys as compared to the resurveys. The simplification and homogenizing of aquatic habitats occur regardless of land ownership.

Changes in Pool Habitats Based on Ecoregions

We found highly significant differences ($p < 0.01$) between Ecoregions for changes in large and deep pools. The North Cascades Ecoregion differed from the Western Cascades, Blue Mountains, and Northern Rockies Ecoregions, showing increased large pool frequencies, while the other regions decreased (Figure 12a). There were no differences between the Coast Range Ecoregions and the other regions. Changes in deep pools differed between the Coast Range and Western Cascades Ecoregions, and the North Cascades, Blue Mountains, and Northern Rockies Ecoregion (Figure 12b). The decreases in deep pools were much greater in the Coast Range and Western Cascades Ecoregions. Since unmanaged streams were not evenly distributed among the five Ecoregions, we conducted a second analysis with unmanaged streams removed from the dataset. The results remained highly significant ($p < 0.01$) and the regional differences in large and deep pools did not change.

We also mapped the changes in pool habitats for the study streams, by Ecoregion (Figures 13 and 14). Streams were classified as increasing, no change, or decreasing in pool habitats using 95% CI. By mapping where the changes occurred, the regional patterns to changes in pool habitats were apparent.

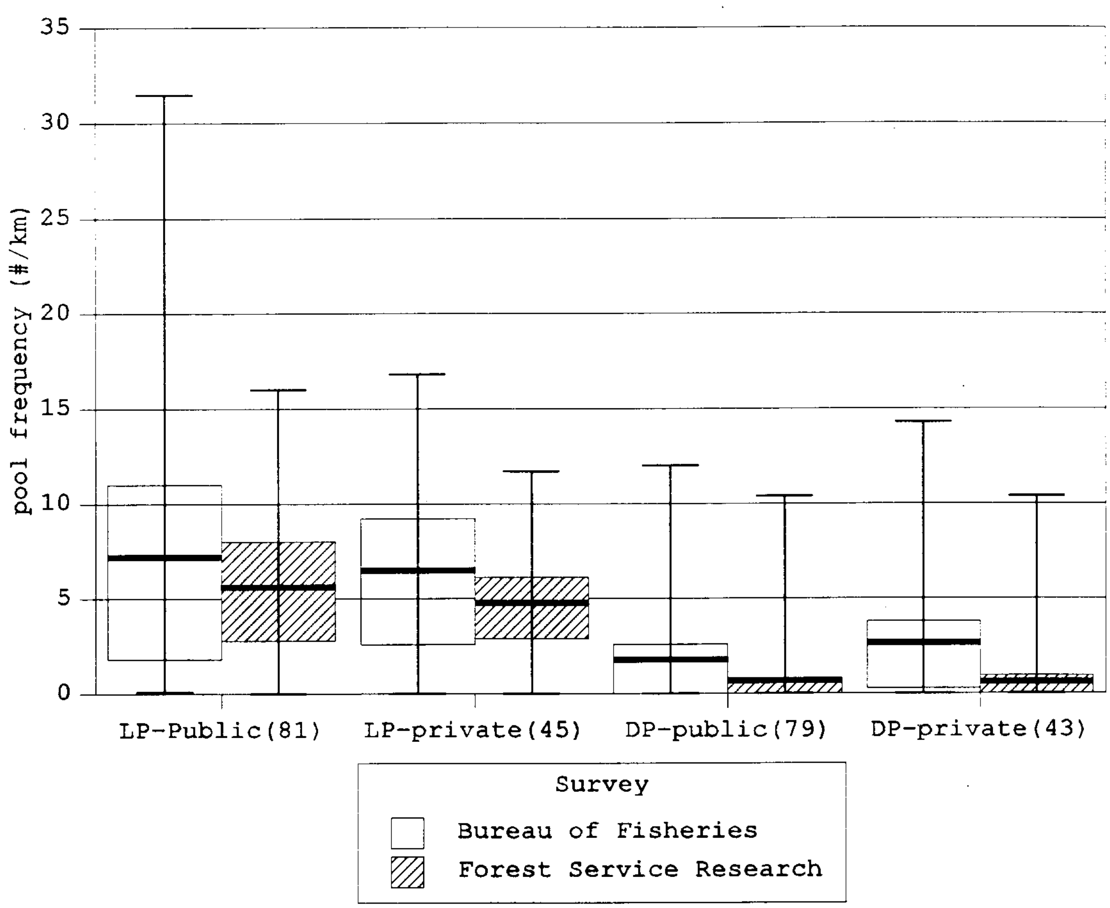
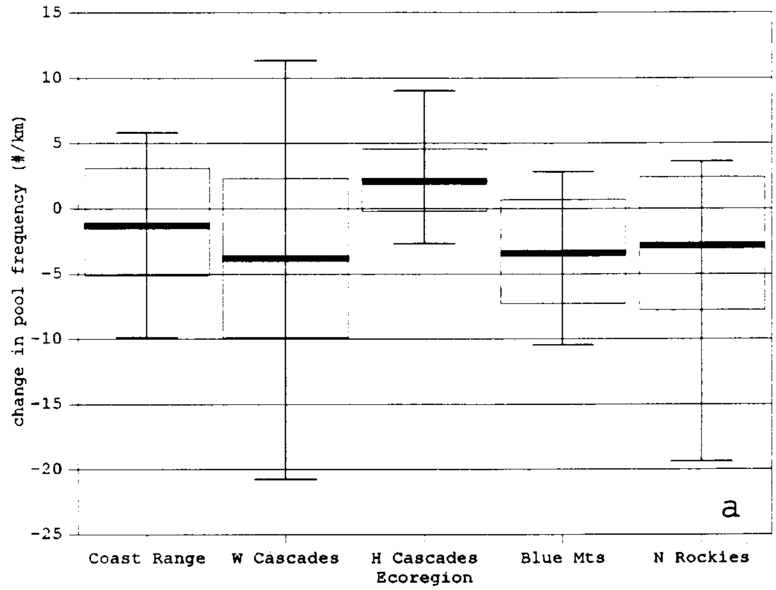


Figure 11. Frequency of large (LP) and deep (DP) pools on public and private lands in the Bureau of Fisheries and Forest Service Research surveys. The vertical line inside the box represents the mean and the ends of the box represent the 25th and 75th quartiles, whiskers represent the range. Number in parentheses is sample size.



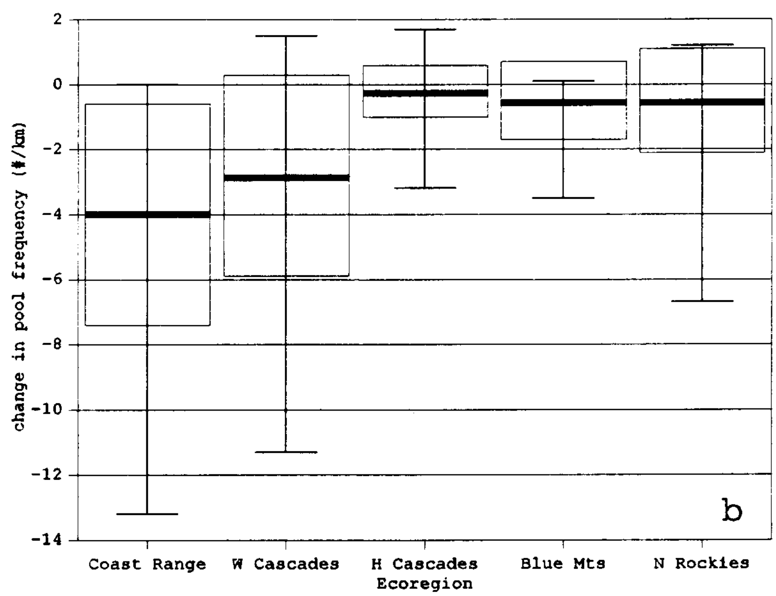


Figure 12. Changes in the frequency of (a) large and (b) deep pools by Ecoregion. Boxes show mean ±SD and whiskers denote range.

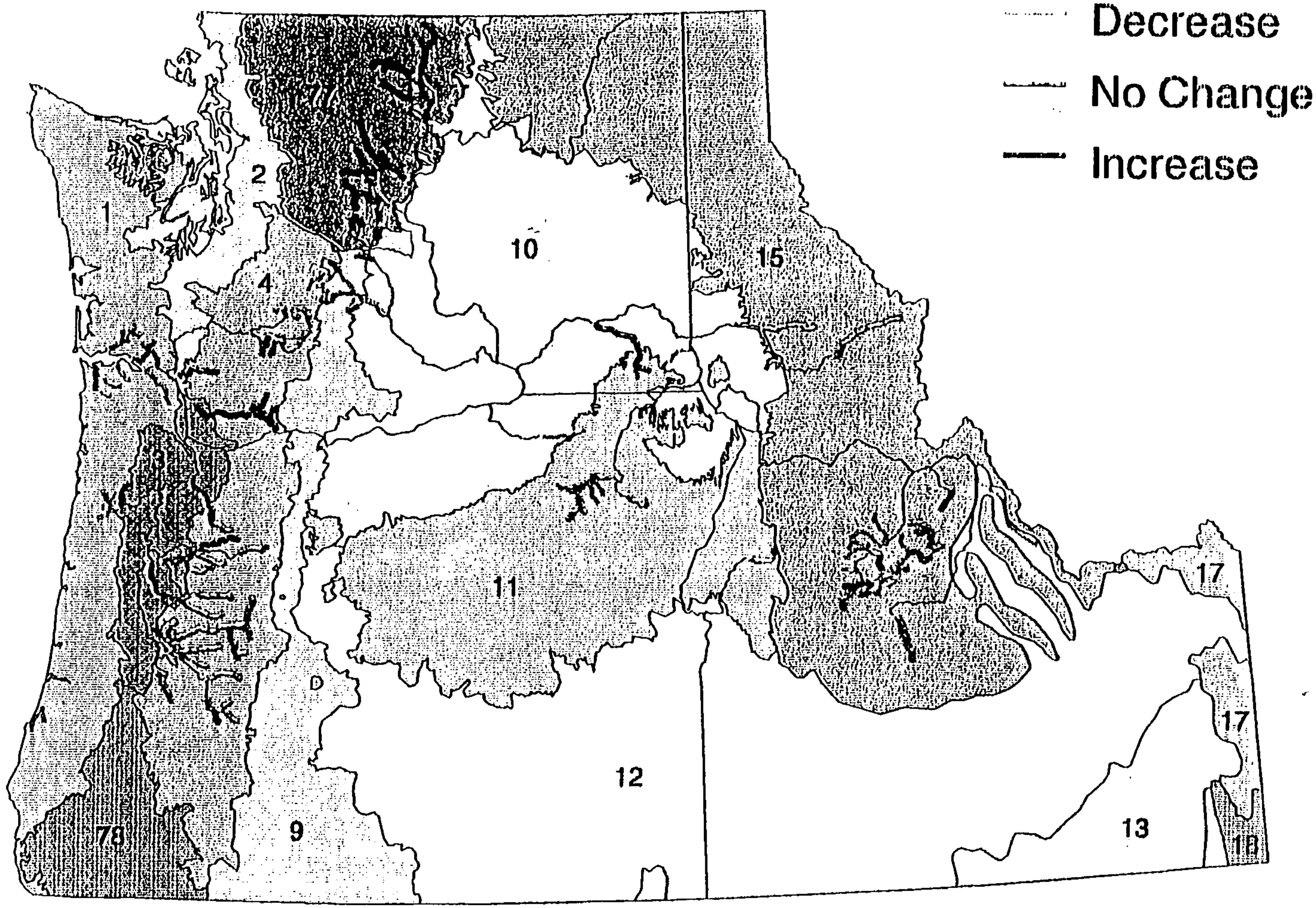


Figure 13. Map showing changes in large pool habitat, by Ecoregion, for study streams.

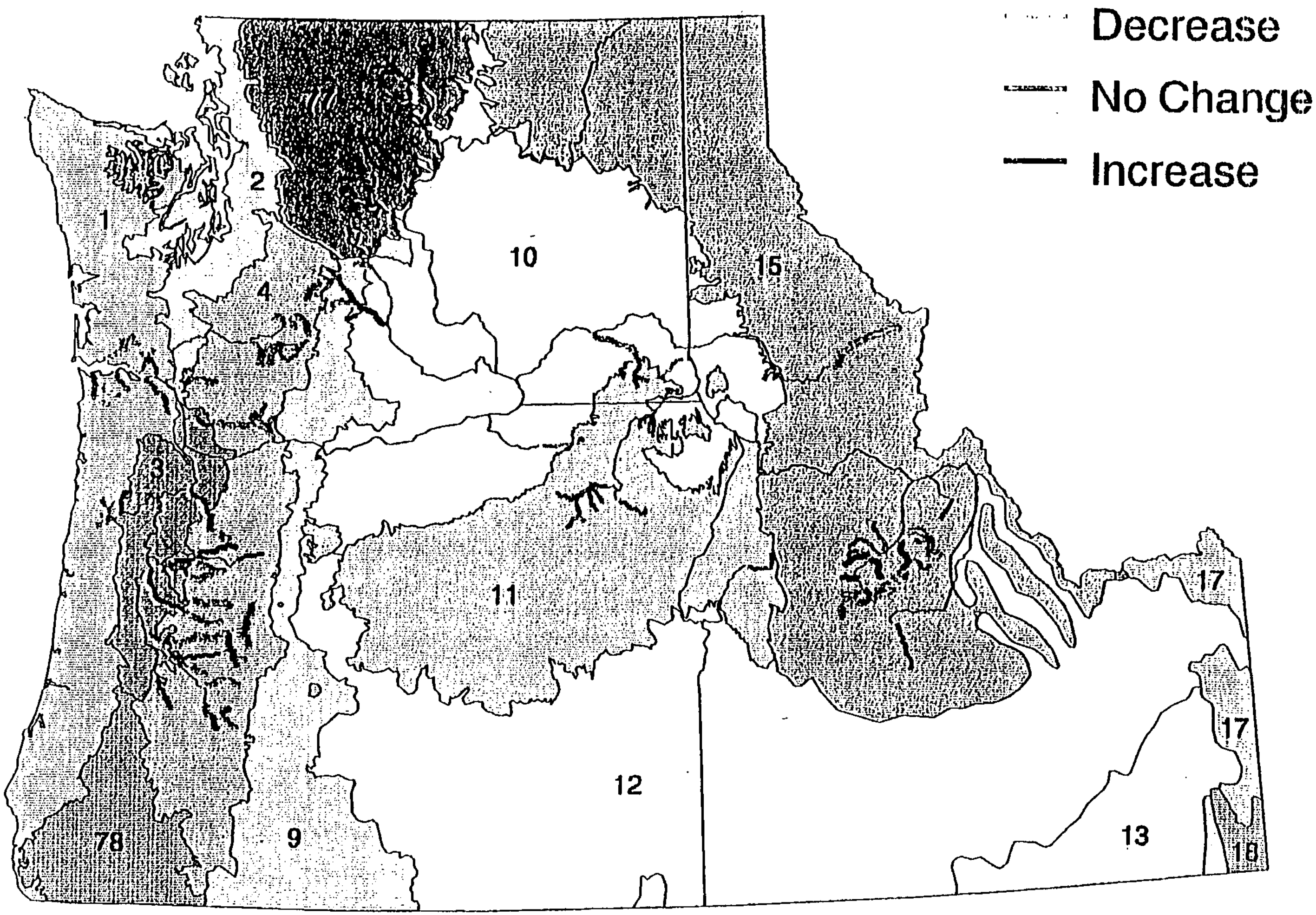


Figure 14. Map showing changes in deep pool habitat, by Ecoregion, for study streams.

The North Cascades Ecoregion was the only Ecoregion in which large and deep pool habitats increased or remained the same. Pool habitats increased regardless of land-use throughout the Ecoregion, although the increase was greater in unmanaged streams. Only one and six streams out of twenty-two surveyed showed decreases in large and deep pools, respectively. This finding is consistent with the earlier findings of McIntosh et al. (1994a, b).

Disturbance History

Records for land-use histories in the Columbia basin were available from a variety of sources. Data were not available on a river basin basis, but were generally available by counties or National Forests. We attempted to use data that roughly corresponded to the river basins used for the pool data.

Beaver

The first effect of Euro-Americans on aquatic ecosystems in the Pacific Northwest was the systematic decimation of beaver (*Castor canadensis*) populations in the early 1800s (Beschta, 1991). Robbins and Wolf (1994) noted that in the spirit of competition, trappers created "fur deserts" to drive out the competition. Beaver populations were virtually eliminated by the time the first Euro-American settlers began arriving on the Oregon Trail. These populations remain at a fraction of their historical abundance throughout the west (Naiman et al., 1986).

Beavers have been described by Naiman et al. (1986) as a keystone species, which "affect ecosystem structure and dynamics far beyond their immediate requirements for food and space." The character and functioning of many streams in the Pacific Northwest were strongly influenced by beaver (Beschta, 1991).

Beaver dams retained sediment and nutrients, enhanced summer low flows, and created habitat for fish and wildlife (Beschta, 1991; Marcus et al., 1990). In addition, beavers were likely to affect the successional dynamics of riparian vegetation. Beschta (1991) concluded "although the periodic breaching of some beaver dams during high flow may have caused local channel scour, the overall effect of beaver activity was to enhance wetland-riparian functions and values." Clearly the biotic and abiotic components of riparian and stream ecosystems evolved under the significant influence of beavers. The loss of beaver has clearly altered this relationship, in ways scientists are only beginning to understand.

Mining

The California gold rushes of the mid-1850s stimulated the search for gold in the Pacific Northwest. This lead to gold rushes in the interior Northwest in the late 1850s and early 1860s and the establishment of permanent settlements in the interior Columbia River basin (Robbins and Wolf, 1994). By the 1940s, gold mining was reduced to a fraction of its historical highs, continuing to the present. The legacy of gold mining is evident throughout the major river drainage's of the Blue Mountains and central Idaho, and less evident in the North Cascades, Western Cascades, and Coast Range. In recent years, interest in gold mining, using cyanide chemical-leach mining for gold from old deposits has increased (Wissmar et al., 1994a,b).

Since the 1940s, sand and gravel mining has become common along the rivers and floodplains of the Pacific Northwest. The demand for sand and gravel has been fueled by industrial development. Most production is confined to deposits near major industrial areas, or highways, due to the high cost of transportation (Spence et al., 1995). In Washington, these areas are near major urban areas, or along the Interstate 5 corridor, while in Oregon, the Willamette valley is the major producer (Spence et al., 1995). Wissmar et al. (1994b) reported that the production of sand, gravel, gypsum, and limestone in eastern Oregon and Washington counties far exceeded that of minerals.

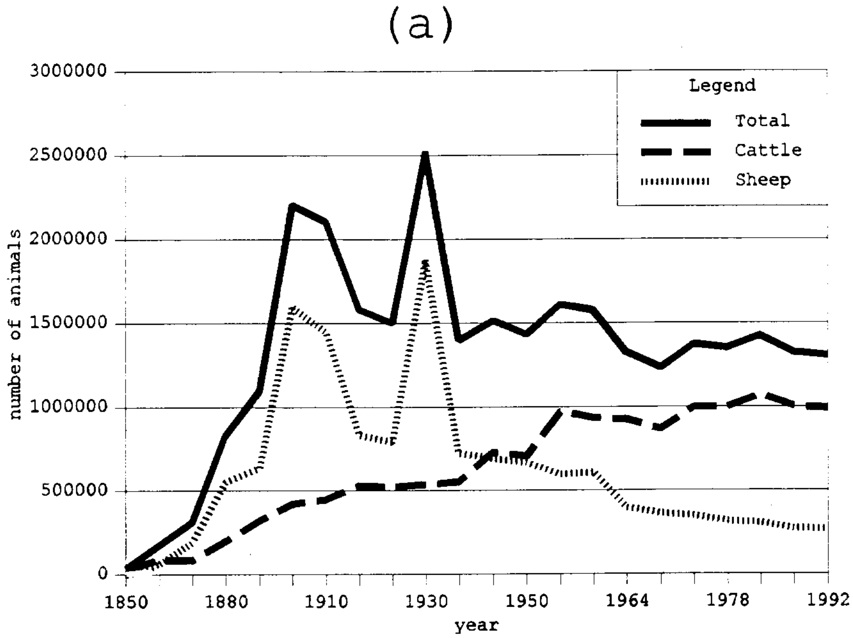
Early mining practices were especially destructive to streams, with entire hillsides and floodplains destroyed in the search for gold. Placer, hydraulic, dredge, and lode mining all altered streamflows and sediment supplies, severely damaged riparian and stream habitats, increased erosion and released leachates (Nelson et al., 1991, Wissmar et al., 1994a and b). These changes in the abiotic environment can affect the reproduction and survival of aquatic biota throughout all phases of their life cycles. McIntosh (1992) documented the negative effects of placer mining in the upper Grande Ronde basin, based on surveyors notes from the Bureau of Fisheries survey of the upper Grande Ronde river. The surveyor notes and photographs portrayed a river that existed in name only, a floodplain and channel that had been completely rearranged by mining. While conditions have improved some since the mining ended in 1941, mine tailings throughout the floodplain severely limit channel and floodplain processes, along with the recovery of vegetation.

Livestock Grazing

The introduction of large non-native ungulates in the Pacific Northwest began when Native Americans brought Spanish horses to the region in the early 1700s (Robbins and Wolf, 1994). Li et al. (1994) suggest the region may have been particularly sensitive to overgrazing because the native vegetation evolved without large ungulates (i.e., Bison) (Mack and Thompson, 1982). By the early 1800s, Native Americans had developed large herds of horses. Early explorers to the region regularly noted the large herds of Indian horses. While the impact of the introduction of horses is unknown, the fact that they were non-native, leads one to conclude they were a new disturbance on native ecosystems (Robbins and Wolf, 1994).

Development of the livestock industry in the Columbia River basin followed the migration of Euro-American emigrants along the Oregon Trail in the mid-1800's. Initial settlements focused on the Willamette valley and later the interior portions of the Columbia River basin (Robbins and Wolf, 1994). We analyzed trends in livestock populations for the study basins using U.S. Bureau of Census data on livestock numbers from 1850 to 1992.

Livestock populations for the study basins grew rapidly from 1850 to 1900 in response to Euro-American populations (Figure 15a). An 1883 report (Gordon et al., 1883) noted that rangelands in the interior Columbia basin had already been damaged by overgrazing (Irwin et al., 1994). Despite the concern of ranchers and government officials, grazing increased until the establishment of Forest Reserves in 1895. As Irwin et al. (1994) reported, a 1898 National Academy of Sciences report put national attention on overgrazing in the Forest Reserves. With the creation of the U.S. Forest Service in 1906, grazing on public lands began to be actively regulated. Livestock numbers declined until 1925 (Figure 15a). From 1925 to 1930, livestock populations grew rapidly, eclipsing previous highs (Figure 15a). The increases were primarily due to increased sheep production due to a policy change emphasizing food production (Irwin et al., 1994). After 1930, renewed concerns about overgrazing caused the passage of the Taylor Grazing Act, and livestock grazing began to decline. Since 1940, livestock populations have decreased slightly, primarily due to the sharp decline in the sheep industry. Sheep grazing declined for a variety of reasons. Sheep were blamed for the overgrazing, range wars followed, wool prices declined, and the government pursued policies to decrease sheep populations (Oliver et al., 1994). These patterns were similar to those for the Pacific Northwest (Idaho, Oregon, and Washington, Figure 15b).



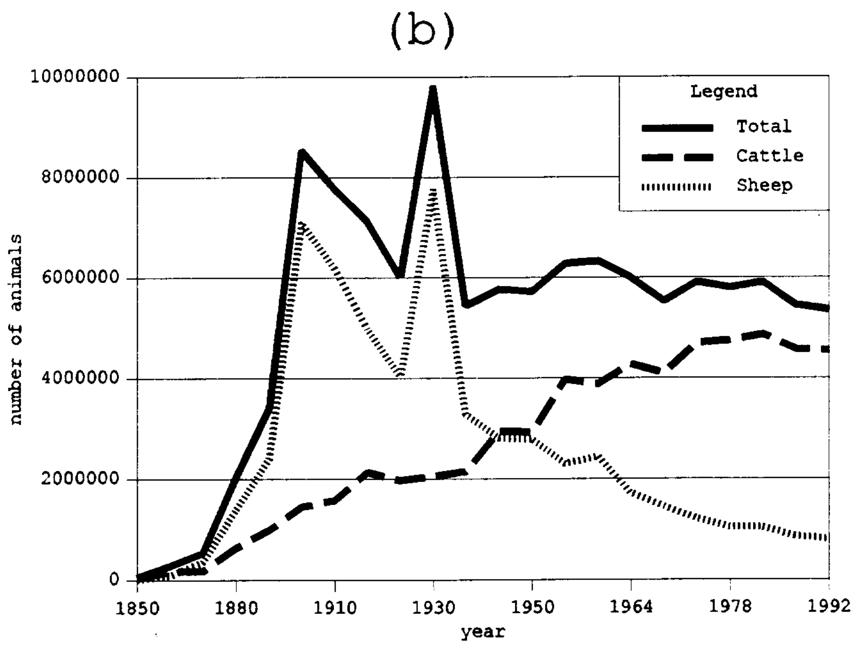
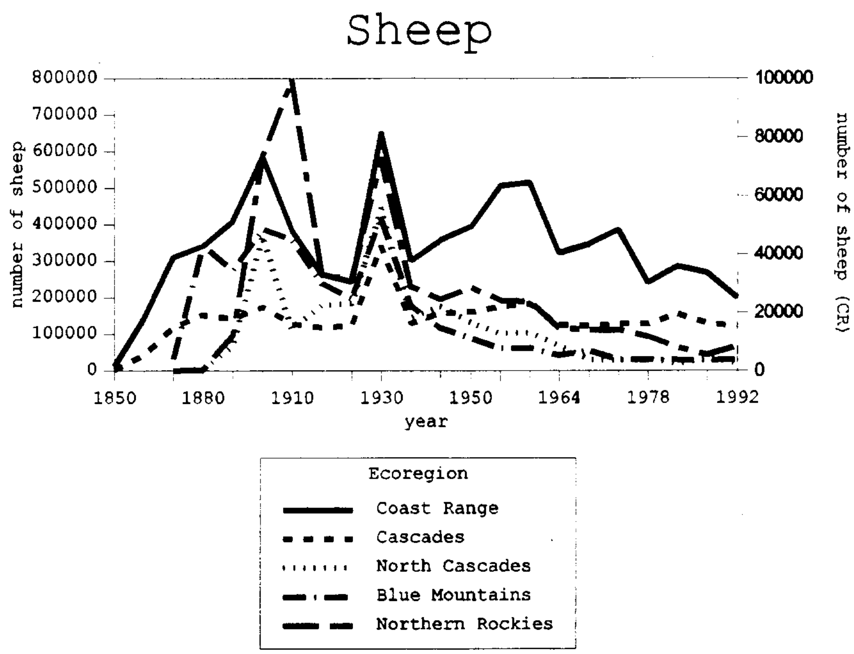


Figure 15. Changes in livestock populations in (a) study basins and (b) Pacific Northwest (Idaho, Oregon, and Washington), from 1850 to 1992.

When types of livestock are considered, the pattern to these changes becomes evident. The large fluctuations in livestock numbers have largely been driven by sheep populations. Sheep populations rose sharply in the late 1800's, peaking in 1900, than declined in response to public concern about overgrazing. Their numbers peaked again in 1930 due to favorable market conditions, but declined sharply after 1940 (Figure 15a). Cattle populations were not cyclic like sheep and have increased steadily since 1850 (Figure 15a). There are now as many cattle in the Columbia basin as there have ever been. Cattle surpassed sheep in number in 1945 and now are 77% of the livestock population. The shift from sheep to cattle has implications for riparian and stream ecosystems. Cattle, which prefer streamside areas, versus sheep which prefer upland and meadow ecosystems, can cause considerable damage to stream and riparian ecosystems (Kauffman and Krueger, 1984; Platts, 1991).

To examine whether there were different geographic patterns to these changes, we summarized the data by Ecoregions. The cyclic patterns to sheep populations were evident across Ecoregions (Figure 16), while cattle populations have been steadily increasing over time (Figure 16). While the patterns were similar between Ecoregions, the timing often varied. This was especially true before 1900. The progression of the livestock industry inland is evident.

We also examined trends in livestock use on public and private lands. A 1986 report (Northwest Power Planning Council) documented that grazing use by livestock on public lands in Idaho, Oregon, and Washington declined from 1945 to 1983. This finding implies that grazing use has been shifting from public to private lands. We also used the limited available data to develop examples on livestock use on private and public lands for two watersheds. Our focus was on cattle, since sheep grazing is greatly reduced in the Columbia River basin, especially in the interior.



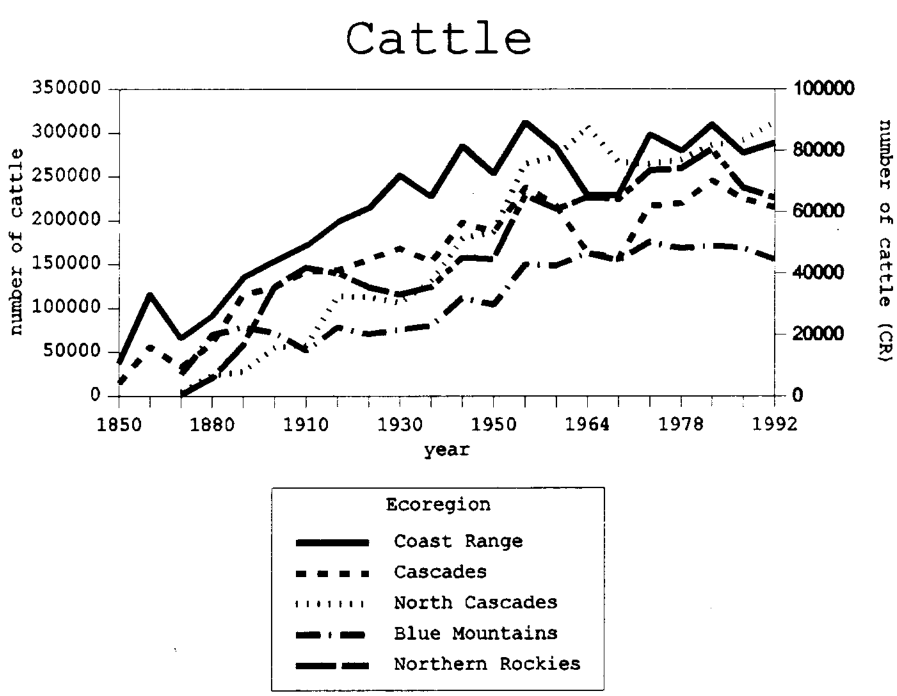
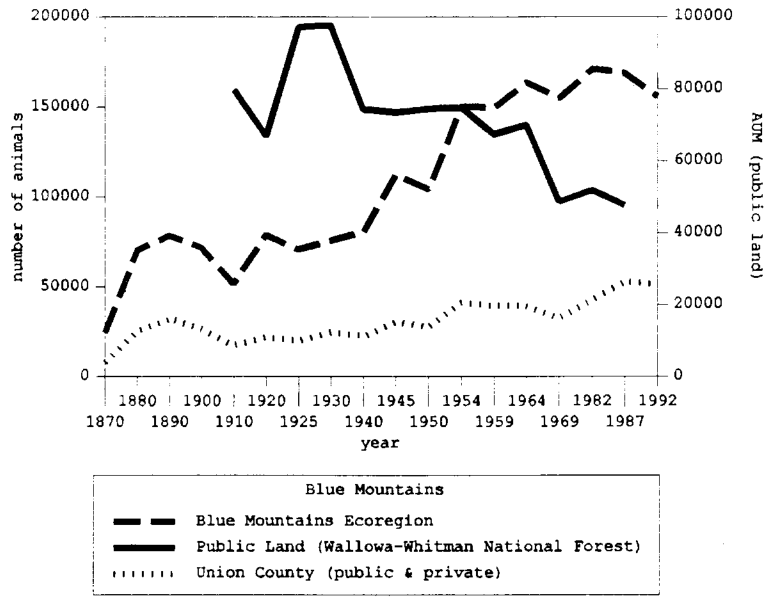


Figure 16. Changes in sheep and cattle populations for study basins, by Ecoregion, from 1850 to 1992, (CR) = Coast Range.

In figure 17, trends in cattle number and use (AUM) for the Blue Mountains Ecoregion, Wallowa-Whitman National Forest, and Union County are displayed. Cattle numbers show an increasing trend for the Blue Mountains Ecoregion and Union County, and a decreasing trend for the Wallowa-Whitman National Forest. These trends show that livestock use is decreasing on public lands and increasing on private lands in the Grande Ronde watershed. There are at least three possible hypotheses for this trend, although we have no data to support them. Livestock numbers on private lands could be increasing due to increases in feedlot operations, increased cultivation and irrigation of private lands for summer pasture and winter feed, or a combination of the above. These practices are likely to increase the carrying capacity of private lands for cattle.

Similar data were available for the North Cascades Ecoregion, part of the Okanogan National Forest, and Okanogan county. These data showed that cattle populations and utilization were increasing on both public and private lands (Figure 17), contrary to the trends in the Blue Mountains Ecoregion. While the general trend has been decreased cattle grazing on public lands, our data suggests these trends have been variable. Unfortunately more data were not available for other watersheds.

Our data confirms that the periods of highest livestock use in the Columbia River basin occurred before 1930. Grazing use was dominated by sheep before 1930. Sheep were moved in large herds from low elevations to high elevations in the spring, summered in mountain meadows and grasslands, and returned to low elevations in the fall to winter, repeating the cycle annually (Oliver et al., 1994). By 1900, the public, livestock producers, and government officials were concerned about the effects of overgrazing. Grazing declined from 1900 to 1925, primarily due to the decline in the sheep industry. Livestock populations peaked again in 1930 at their highest levels, due to a boom in the sheep industry. The heavy grazing during this



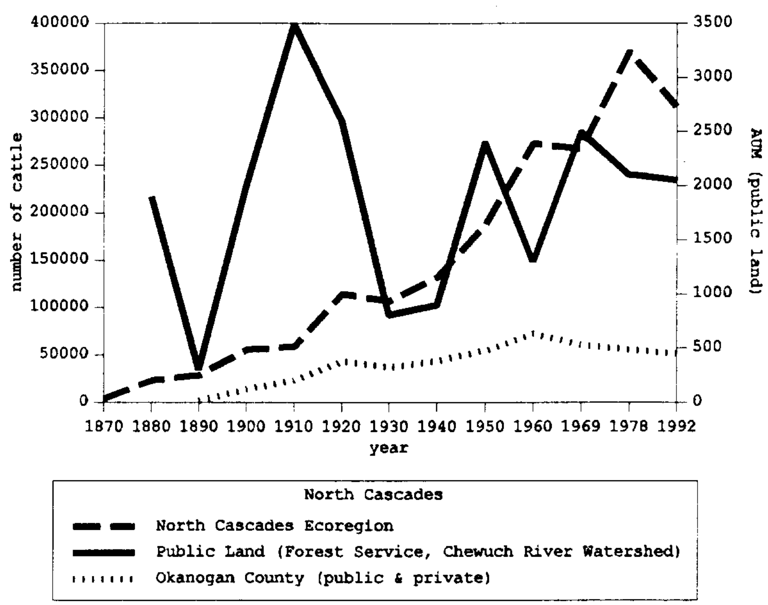


Figure 17. Changes in cattle use between public and private lands in the Blue Mountains and North Cascades Ecoregions.

period also corresponded with the worst drought of record in the Pacific Northwest, which occurred from 1928 to 1941 (U.S. Geological Survey, 1991). Sheep grazing declined sharply after 1935, due to regulation and falling wool prices.

Recent research in the Blue Mountains (Skovlin and Thomas, 1995), using repeat photography from the early 1900s to 1992, confirms the effects of overgrazing at the turn of the century. These effects include severe reductions in vegetative cover, loss of top soil due to erosion, increases in weedy plant species, and the introduction of exotic plant species. Current photographs confirm the generalization that upland areas have improved, while riparian and mountain meadows have not. Skovlin and Thomas (1995) cite the loss of woody vegetation and hydrologic connectivity, due to cattle grazing, road construction and drainage, and timber harvest as the primary causes.

We also reviewed the available data on range condition. The literature suggests large-scale range degradation was halted by the 1930s, with range conditions improving since then (Box, 1990; U.S. Department of Interior, 1990). Range condition may be improving, but the most recent assessment shows about 50% of federal rangelands are in fair to poor condition, based on vegetative potential (U.S. Government Accounting Office, 1988b). A similar assessment found that 78% of private rangelands in Oregon were in fair to poor condition (U.S. Department of Agriculture, Soil Conservation Service, 1985). Additional documentation suggests that most of the improvements have been in the uplands, while riparian areas remain in poor condition (Chaney et al., 1990; U.S. Government Accounting Office, 1988a). The conclusions of these assessments must be viewed cautiously, due to considerable criticism over the reliability of range assessments. These national assessments are compromised by a lack of current, comprehensive, and representative data, along with inconsistencies in methodologies over time (National Research Council, 1994).

Timber Harvest

Timber harvest in the Columbia River basin began as Euro-American settlers began migrating to the Pacific Northwest on the Oregon Trail in the mid-1800s. Early harvest was primarily to meet local needs (Robbins and Wolf, 1994). The California gold rush of the mid-1800s increased the demand for raw materials to supply the gold fields. Lumber from western Oregon was a commodity in high demand (Robbins and Wolf, 1994). Some of the earliest commercial sawmills in Oregon were at the mouth of the Columbia, as early as 1844 (Farnell, 1981). Timber harvest began in the lower Columbia basin, and progressed up the basin until readily accessible timber was exhausted, or new technologies improved access.

In eastern Oregon and Washington, along with Idaho, timber harvest started later, in response to the gold rushes in the interior Columbia basin in the early 1860s. Lumber mills were built to support the mines and local markets (Robbins and Wolf, 1994). Between 1860 and 1880, timber near the mining districts was sufficient to meet local demands. The regional timber industry changed rapidly from 1880-1900, as the industry moved from the Great Lakes region to the Pacific Northwest, and the railroads arrived (Robbins and Wolf, 1994). Railroad tracks were laid up most major drainages, providing reliable access to an abundant timber supply. By the beginning of the twentieth century, the timber industry in the Pacific Northwest was supplying local and national needs (Robbins and Wolf, 1994).

The systematic collection of timber harvest records in the Pacific Northwest began in 1925. Before 1925 the record is scattered and incomplete. These records show very different patterns of harvest throughout the Columbia basin. Our analysis by Ecoregions shows harvests started at the coast and moved inland over time. In the Coast Range Ecoregion, harvest had already peaked in 1925 and has been decreasing or steady since then (Figure 18). Timber harvest in the Cascades Ecoregion

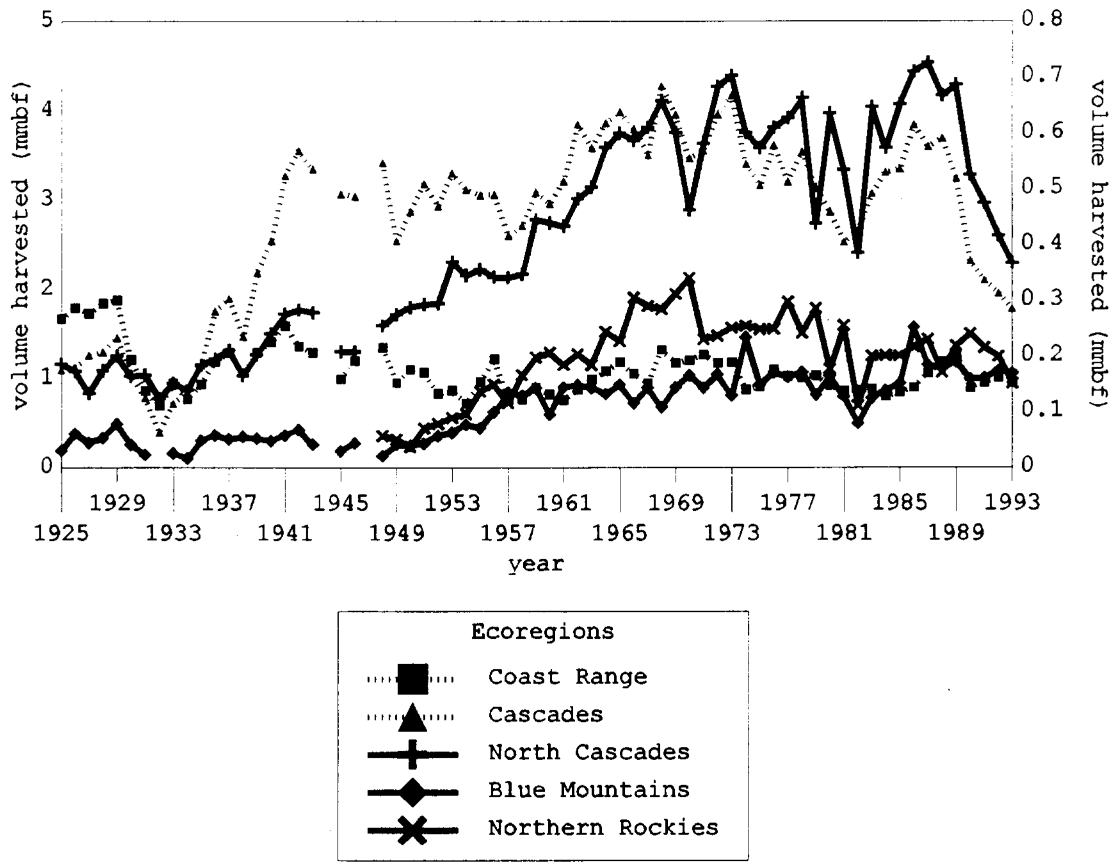


Figure 18. Timber harvest for study basins, by Ecoregion, from 1925 to 1993. Data gaps due to no reports compiled for 1944 and 1947. Dashed lines correspond with primary y-axis (left-side).

were at low levels until 1935, and increased rapidly from 1935 to 1945. Timber harvest remained high until the late 1980s, when the old growth controversy began to affect timber supplies. In the interior Columbia river basin, we find a similar pattern for the North Cascades, Blue Mountains, and Northern Rockies Ecoregions, except timber harvest did not increase significantly until after World War II (Figure 18). The rate of increase was also much slower in the interior as compared to the western Cascades.

Besides the volume of timber harvested, harvest methods must be considered. Harvest methods include silvicultural techniques and the transportation of timber. The earliest harvests were next to major rivers and streams, where the waterways were used as log highways (Sedell et al., 1991). By the 1880s, timber had been cleared along most major rivers and streams in western Washington and Oregon (Sedell and Luchessa, 1982). Harvest practices typically resulted in the largest trees being cut through selective cutting (i.e., high-graded, "cutting the best, leaving the rest") and overstory removal (Oliver et al., 1994). Initially, logs were cut and floated down the adjacent stream. This was a common practice throughout the Columbia River basin (Sedell and Duvall, 1985, Sedell et al., 1991). As the river and stream corridors were cut, loggers had to reach logs at greater distances from the streams, and eventually the mills. Splash dams and sluiceways were created to store and move logs at high flows. Still later, artificial freshets were created to move logs throughout the year.

The historical record shows that splash dams were quite common in western Oregon and Washington (Sedell and Duvall, 1985). Splash dams were less common in the interior, but rivers were frequently used to move logs to the mill. Splash dams have been documented in the Grande Ronde River basin (Beckham, 1995a; McIntosh, 1992; Skovlin, 1991), and log drives have been documented in the Yakima, Wenatchee, Methow River (Beckham, 1995b,c), and Entiat basins (Kerr, 1980; as cited in Mullan et al., 1992). The limited use of splash dams may be due the timing of intensive logging in the interior. The interior Columbia basin was not the focus of intensive logging until after World War II, when railroads and roads, not rivers, were the more reliable means of moving timber to mills.

For streams to be used for log drives, they had to be "improved." Stream improvements included confining flows to the main channel and the removal of large woody debris, log jams, and boulders to move logs efficiently (Sedell and Duvall, 1985). Considerable research has documented the magnitude and extent of stream improvement for log transportation (Sedell and Duvall, 1985; Sedell et al., 1991; Sedell and Luchessa, 1982). When splash dams were used to store water and create artificial freshets, the release of water and logs had significant impacts on the stream channel. Likely impacts included the scouring of streambeds and banks, straightening of stream channels, and the destruction of aquatic biota, such as salmonid juveniles and eggs, and macroinvertebrates (Sedell et al., 1991).

As the railroad networks were extended in the Columbia, railroads replaced log drives as the major method of moving timber. Railroad logging is evident, by the legacy of abandoned railroad grades along rivers and streams in many parts of the basin (Skovlin, 1991). Spur railroads were common throughout Oregon, northeast Washington, and northern Idaho, but less common in central Washington and Idaho (Oliver et al., 1994; Robbins and Wolf, 1994). Access to timber was still limited by the movement of timber to the rails, most often by oxen yarding the logs to the tracks (Skovlin, 1991).

After World War II, with the surplus of heavy machinery and availability of trucks (Oliver et al., 1994), roads became the dominant method for moving timber to the mills. Loggers were no longer limited by access to remote timber stands. Several recent reports have quantified the extent of the road network on public lands in the Pacific Northwest. The U.S. Department of Agriculture (1993) estimated there were over 175,000 km of roads and 250,000 stream crossings (culverts) within the range of the northern spotted owl (*Strix occidentalis caurina*). This analysis extended from the Canadian border to just north of San Francisco and from the Pacific Ocean east to Highway 97, an area of almost 10 million hectares. Their report concluded that most stream crossings could not withstand a 25-year flow event without failure. Stream crossing failures often result in severe impacts to water quality and habitat (U.S. Department of Agriculture, 1993). We estimated the number of kilometers of roads in the Columbia River basin from the FEMAT report (U.S. Department of Agriculture, 1993) and the Eastside Ecosystem Management Project (Eastside Ecosystem Management Project, unpublished data). From these reports, we calculated there were over 277,000 km of roads on public land in the Columbia River basin. In addition, we found 89% (93/104) of the managed streams in our resurveys had roads next to the stream channel or in the floodplain. Clearly the number of roads in the Columbia River basin, along with their proximity to stream and riparian ecosystems, pose a substantial threat to the integrity of these systems. Further, they pose a formidable challenge to restoration, both logistically and financially.

The high densities of logging roads throughout the Columbia basin have been consistently identified as having major effects on stream and riparian ecosystems (Henjum et al., 1994; National Research Council, 1995; U.S. Department of Agriculture, 1993). These effects included increased erosion and sedimentation, altered hydrologic regimes, decreased stream shading through the removal of riparian vegetation, isolation of the stream channel from the floodplain, and the straightening of stream channels (Furniss et al., 1991). All these changes can adversely affect fish habitat. Protecting and "improving" (e.g., large woody debris removal, rip-rap, channelization) this infrastructure is likely to prevent the recovery of aquatic/riparian ecosystems. Harvest systems also began to change, from selective cutting and overstory removal, to even-aged management (e.g., clear-cutting) (Oliver et al., 1994).

The history of timber harvest in the Columbia River basin suggests a changing pattern in the degree and type of impacts. Early logging practices were focused on riparian areas and adjacent hillslopes. The practice of "high-grading" resulted in the largest trees being removed, reducing stream shading and the supply of large woody debris. Stream channels were directly influenced by splash dams, log drives, and "stream improvements." By World War II, stream and riparian habitats in many areas had been simplified and homogenized through the loss of riparian vegetation and large woody debris, channel roughness, and aquatic habitats. After World War II, the demands for timber and technological advances removed all barriers to reaching remote timber stands. Timber harvest expanded to the uplands and higher elevations. This access was enhanced by a rapidly expanding road network, which increased, or at least maintained the impact of timber harvest on already damaged stream and aquatic ecosystems.

Agriculture

Agriculture, like other land-use practices, developed with the expanding populations in the Columbia River basin. Most major river valleys were under intense cultivation by the turn of the century (Robbins and Wolf, 1994). Lands dedicated to farming increased until about 1960, and then leveled off (Northwest Power Planning Council, 1986). After 1950, only the Willamette river basin lost substantial acreage of farmland (Northwest Power Planning Council, 1986). The major crop-producing regions are located in central Washington (e.g., Yakima, Wenatchee, and Methow river basins) and southern Idaho (Thompson, 1976). This also corresponds with the areas of greatest irrigation development. Irrigation diversions and impoundments are now common throughout the Columbia River basin (Wissmar et al., 1994b), with the number of irrigated acres increasing rapidly from 1900 to 1980 (Figure 19, Northwest Power Planning Council, 1986). Water rights are now over-appropriated in most river basins (National Research Council, 1995).

The larger irrigation projects (e.g., Columbia Basin Project) also focused development in the large river valleys, such as the Yakima and the Methow. Irrigated agriculture, not timber and livestock, became the economic base in many of these areas (McIntosh et al., 1994b). By emphasizing the large river valleys, development pressure may have reduced on the headwater and tributary streams.

Agricultural practices that can affect stream habitat include increased sedimentation from erosion, the removal of large woody debris and riparian vegetation, stream channelization, and the construction of revetments (Spence et al., 1995). These practices reduce habitat complexity and decrease channel stability (Karr and Schlosser, 1978). The loss of pool-forming elements and stream channel/floodplain interactions is also likely to reduce pool habitats in agricultural lands. In addition, the large investment in infrastructure (i.e., revetments, bridges, roads) on agricultural lands greatly limit the opportunities for restoration.

Stream Improvements

A historical definition of "stream improvements" would likely emphasize the systematic removal of large woody debris and debris jams, along with the straightening of stream channels. These activities have been carried out in the Pacific Northwest for over 150 years (Sedell et al., 1988). Large to medium-sized rivers were cleared for navigation from the mid-

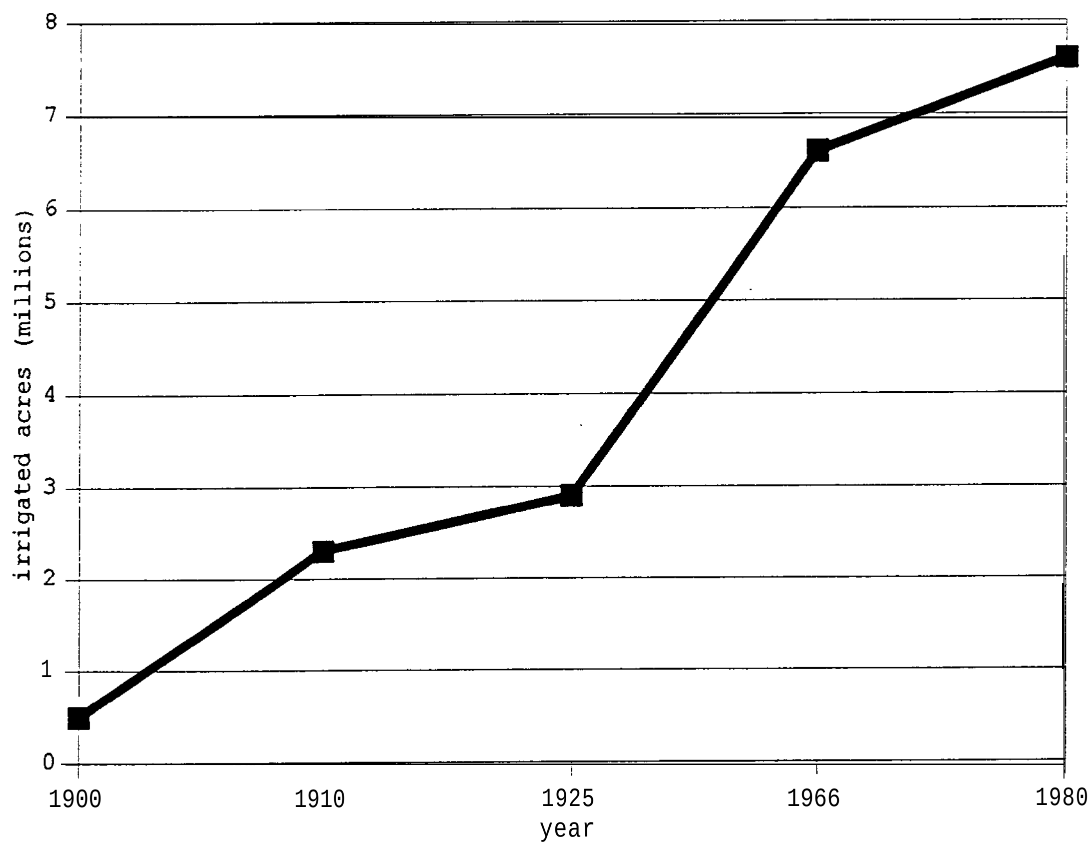


Figure 19. Change in irrigated acreage in the Columbia River basin from 1900 to 1980.

1800s to 1920. Small rivers and streams were cleared from the 1880s to about 1915, so logs could be moved to the mills. These log drives were often enhanced with splash dams. Under these practices, large volumes of large woody debris were removed from the rivers and streams of the Pacific Northwest, greatly altering their physical and biological condition (Harmon et al., 1986).

Fishery management agencies proposed stream improvement programs as early as the Bureau of Fisheries survey. Their major concerns were barriers to fish migration (Rich, 1948). The Bureau of Fisheries surveys also emphasized barriers to fish passage. Published summaries of the Bureau of Fisheries survey are dominated by documentation of the extent of potential migration barriers (Bryant, 1949; Bryant and Parkhurst, 1950; Parkhurst, 1950a,b,c; Parkhurst et al., 1950). In the 1950s and 60s, fishery managers undertook large stream improvement programs, believing that log jams limited fish migration and caused excessive channel scour during floods (Wendler and Deschamps, 1955). It was not until the ecological value of large woody debris and log jams were documented in the 1980s that these practices declined (Sedell et al., 1988).

In addition, since the 1964 flood in the Pacific Northwest, the Federal Government has funded "stream improvements" after every major storm, to protect structures (e.g., bridges and culverts) and reduce liability suits (Maser and Sedell, 1994). The extensiveness of the road and drainage network also severely limits opportunities for watershed restoration. Maser and Sedell (1994) concluded that the combination of these practices has left entire drainage basins with a fraction of the large woody debris once found in pre-settlement streams and rivers. Recent research (Bilby and Ward, 1991; McIntosh et al., 1994a; b, Ralph et al., 1994) shows that harvest practices have decreased the frequency and altered the distribution of large woody debris in harvested versus unharvested streams.

DISCUSSION

Our study of pool habitats in the Columbia River basin showed significant decreases in the quantity and quality of pools over the last fifty to sixty years. The variability in pool frequencies among streams was also much greater historically, with pool frequencies becoming much more homogeneous in the resurveys. We also concluded that the land-use history of the stream affected the size and direction of change. The quantity and quality of pool habitats increased or remained unchanged in unmanaged streams, while they decreased in managed streams. We found no difference in changes to pool habitats based on land ownership (public vs. private land).

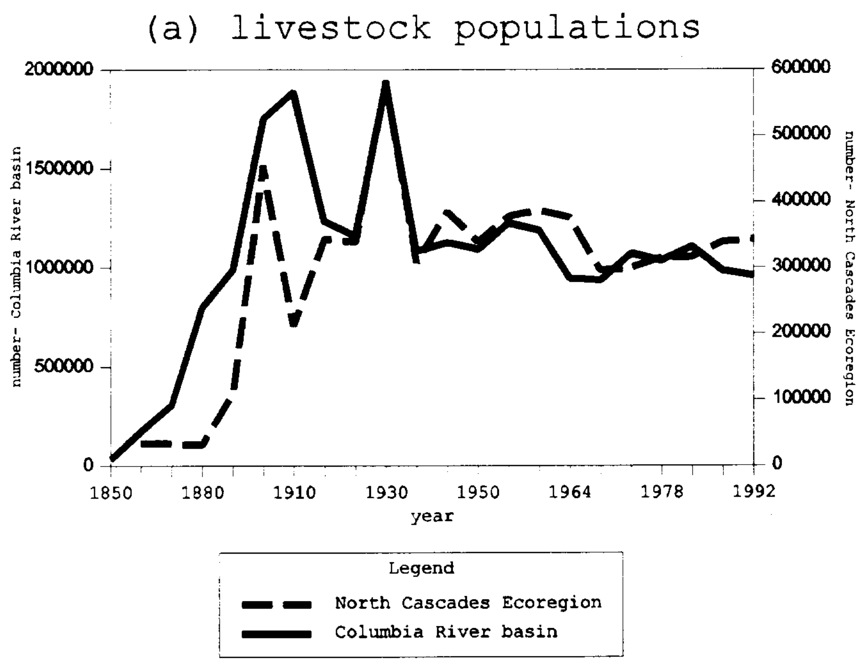
Despite differences in regional characteristics (e.g., geology, landforms), stream size, and land-use history, managed streams lost pools. These results support the conclusion that a wide range of land-use practices causes the simplification (i.e., decreased quality and quantity) of stream habitats. Previous research using the Bureau of Fisheries data has shown similar trends at smaller scales, from individual streams (Peets, 1993; Smith, 1993), to large watersheds (McIntosh, 1992; Minear, 1994), and portions of the Columbia River basin (McIntosh et al., 1994a,b). The losses in pool habitat we have documented show these changes have been widespread. What is most alarming about this finding is that most managed streams had already been affected by land-use practices before the Bureau of Fisheries surveys. Land-use practices began to be regulated after World War II, becoming stricter over time, but the loss of pool habitats continued to be pervasive.

If pool habitats have decreased in managed streams due to land-use practices, than why have pools increased in unmanaged streams? We have no definitive answer to this question, but at least a hypothesis. Before the Bureau of Fisheries surveys, there had been no large floods (> 50-year return interval) in the

Columbia River basin since 1894 (U.S. Geological Survey, 1991). This meant there had been no large pool-forming events for forty to fifty years. In addition, the longest drought of record occurred from 1928-1941 (U.S. Geological Survey, 1991). Since the Bureau of Fisheries surveys was completed in 1945, there have been two large floods (> 50-year return intervals), in 1948 and 1964, which have affected the Columbia River basin (U.S. Geological Survey, 1991). If we assume that unmanaged streams were functionally intact at the time of these floods, the interactions of these floods with intact stream/riparian ecosystems were likely to be major pool-forming events. The natural processes, such as floods, sedimentation, and the recruitment of large woody debris, which have shaped and maintained aquatic ecosystems over time were functional.

The data also show a regional pattern to change. All Ecoregions, except the North Cascades Ecoregion, showed significant decreases in pool habitats. The increased pool frequencies in the North Cascades Ecoregion occurred despite land use, although increases in pool habitats were twice as great in unmanaged as compared to managed streams. McIntosh et al. (1994a,b) found similar results for streams in eastern Oregon and Washington.

To address why pools might have increased in the North Cascades Ecoregion, we compared its land-use history to the other study basins, contrasting patterns of development. Trends in livestock populations were similar between the North Cascades Ecoregion and the rest of the study basins (Figure 20a). Livestock numbers peaked at the turn of the century and again in 1930, declining by 1940 and remaining steady to the present. These cycles were driven by sheep before 1940, shifting to cattle after 1940. The change from sheep to cattle may have moved grazing pressures from the uplands to riparian areas. Cattle populations have also risen steadily in the Columbia River basin since their introduction in the 1840s. In addition, timber harvest did not peak in the North Cascades Ecoregion until the



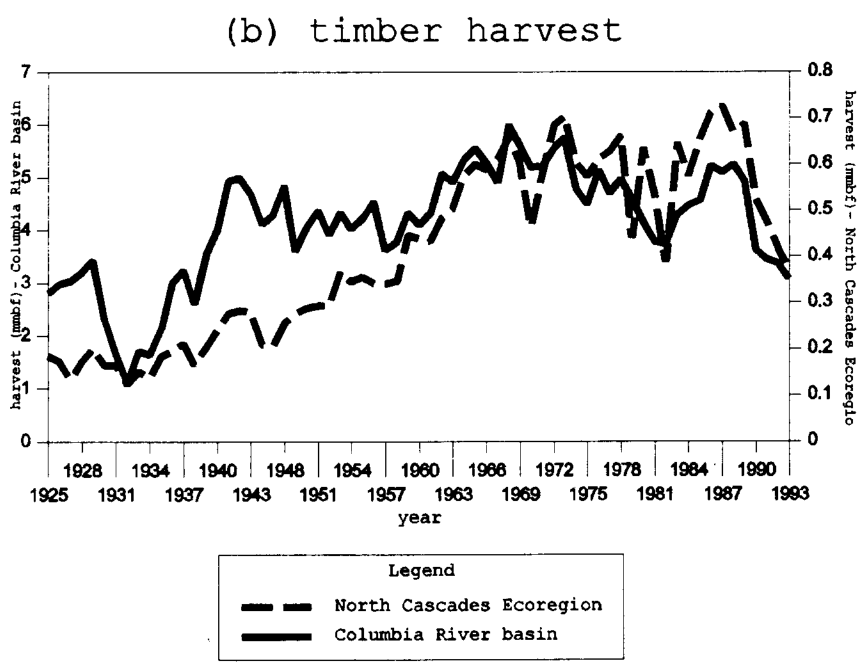


Figure 20. Comparison of trends in (a) livestock populations and (b) timber harvest for the North Cascades Ecoregion and the Columbia River basin.

late 1960s, about 20-30 years later then the rest of the basin (Figure 20b).

We also looked at land allocation in the North Cascades Ecoregion. More than 65% of the land base of the Wenatchee and Okanogan National Forests is in roadless or wilderness areas, effectively protecting the headwaters of most watersheds (McIntosh et al., 1994b). Only one other region, central Idaho, has comparable levels of wilderness/roadless designation. The combination of decreased grazing pressure, later entry for timber harvest, and land allocation may explain the temporal increases in pool habitats in the North Cascades Ecoregion. Prior research (Mullan et al., 1992; Wissmar et al., 1994b) had suggested that the land-use history in north-central Washington were different from the Blue Mountains and areas west of the Cascades. Our results reinforce this conclusion. McIntosh et al. (1994b) concluded that the increases in pool habitats in the North Cascades were encouraging, but must be tempered by the poor condition of some watersheds and potential lag effects of later timber harvest.

The only other large watershed where pool habitats remained the same or increased was the Middle Fork of the Salmon River, a designated wilderness area. This suggests that land allocation within a watershed is critical to the protection and restoration of aquatic ecosystems. These conclusions have important implications in the ongoing debate over how to protect and restore the rivers and watersheds of the Pacific Northwest. Current approaches being implemented by the Federal Government, such as FEMAT (U.S. Department of Agriculture, 1993) have adopted key watersheds and the use of large riparian reserves for aquatic ecosystem management, protection, and restoration. An unresolved question is, do key watersheds and riparian reserves behave like large, naturally functioning watersheds? A critical caveat may be only if riparian reserves and key watersheds are allowed to recover and function naturally. This means regulating activities (e.g., new roads, timber harvest, livestock grazing) in these areas so as not to impede or forestall recovery processes.

Our analysis of land-use records showed there were also regional patterns to Euro-American development in the Columbia River basin. Development generally proceeded up the basin and along the major migration routes. More isolated areas, such as the North Cascades Ecoregion, remain relatively undeveloped today (Mullan et al., 1992). Early development pressures focused around population centers and readily accessible areas (i.e., along waterways). As populations grew, demand for resources caused development to expand throughout the watershed. By the turn of the century, rangelands were severely overgrazed and stream/riparian systems had been simplified by snagging, log drives, splash dams, and timber harvest. The crash in the sheep industry in the 1930s reduced grazing pressures, but the housing boom and heavy machinery allowed the timber industry to expand into previously inaccessible areas.

Intensive timber harvest and road construction began after World War II and continued until the late 1980s. There are now over 277,000 km of roads on public lands in the Columbia River basin. Almost 90% of our study streams in managed watersheds have a road next to the stream or within the floodplain. The boom in the timber industry further simplified stream/riparian ecosystems by increasing sediment delivery and peak flows, reducing or eliminating the interaction between stream channels and floodplains, and reducing large woody debris and riparian vegetation.

In addition, the fisheries profession further exacerbated the loss of Large woody debris by recommending its removal to reduce barriers to fish migration. These practices acted cumulatively to reduce the capacity of stream ecosystems to recover from disturbance, either natural or anthropogenic, and to support self-sustaining fish communities. As Beschta et al. (1995) concluded, the legacy of past practices already limits the function and integrity of existing watersheds. Today's managers must not only manage for current uses, but must also correct the mistakes of the past.

Our analysis of land-use history would have benefited from more site-specific data, but little were available, given the scale of our study area. In addition, all of our analysis focused on the temporal patterns to disturbance. This analysis would have been improved by examining the spatial patterns of disturbance. For example, data on timber harvest, such as the location, area, and type of harvest would have allowed us assess when the likely impacts to stream and riparian habitats might have occurred. We could have quantified where and when the harvest occurred and what proportion of the watersheds and riparian areas had been harvested. The same would have been possible for grazing, roads, and "stream improvements." By quantifying the different spatial and temporal patterns to disturbance among watersheds and comparing them to the changes in pool habitats, we may have detected more site-specific patterns to changes in stream habitats.

We were also unable to quantify the magnitude and extent of all disturbances that were likely to affect stream ecosystems. This was due to the lack of appropriate data, or a poor understanding of how some disturbances affect streams. Examples would include natural disturbances, such as fire, and human disturbances, such as the response to floods (i.e., large woody debris removal, channelization, fire). We were only able to document trends in land-uses that were readily quantifiable, such as timber harvest and grazing. To sort the specific effects of all types of disturbance would have required a watershed analysis for almost all of our study streams. If current attempts at watershed analysis by the Federal Government continue, our collective understanding of the impacts of different land-uses may significantly improve. As watershed analysis is currently posed, it should provide a systematic method to characterize watershed condition, along with the watershed and ecological processes that determine the biophysical capabilities of a watershed (U.S. Department of Agriculture, 1993). If these efforts are successful, they are likely to provide a sounder ecological approach to land management and restoration.

Past research using paired watersheds and before-and-after comparisons have concluded that land-use practices simplify stream habitats. The results were similar whether timber harvest (Bisson and Sedell, 1984; Fausch and Northcote, 1992; Frissell, 1992; Hartman and Scrivener, 1990; Megahan et al., 1992; Ralph et al., 1994; Overton et al., 1993; Reeves et al., 1993), grazing (Platts et al., 1991), mining (Nelson et al., 1991), agriculture (Karr and Schlosser, 1978; Karr et al., 1983), flood control (Cederholm and Koski, 1977; Chapman and Knudsen, 1980), urbanization (Leidy, 1984; Leidy and Fiedler, 1985) or a combination of land-uses (Beechie et al., 1994) was practiced. Most research on pool loss has focused on the effects of timber harvest. Many researchers have found that pool frequency or area was significantly less in logged watersheds, in response to lower levels of large woody debris (Bilby and Ward, 1991; Hicks, 1990; Montgomery et al., 1995; Overton et al., 1993; Ralph et al., 1994; Reeves et al., 1993) or increased sediment delivery coupled with decreased large woody debris (Burns, 1972; Frissell, 1992). As noted before, the influence of different land-use practices on pool-forming processes is similar. Increased sediment delivery and/or loss of pool-forming elements results in decreased pool habitats despite the cause. As Ralph et al. (1994) concluded, the biophysical effects of land-use are moderately well understood, but their extent and significance across broad regional landscapes are poorly documented. We believe our study provides the first documentation of the effect of land-use on stream habitats at the regional scale.

We found only one study that potentially contradicted our findings. Carlson et al. (1990) concluded that past timber harvest practices had not altered stream habitats in northeast Oregon streams. They examined the effects of timber harvest in stream segments where harvest had occurred in the past 6-17 years. Their study streams consisted of short reaches (300-m) in small watersheds (drainage area ≤ 25 km^2). Roads were not located in the stream/riparian corridor, but typically along the ridges, and skid trails were properly drained. We would conclude that these stream segments are not representative of the land-use history for streams of the Blue Mountains or the Columbia River basin. Unlike our study streams, their stream segments have not been affected continuously since Euro-American development began (i.e., grazing, splash dams, log drives, repeated entry and harvest, and roads).

There are three primary ways that pools can be lost in streams. Pools can be filled by sediment (Alexander and Hansen, 1986; Jackson and Beschta, 1984; Lisle, 1982; Lisle and Hilton, 1992; Megahan, 1982), pool-forming elements, such as riparian vegetation, large woody debris, and boulders, can be eliminated (Bilby, 1984; Bisson and Sedell, 1984; Fausch and Northcote, 1992; Hicks, 1990; McIntosh et al., 1994b; Ralph et al., 1994; Sullivan et al., 1987), or both processes may work synergistically. These effects can be acute, such as the filling of pools with sediment during a large flood, or chronic, in response to slow, subtle changes in sediment supplies and the abundance of pool-forming elements, or any number of permutations of the above.

The long-term loss in pool habitats we have documented is probably the least-responsive, yet most persistent effect of land-use. Peterson et al. (1992) concluded that "primary pools," like those assessed in these surveys, are "relatively insensitive to management influences except in extreme cases." Decreased pool habitats is likely to be the end-result of the loss of riparian vegetation, pool-forming elements, and altered sediment supplies. Recovery of large, deep pool habitats is likely to take decades, depending on the mechanisms of pool formation. For example, where large woody debris is the primary mechanism of pool formation, it may take centuries for trees to grow large enough to be recruited into streams. In wet meadow and shrub dominated ecosystems, the time span may be much less. These processes will take even longer to recover unless management activities (e.g., road construction, riparian timber harvest, livestock grazing) and effects (e.g., degraded riparian vegetation, low large woody debris recruitment, high road densities) that forestall recovery, remains the status quo.

What do these changes mean for fish and fish habitat? We would conclude that the capability of streams in managed watersheds in the Columbia River basin to support fish and other aquatic organisms have been severely reduced. Besides the loss of pool habitats, high stream temperatures and fine sediment levels, along with low large woody debris levels, are common. These conditions act cumulatively to simplify stream habitats available to the diversity of native fishes endemic to the region. These conclusions are magnified by the status of anadromous fishes in the Columbia River basin. Most of the anadromous fish fauna in the basin is now at risk of extinction (National Research Council, 1995). A guarded exception is the North Cascades Ecoregion, where most native fish species are listed as depressed but stable (National Research Council, 1995). We believe it is no coincidence that this corresponds to the Ecoregion where pool habitats have increased over the last fifty to sixty years.

This conclusion is especially intriguing, given that anadromous fish from the North Cascades Ecoregion must pass from 4 to 9 mainstem dams each direction over their lifecycles. In the Snake River Basin, anadromous fishes must pass 4 to 8 mainstem dams, yet most anadromous stocks from the Snake are either endangered or severely depressed. Improved habitat conditions in the North Cascades Ecoregion may have slowed the declined of anadromous fishes compared with other Ecoregions.

A final consideration is where these streams occur on the landscape. Most of the managed streams in the Bureau of Fisheries survey occurred in the lower reaches of the watershed. The focus of their study was streams that had supported spring chinook salmon. These portions of the watershed are not currently a major part of the debate over salmon, let alone watershed restoration. The focus instead is the upper reaches where salmonids still survive. In addition, headwater reaches are typically on public lands, where restoration may be easier due to ownership and continuity. Lower reaches are not given much priority due to the complexities of private ownership and the fact that most of these reaches are currently uninhabitable by salmonids.

Lichotowich and Mobrand (1995) have argued that these lower reaches were where most chinook salmon production came from historically. They propose that focusing habitat restoration on the upper reaches will bring minimal gains in chinook salmon populations. Instead, restoring habitats in the lower reaches and connectivity between the lower and upper reaches of watersheds is essential to the revival of chinook salmon populations (Lichotowich and Mobrand, 1995). We agree with these conclusions. In the short-term (< 10 years), our best opportunity to slow the decline is on public land. Over the long-term, we cannot reconnect watersheds and restore salmon without significant contributions from private lands.

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APPENDICES

Appendix A

List of Cooperators

List of Cooperators:

Boise National Forest
Buell and Associates, Inc.
Challis National Forest
Clearwater Associates
Eastside Ecosystem Management Project
Gifford Pinchot National Forest
Intermountain Research Station
Okanogan National Forest
Oregon Department of Fish and Wildlife
Oregon State University
Pacific Northwest Research Station
Salmon National Forest
Umatilla National Forest
University of Washington
Wallowa-Whitman National Forest
Wenatchee National Forest
Willamette National Forest

Appendix B

Pool Data

Changes in Large Pools for the Columbia River basin.
BOF=Bureau of Fisheries, USFS=Forest Service Research.

Stream	Length km	BOF #/km	USFS #/km	Change
Trout Ck, WA	10.9	1.8	13.2	11.4
Early Winters Ck, WA	18.3	1.1	10.2	9.1
Icicle Ck, WA	14.2	3.7	10.2	6.5
Jack Ck, WA	6.9	1.9	8.0	6.1
W Fk Grays R, WA	5.1	4.5	10.3	5.8
Lake Ck, WA	11.8	0.6	5.3	4.7
Chiwaukum Ck, WA	9.0	0.1	4.4	4.3
Mad R, WA	37.2	1.0	5.2	4.2
Wind R, WA	32.8	2.0	6.2	4.2
Staley Ck, OR	5.3	7.2	11.3	4.1
W Fk Mayfield Ck, ID	3.9	4.6	8.2	3.6
Panther Ck, ID	6.3	1.3	4.8	3.5
E Fk Elochoman, WA	5.1	8.5	11.7	3.2
Elk Ck, ID	11.3	12.6	15.7	3.1
Peshastin Ck, WA	10.7	0.6	3.6	3.0
Little Naches R, WA	15.6	1.7	4.6	2.9
Elochoman R, WA	24.0	2.8	5.6	2.8
Tucannon R, WA	88.9	2.0	4.8	2.8
Nason Ck , WA	33.6	4.9	7.7	2.8
N Fk Teanaway, WA	12.2	3.1	5.9	2.8
L North Santiam, OR	23.0	1.6	4.3	2.7
Taneum Ck WA	17.2	0.7	3.4	2.7
Grays R, WA	14.6	5.1	7.6	2.5
E Fk Lewis R, WA	7.7	6.6	9.1	2.5
Chewuch R, WA	64.1	1.0	3.4	2.4
Rattlesnake Ck, WA	26.8	1.7	4.1	2.4
Chiwawa R, WA	59.1	1.8	4.2	2.4

Swauk Ck, WA	9.7	1.1	3.4	2.3
Abernathy Ck, WA	13.4	3.9	6.1	2.2
Warm Springs Ck, ID	24.5	5.9	8.0	2.1
Methow R, WA	69.7	1.4	3.0	1.6
White R, WA	20.2	1.2	2.7	1.5
Coweeman R, WA	42.5	5.1	6.6	1.5
M Fk Teanaway, WA	13.5	1.6	3.0	1.4
Willamina Ck, OR	16.1	4.4	5.8	1.4
W Fk Methow, WA	3.4	2.4	3.6	1.2
W Fk Camas Ck, ID	3.3	0.3	1.5	1.2
Twisp R, WA	42.5	2.8	3.9	1.1
Tieton R, WA	12.9	0.2	1.3	1.1
Lost R, WA	11.8	2.0	3.1	1.1
Pistol Ck, ID	16.0	3.7	4.8	1.1
Greenhorn Ck, WA	3.2	0.9	1.9	1.0
Marble Ck, ID	15.0	3.2	4.1	0.9
Rock Ck, OR	2.3	0.0	0.9	0.9
Indian Ck, ID	18.0	5.0	5.8	0.8
Panther Ck, WA	10.0	5.8	6.5	0.7
Little Pistol Ck, ID	16.0	2.8	3.4	0.6
Entiat R, WA	42.2	2.1	2.6	0.5
Big Ck, OR	11.4	9.4	9.5	0.1
Bumping R, WA	26.0	1.1	1.1	0.0
Jordan Ck, OR	3.1	0.0	0.0	0.0
Banner Ck, ID	1.3	11.5	11.5	0.0
Rock Ck, OR	8.8	7.6	7.6	0.0
Five Points Ck, OR	2.7	1.8	1.8	0.0
L Wenatchee R, WA	16.3	5.9	5.8	-0.1
Mayfield Ck, ID	5.7	1.1	0.9	-0.2
E Fk Mayfield Ck, ID	2.9	11.0	10.7	-0.3

Rapid R, ID	21.1	3.5	3.1	-0.4
Mission Ck, WA	16.9	0.6	0.1	-0.5
Meadow Ck, OR	18.7	2.5	2.0	-0.5
Sulphur Ck, OR	16.7	14.9	14.3	-0.6
N Fk Cispus R, WA	9.7	13.9	13.3	-0.6
Naches R, WA	8.8	1.5	0.8	-0.7
Loon Ck, ID	46.7	4.1	3.4	-0.7
American R, WA	24.5	3.4	2.5	-0.9
Swift Ck, OR	5.3	6.8	5.8	-1.0
Asotin Ck, WA	37.5	3.1	2.1	-1.0
Clatskanie R, OR	24.9	7.0	5.9	-1.1
Marsh Ck, ID	19.2	9.9	8.3	-1.6
N Fk Grays R, WA	9.2	7.7	5.9	-1.8
S Fk Brietenbush R, OR	2.0	18.0	16.0	-2.0
Lemhi R , ID	94.9	4.2	1.8	-2.4
Cispus R, WA	41.2	5.0	2.6	-2.4
Horse Ck, OR	24.0	7.1	4.7	-2.4
McKenzie R, OR	122.1	7.8	5.2	-2.6
Agency Ck, OR	7.2	10.2	7.6	-2.6
Gold Ck, WA	10.9	3.9	1.2	-2.7
Umatilla R, OR	27.7	8.3	5.5	-2.8
Grande Ronde R, OR	71.0	4.2	1.3	-2.9
N Fk Catherine Ck, OR	6.6	4.7	1.7	-3.0
Orofino Ck, ID	8.4	4.8	1.7	-3.1
Skate Ck, WA	15.0	13.1	9.6	-3.5
Augusta Ck, OR	3.2	8.1	4.4	-3.7
Panjab Ck, WA	4.8	4.6	0.8	-3.8
S Santiam, OR	29.6	10.7	6.8	-3.9
S Fk Winberry Ck, OR	12.9	8.7	4.7	-4.0
Molalla R, OR	26.2	9.1	5.0	-4.1

Thomas Ck, OR	13.7	9.9	5.8	-4.1
Lewis and Clark R, OR	16.7	8.5	4.4	-4.1
Clear Fork, WA	2.4	11.6	7.5	-4.1
Salmon Ck, OR	14.5	7.0	2.8	-4.2
Calapooia R, OR	34.9	10.8	6.3	-4.5
Beaver Ck, ID	15.1	8.7	3.8	-4.9
Bear Valley Ck, ID	24.5	8.7	3.7	-5.0
N Fk Brietenbush, OR	9.6	10.6	5.5	-5.1
Trapper Ck, WA	3.2	11.2	5.6	-5.6
Catherine Ck, OR	30.7	9.1	3.5	-5.6
Yellowjacket Ck, WA	8.2	15.8	10.2	-5.6
Salmon R, ID	28.1	7.9	1.9	-6.0
Lochsa R, ID	22.4	10.1	4.1	-6.0
Fall Ck, OR	15.3	10.3	4.1	-6.2
W Fk Elochoman R, WA	5.5	11.9	5.7	-6.2
Crabtree Ck, OR	14.5	10.0	3.4	-6.6
S Fk Klaskinine, OR	15.8	14.3	7.6	-6.7
Knapp Ck, ID	1.3	16.9	10.0	-6.9
McCoy Ck, OR	4.7	9.2	1.7	-7.5
Sheep Ck, OR	9.2	14.8	6.9	-7.9
Beaver Ck, OR	3.4	9.8	1.5	-8.3
S Fk McKenzie R, OR	31.7	11.4	2.9	-8.5
Mosby Ck, OR	22.7	15.0	5.5	-9.5
S Fk Catherine Ck, OR	3.3	11.2	1.5	-9.7
Cape Horn Ck, ID	7.5	17.3	7.5	-9.8
E Fk Grays R, WA	4.3	16.8	6.9	-9.9
M Fk Weiser R, ID	15.0	15.7	5.2	-10.5
Lake Ck, WA	3.1	19.6	8.5	-11.1
Trail Ck, ID	0.8	11.2	0.0	-11.2
M Fk Willamette, OR	32.5	22.2	7.6	-14.6

Iron Ck, WA	4.3	28.5	11.3	-17.2
Camas Ck, ID	3.6	25.6	6.1	-19.5
Brietenbush R, OR	7.5	31.5	10.7	-20.8
Summary (n = 120)	2256.9	7.1	5.4	-1.7
	SD	6.1	3.4	

Changes in Deep Pools for the Columbia River basin.
BOF=Bureau of Fisheries, USFS=Forest Service Research.

	Length	BOF	USFS	
Stream	km	#/km	#/km	Change
White R, WA	20.2	0.8	2.5	1.7
Staley Ck, OR	5.3	3.0	4.5	1.5
L North Santiam, OR	23.0	1.0	2.4	1.4
Sulphur Ck, ID	16.7	0.0	1.2	1.2
Mosby Ck, OR	22.7	2.7	1.8	0.9
Tieton R, WA	12.9	0.1	0.9	0.8
Loon Ck, ID	46.7	0.7	1.4	0.7
Chiwaukum Ck, WA	9.0	0.0	0.6	0.6
Rapid R, ID	21.1	0.0	0.5	0.5
Early Winters Ck, WA	18.3	0.1	0.5	0.4
Marsh Ck, ID	19.2	0.3	0.7	0.4
Cispus R, WA	41.2	2.3	2.6	0.3
W Fk Methow, WA	3.4	0.3	0.6	0.3
Trout Ck, WA	10.9	0.6	0.9	0.3
Pistol Ck, ID	16.0	0.0	0.3	0.3
Wind R, WA	32.8	1.7	1.9	0.2
Mad R, WA	37.2	0.1	0.3	0.2
Lost R, WA	11.8	0.6	0.7	0.1
Nason Ck , WA	33.6	1.0	1.1	0.1
Methow R, WA	69.7	0.5	0.6	0.1
M Fk Weiser R, ID	15.0	0.0	0.1	0.1
Little Naches R, WA	15.6	0.7	0.8	0.1
Little Pistol Ck, ID	16.0	0.0	0.1	0.1
Taneum Ck, WA	17.2	0.0	0.1	0.1
Indian Ck, ID	18.0	0.0	0.1	0.1
M Fk Teanaway, WA	13.5	0.1	0.1	0.0

E Fk Mayfield Ck, ID	2.9	0.0	0.0	0.0
Catherine Ck, OR	30.7	0.2	0.2	0.0
Warm Springs Ck, ID	24.5	0.0	0.0	0.0
Swauk Ck, WA	9.7	0.0	0.0	0.0
Panther Ck, ID	6.3	0.0	0.0	0.0
Abernathy Ck, WA	13.4	0.2	0.2	0.0
Chiwawa R, WA	59.1	1.3	1.3	0.0
Bumping R, WA	26.0	0.8	0.8	0.0
Trail Ck, ID	0.8	0.0	0.0	0.0
Peshastin Ck, WA	10.7	0.0	0.0	0.0
Lake Ck WA	11.8	0.0	0.0	0.0
Sheep Ck, OR	9.2	0.0	0.0	0.0
N Fk Catherine Ck, OR	6.6	0.0	0.0	0.0
Greenhorn Ck, WA	3.2	0.0	0.0	0.0
S Fk Catherine Ck, OR	3.3	0.0	0.0	0.0
Rock Ck, OR	2.3	0.0	0.0	0.0
W Fk Mayfield Ck, ID	3.9	0.0	0.0	0.0
Meadow Ck, OR	18.7	0.0	0.0	0.0
Beaver Ck, OR	3.4	0.0	0.0	0.0
Jordan Ck, OR	3.1	0.0	0.0	0.0
W Fk Camas Ck, ID	3.3	0.0	0.0	0.0
Five Points Ck, OR	2.7	0.0	0.0	0.0
McCoy Ck, OR	4.7	0.0	0.0	0.0
Mayfield Ck, ID	5.7	0.0	0.0	0.0
Banner Ck, ID	1.3	0.0	0.0	0.0
Entiat R, WA	42.2	1.2	1.1	-0.1
Marble Ck, ID	15.0	0.1	0.0	-0.1
Grande Ronde R, OR	71.0	0.3	0.1	-0.2
Beaver Ck, ID	15.1	0.2	0.0	-0.2
Tucannon R, WA	88.9	0.2	0.0	-0.2

Mission Ck, WA	16.9	0.2	0.0	-0.2
Brietenbush R, OR	7.5	10.7	10.4	-0.3
Chewuch R , WA	64.1	0.7	0.4	-0.3
Fall Ck, OR	15.3	2.8	2.5	-0.3
Naches R, WA	8.8	1.1	0.8	-0.3
Salmon R, ID	28.1	0.5	0.1	-0.4
Rattlesnake Ck, WA	26.8	0.6	0.1	-0.5
Jack Ck, WA	6.9	0.6	0.1	-0.5
N Fk Teanaway, WA	12.2	1.3	0.7	-0.6
Asotin Ck, WA	37.5	0.7	0.0	-0.7
Swift Ck, OR	5.3	0.9	0.2	-0.7
Knapp Ck, ID	1.3	0.8	0.0	-0.8
Cape Horn Ck, ID	7.5	0.8	0.0	-0.8
Gold Ck, WA	10.9	0.9	0.0	-0.9
Twisp R, WA	42.5	1.1	0.1	-1.0
Bear Valley Ck, ID	24.5	1.2	0.2	-1.0
Grays R, WA	14.6	3.3	2.3	-1.0
E Fk Lewis R, WA	7.7	2.8	1.7	-1.1
Elochoman R, WA	24.0	1.7	0.5	-1.2
Panther Ck, WA	10.0	1.6	0.4	-1.2
Trapper Ck, WA	3.2	1.6	0.3	-1.3
Icicle Ck, WA	14.2	2.2	0.8	-1.4
W Fk Grays R, WA	5.1	1.6	0.0	-1.6
Horse Ck, OR	24.0	2.0	0.4	-1.6
Molalla R, OR	26.2	4.4	2.8	-1.6
Calapooia R, OR	34.9	4.2	2.5	-1.7
L Wenatchee R, WA	16.3	4.6	2.9	-1.7
Willamina Ck, OR	16.1	2.9	0.9	-2.0
W Fk Elochoman R, WA	5.5	2.0	0.0	-2.0
Thomas Ck, OR	13.7	3.1	1.1	-2.0

Crabtree Ck, OR	14.5	2.7	0.6	-2.1
Lewis and Clark R, OR	16.7	2.8	0.6	-2.2
Coweeman R, WA	42.5	2.4	0.1	-2.3
Elk Ck, ID	11.3	2.7	0.3	-2.4
Augusta Ck, OR	3.2	2.5	0.0	-2.5
S Fk Winberry Ck, OR	12.9	3.5	0.9	-2.6
S Fk McKenzie R, OR	31.7	3.1	0.3	-2.8
Lochsa R, ID	22.4	5.4	2.5	-2.9
Rock Ck, OR	8.8	4.9	1.7	-3.2
American R, WA	24.5	3.6	0.4	-3.2
N Fk Grays R, WA	9.2	3.4	0.0	-3.4
Umatilla R, OR	27.7	4.2	0.7	-3.5
Panjab Ck, WA	4.8	3.5	0.0	-3.5
E Fk Grays R, WA	4.3	4.1	0.0	-4.1
McKenzie R, OR	122.1	6.2	1.6	-4.6
Clatskanie R, OR	24.9	5.4	0.8	-4.6
Skate Ck, WA	15.0	5.9	1.2	-4.7
M Fk Willamette, OR	32.5	6.3	1.3	-5.0
Yellowjacket Ck, WA	8.2	10.5	4.8	-5.7
Big Ck, OR	11.4	6.8	0.9	-5.9
E Fk Elochoman, WA	5.1	6.0	0.0	-6.0
Clear Fork, WA	2.4	7.0	0.8	-6.2
Salmon Ck, OR	14.5	7.9	1.6	-6.3
N Fk Cispus R, WA	9.7	6.8	0.4	-6.4
Lake Ck, WA	3.1	7.2	0.7	-6.5
Camas Ck, ID	3.6	6.7	0.0	-6.7
Agency Ck, OR	7.2	10.3	0.8	-9.5
S Santiam, OR	29.6	10.7	0.1	-10.6
Iron Ck, WA	4.3	12.0	0.7	-11.3
S Fk Klaskinine, OR	15.8	14.3	1.1	-13.2

SUMMARY (n = 116)	2142.1	2.3	0.8	-1.5
	SD	3.0	1.3	

Changes in Large Pools in Managed Watersheds.
BOF=Bureau of Fisheries, USFS=Forest Service Research.

Stream	Length km	BOF #/km	USFS #/km	Change
Trout Ck, WA	10.9	1.8	13.2	11.4
Early Winters Ck, WA	18.3	1.1	10.2	9.1
W Fk Grays R, WA	5.1	4.5	10.3	5.8
Mad R, WA	37.2	1.0	5.2	4.2
Wind R, WA	32.8	2.0	6.2	4.2
Staley Ck, OR	5.3	7.2	11.3	4.1
W Fk Mayfield Ck, ID	3.9	4.6	8.2	3.6
Panther Ck, ID	6.3	1.3	4.8	3.5
E Fk Elochoman, WA	5.1	8.5	11.7	3.2
Elk Ck, ID	11.3	12.6	15.7	3.1
Peshastin Ck, WA	10.7	0.6	3.6	3.0
Little Naches R, WA	15.6	1.7	4.6	2.9
Elochoman R, WA	24.0	2.8	5.6	2.8
Tucannon R, WA	72.4	2.5	5.3	2.8
Nason Ck , WA	33.6	4.9	7.7	2.8
N Fk Teanaway, WA	12.2	3.1	5.9	2.8
Rattlesnake Ck, WA	8.0	1.9	4.6	2.7
L North Santiam, OR	23.0	1.6	4.3	2.7
Taneum Ck, WA	17.2	0.7	3.4	2.7
Grays R, WA	14.6	5.1	7.6	2.5
Chewuch R, WA	33.9	1.0	3.5	2.5
E Fk Lewis R, WA	7.7	6.6	9.1	2.5
Abernathy Ck, WA	13.4	3.9	6.1	2.2
Swauk Ck, WA	9.5	1.2	3.4	2.2
Methow R, WA	69.7	1.4	3.0	1.6
Coweeman R, WA	42.5	5.1	6.6	1.5
Willamina Ck, OR	16.1	4.4	5.8	1.4

Rapid R, ID	7.7	2.5	3.8	1.3
W Fk Camas Ck, ID	3.3	0.3	1.5	1.2
Twisp R, WA	42.5	2.8	3.9	1.1
Tieton R, WA	12.9	0.2	1.3	1.1
Greenhorn Ck, WA	3.2	0.9	1.9	1.0
Rock Ck, OR	2.3	0.0	0.9	0.9
Panther Ck, WA	10.0	5.8	6.5	0.7
Entiat R, WA	42.2	2.1	2.6	0.5
Big Ck, OR	11.4	9.4	9.5	0.1
Bumping R, WA	26.0	1.1	1.1	0.0
Five Points Ck, OR	2.7	1.8	1.8	0.0
Jordan Ck, OR	3.1	0.0	0.0	0.0
Rock Ck, OR	8.8	7.6	7.6	0.0
Banner Ck, ID	1.3	11.5	11.5	0.0
L Wenatchee R, WA	16.3	5.9	5.8	-0.1
Mayfield Ck, ID	5.7	1.1	0.9	-0.2
Mission Ck, WA	16.9	0.6	0.1	-0.5
Meadow Ck, OR	18.7	2.5	2.0	-0.5
N Fk Cispus R, WA	9.7	13.9	13.3	-0.6
Naches R, WA	8.8	1.5	0.8	-0.7
American R, WA	24.5	3.4	2.5	-0.9
Clatskanie R, OR	24.9	6.8	5.9	-0.9
Asotin Ck, WA	37.5	3.1	2.1	-1.0
Swift Ck, OR	5.3	6.8	5.8	-1.0
Loon Ck, ID	14.6	5.5	3.8	-1.7
N Fk Grays R, WA	9.2	7.7	5.9	-1.8
S Fk Brietenbush R, OR	2.0	18.0	16.0	-2.0
Lemhi R, ID	94.9	4.2	1.8	-2.4
Horse Ck, OR	24.0	7.1	4.7	-2.4
McKenzie R, OR	122.1	7.8	5.2	-2.6

Agency Ck, OR	**7.2**	**10.2**	**7.6**	**-2.6**
Gold Ck, WA	10.9	3.9	**1.2**	**-2.7**
Umatilla R, OR	**27.7**	**8.3**	**5.5**	**-2.8**
Grande Ronde R, OR	71.0	**4.2**	**1.3**	-2.9
N Fk Catherine Ck, OR	6.6	4.7	1.7	-3.0
Orofino Ck, ID	8.4	4.8	1.7	-3.1
Skate Ck, WA	15.0	13.1	9.6	-3.5
Augusta Ck, OR	3.2	8.1	4.4	-3.7
South Santiam, OR	29.6	10.7	6.8	-3.9
S Fk Winberry Ck, OR	12.9	8.7	4.7	-4.0
Thomas Ck, OR	13.7	9.9	5.8	-4.1
Molalla R, OR	26.2	9.1	5.0	-4.1
Cispus R, WA	41.2	**6.7**	**2.6**	**-4.1**
Lewis 'and Clark R, OR	16.7	**8.5**	**4.4**	**-4.1**
Clear Fork, WA	**2.4**	**11.6**	**7.5**	**-4.1**
Salmon Ck. OR	14.5	**7.0**	**2.8**	**-4.2**
Marsh Ck, ID	**10.4**	**16.5**	**12.2**	**-4.3**
Calapooia R, OR	34.9	10.8	**6.3**	**-4.5**
Beaver Ck, ID	15.1	8.7	3.8	-4.9
Trapper Ck, WA	3.2	11.2	5.6	-5.6
Catherine Ck, OR	30.7	9.1	3.5	-5.6
Yellowjacket Ck, WA	8.2	15.8	10.2	-5.6
Panjab Ck, WA	3.1	7.1	1.3	-5.8
Salmon R, ID	28.1	7.9	1.9	-6.0
Lochsa R, ID	22.4	10.1	4.1	-6.0
Fall Ck, OR	15.3	10.3	4.1	**-6.2**
W Fk Elochoman R, WA	**5.5**	11.9	**5.7**	**-6.2**
Crabtree Ck, OR	14.5	10.0	**3.4**	**-6.6**
S Fk Klaskinine, OR	15.8	14.3	**7.6**	**-6.7**
Knapp Ck, ID	1.3	16.9	10.0	-6.9

McCoy Ck, OR	4.7	9.2	1.7	-7.5
Sheep Ck, OR	9.2	14.8	6.9	-7.9
Beaver Ck, OR	3.4	9.8	1.5	-8.3
S Fk McKenzie R, OR	31.7	11.4	2.9	-8.5
N Fk Brietenbush, OR	8.0	12.7	4.1	-8.6
Mosby Ck, OR	22.7	15.0	5.5	-9.5
Bear Valley Ck, ID	16.5	13.6	4.0	-9.6
S Fk Catherine Ck, OR	3.3	11.2	1.5	-9.7
Cape Horn Ck, ID	7.5	17.3	7.5	-9.8
E Fk Grays R, WA	4.3	16.8	6.9	-9.9
M Fk Weiser R, ID	15.0	15.7	5.2	-10.5
Lake Ck, WA	3.1	19.6	8.5	-11.1
Trail Ck, ID	0.8	11.2	0.0	-11.2
M Fk Willamette, OR	32.5	22.2	7.6	-14.6
Iron Ck, WA	4.3	28.5	11.3	-17.2
Camas Ck, ID	3.6	25.6	6.1	-19.5
Brietenbush R, OR	7.5	31.5	10.7	-20.8
SUMMARY (n = 104)	1866.7	7.8	5.4	-2.4
	SD	6.3	3.5	

Changes in Large Pools in Unmanaged Watersheds.
BOF=Bureau of Fisheries, USFS=Forest Service Research.

	Length	BOF	USFS	
Stream	km	#/km	#/km	Change
Bear Valley Ck, ID	8.0	1.8	12.0	10.2
N Fk Brietenbush, OR	1.6	2.5	12.5	10.0
Icicle Ck, WA	14.2	3.7	10.2	6.5
Jack Ck, WA	6.9	1.9	8.0	6.1
Lake Ck, WA	11.8	0.6	5.3	4.7
Chiwaukum Ck, WA	9.0	0.1	4.4	4.3
Tucannon R, WA	16.5	0.0	2.5	2.5
Chiwawa R, WA	59.1	1.8	4.2	2.4
Chewuch R, WA	30.2	1.0	3.4	2.4
Rattlesnake Ck, WA	18.8	1.6	3.9	2.3
Warm Springs Ck, ID	24.5	5.9	8.0	2.1
Marsh Ck, ID	8.8	2.0	3.6	1.6
White R, WA	20.2	1.2	2.7	1.5
M Fk Teanaway, WA	13.5	1.6	3.0	1.4
W Fk Methow, WA	3.4	2.4	3.6	1.2
Lost R, WA	11.8	2.0	3.1	1.1
Pistol Ck, ID	16.0	3.7	4.8	1.1
Marble Ck, ID	15.0	3.2	4.1	0.9
Indian Ck, ID	18.0	5.0	5.8	0.8
Little Pistol Ck, ID	16.0	2.8	3.4	0.6
Panjab Ck, WA	1.7	0.0	0.0	0.0
Loon Ck, ID	32.1	3.5	3.3	-0.2
E Fk Mayfield Ck, ID	2.9	11.0	10.7	-0.3
Sulphur Ck, ID	16.7	14.9	14.3	-0.6
Rapid R, ID	13.4	4.1	2.7	-1.4
SUMMARY (n = 25)	390.1	3.1	5.6	2.5
	SD	3.3	3.6	

Changes in Deep Pools in Managed Watersheds.
BOF=Bureau of Fisheries, USFS=Forest Service Research.

	Length	BOF	USFS	
Stream	km	#/km	#/km	Change
Staley Ck, OR	5.3	3.0	4.5	1.5
L North Santiam, OR	23.0	1.0	2.4	1.4
Tieton R, WA	12.9	0.1	0.9	0.8
Rapid R, ID	7.7	0.0	0.6	0.6
Early Winters Ck, WA	18.3	0.1	0.5	0.4
Loon Ck, ID	14.6	0.7	1.0	0.3
Cispus R, WA	41.2	2.3	2.6	0.3
Trout Ck, WA	10.9	0.6	0.9	0.3
Wind R, WA	32.8	1.7	1.9	0.2
Mad R, WA	37.2	0.1	0.3	0.2
Mayfield Ck, ID	5.7	0.0	0.2	0.2
Nason Ck , WA	33.6	1.0	1.1	0.1
Methow R, WA	69.7	0.5	0.6	0.1
M Fk Weiser R, ID	15.0	0.0	0.1	0.1
Little Naches R, WA	15.6	0.7	0.8	0.1
Taneum Ck, WA	17.2	0.0	0.1	0.1
W Fk Mayfield Ck, ID	3.9	0.0	0.0	0.0
Peshastin Ck, WA	10.7	0.0	0.0	0.0
Beaver Ck, OR	3.4	0.0	0.0	0.0
S Fk Catherine Ck, OR	3.3	0.0	0.0	0.0
Panther Ck, ID	6.3	0.0	0.0	0.0
Abernathy Ck, WA	13.4	0.2	0.2	0.0
Bumping R, WA	26.0	0.8	0.8	0.0
Five Points Ck, OR	2.7	0.0	0.0	0.0
Swauk Ck, WA	9.7	0.0	0.0	0.0
Catherine Ck, OR	30.7	0.2	0.2	0.0

Banner Ck, ID	1.3	0.0	0.0	0.0
McCoy Ck, OR	4.7	0.0	0.0	0.0
Jordan Ck, OR	3.1	0.0	0.0	0.0
Trail Ck, ID	0.8	0.0	0.0	0.0
Greenhorn Ck, WA	3.2	0.0	0.0	0.0
W Fk Camas Ck, ID	3.3	0.0	0.0	0.0
Rock Ck, OR	2.3	0.0	0.0	0.0
Meadow Ck, OR	18.7	0.0	0.0	0.0
N Fk Catherine Ck, OR	6.6	0.0	0.0	0.0
Sheep Ck, OR	9.2	0.0	0.0	0.0
Marsh Ck, ID	10.4	0.1	0.0	-0.1
Entiat R, WA	42.2	1.2	1.1	-0.1
Tucannon R, WA	72.4	0.2	0.0	-0.2
Grande Ronde R, OR	71.0	0.3	0.1	-0.2
Beaver Ck, ID	15.1	0.2	0.0	-0.2
Mission Ck, WA	16.9	0.2	0.0	-0.2
Brietenbush R, OR	7.5	10.7	10.4	-0.3
Fall Ck, OR	15.3	2.8	2.5	-0.3
Naches R, WA	8.8	1.1	0.8	-0.3
Salmon R, ID	28.1	0.5	0.1	-0.4
N FK Teanaway, WA	12.2	1.3	0.7	-0.6
Asotin Ck, WA	37.5	0.7	0.0	-0.7
Swift Ck, OR	5.3	0.9	0.2	-0.7
Chewuch R, WA	33.9	1.1	0.4	-0.7
Knapp Ck, ID	1.3	0.8	0.0	-0.8
Cape Horn Ck, ID	7.5	0.8	0.0	-0.8
Mosby Ck, OR	22.7	2.7	1.8	-0.9
Gold Ck, WA	10.9	0.9	0.0	-0.9
Twisp R, WA	42.5	1.0	0.1	-0.9
Rattlesnake Ck, WA	8.0	1.1	0.1	-1.0

Grays R, WA	14.6	3.3	2.3	-1.0
E Fk Lewis R, WA	7.7	2.8	1.7	-1.1
Elochoman R, WA	24.0	1.7	0.5	-1.2
Panther Ck, WA	10.0	1.6	0.4	-1.2
Trapper Ck, WA	3.2	1.6	0.3	-1.3
Bear Valley Ck, ID	16.5	1.5	0.0	-1.5
W Fk Grays R, WA	5.1	1.6	0.0	-1.6
Horse Ck, OR	24.0	2.0	0.4	-1.6
Molalla R, OR	26.2	4.4	2.8	-1.6
Calapooia R, OR	34.9	4.2	2.5	-1.7
L Wenatchee R, WA	16.3	4.6	2.9	-1.7
Willamina Ck, OR	16.1	2.9	0.9	-2.0
W Fk Elochoman R, WA	5.5	2.0	0.0	-2.0
Thomas Ck, OR	13.7	3.1	1.1	-2.0
Crabtree Ck, OR	14.5	2.7	0.6	-2.1
Lewis and Clark R, OR	16.7	2.8	0.6	-2.2
Coweeman R, WA	42.5	2.4	0.1	-2.3
Elk Ck, ID	11.3	2.7	0.3	-2.4
Augusta Ck, OR	3.2	2.5	0.0	-2.5
S Fk Winberry Ck, OR	12.9	3.5	0.9	-2.6
S Fk McKenzie R, OR	31.7	3.1	0.3	-2.8
Lochsa R, ID	22.4	5.4	2.5	-2.9
Rock Ck, OR	8.8	4.9	1.7	-3.2
American R, WA	24.5	3.6	0.4	-3.2
N Fk Grays R, WA	9.2	3.4	0.0	-3.4
Umatilla R, OR	27.7	4.2	0.7	-3.5
E Fk Grays R, WA	4.3	4.1	0.0	-4.1
McKenzie R, OR	122.1	6.2	1.6	-4.6
Clatskanie R, OR	24.9	5.4	0.8	-4.6
Skate Ck, WA	15.0	5.9	1.2	-4.7

M Fk Willamette, OR	32.5	6.3	1.3	-5.0
Panjab Ck, WA	3.1	5.5	0.0	-5.5
Yellowjacket Ck, WA	8.2	10.5	4.8	-5.7
Big Ck, OR	11.4	6.8	0.9	-5.9
E Fk Elochoman, WA	5.1	6.0	0.0	-6.0
Clear Fork, WA	2.4	7.0	0.8	-6.2
Salmon Ck, OR	14.5	7.9	1.6	-6.3
N Fk Cispus R, WA	9.7	6.8	0.4	-6.4
Lake Ck, WA	3.1	7.2	0.7	-6.5
Camas Ck, ID	**3.6**	**6.7**	**0.0**	**-6.7**
Agency Ck, OR	**7.2**	**10.3**	**0.8**	**-9.5**
S Santiam, OR	29.6	10.7	0.1	-10.6
Iron Ck, WA	**4.3**	**12.0**	**0.7**	**-11.3**
S Fk Klaskinine, OR	15.8	14.3	1.1	-13.2
SUMMARY (n= 100)	1753.7	**2.6**	**0.8**	**-1.8**
	SD	3.1	1.4	

Changes in Deep Pools in Unmanaged Watersheds.
BOF=Bureau of Fisheries, USFS=Forest Service Research.

	Length	BOF	USFS	
Stream	km	#/km	#/km	Change
White R, WA	20.2	0.8	2.5	1.7
Sulphur Ck, ID	16.7	0.0	1.2	1.2
Marsh Ck, ID	8.8	0.5	1.5	1.0
Loon Ck, ID	32.1	0.7	1.6	0.9
Chiwaukum Ck, WA	9.0	0.0	0.6	0.6
Rapid R, ID	13.4	0.0	0.4	0.4
W Fk Methow, WA	3.4	0.3	0.6	0.3
Pistol Ck, ID	16.0	0.0	0.3	0.3
Chewuch R, WA	30.2	0.2	0.4	0.2
Bear Valley Ck, ID	8.0	0.6	0.8	0.2
Warm Springs Ck, ID	24.5	0.0	0.2	0.2
Lost R, WA	11.8	0.6	0.7	0.1
Little Pistol Ck, ID	16.0	0.0	0.1	0.1
Indian Ck, ID	18.0	0.0	0.1	0.1
Tucannon R, WA	16.5	0.0	0.0	0.0
Lake Ck, WA	11.8	0.0	0.0	0.0
Panjab Ck, WA	1.7	0.0	0.0	0.0
M Fk Teanaway, WA	13.5	0.1	0.1	0.0
E Fk Mayfield Ck, ID	2.9	0.0	0.0	0.0
Chiwawa R, WA	59.1	1.3	1.3	0.0
Marble Ck, ID	15.0	0.1	0.0	-0.1
Rattlesnake Ck, WA	18.8	0.4	0.1	-0.3
Jack Ck, WA	6.9	0.6	0.1	-0.4
Icicle Ck, WA	14.2	2.2	0.8	-1.4
SUMMARY (n = 24)	388.5	0.3	0.5	0.2
	SD	0.5	0.6	

Changes in Large Pools on Public Lands.
BOF=Bureau of Fisheries, USFS=Forest Service Research.

	Length	BOF	USFS`	
Stream	km	#/km	#/km	Change
Trout Ck	10.9	1.8	13.2	11.4
Early Winters Ck	18.3	1.1	10.2	9.1
Icicle Ck	14.2	3.7	10.2	6.5
Jack Ck	6.9	1.9	8.0	6.1
Wind R	15.6	1.5	7.2	5.7
Lake Ck	11.8	0.6	5.3	4.7
Chiwaukum Ck	9.0	0.1	4.4	4.3
Mad R	37.2	1.0	5.2	4.2
Staley Ck	5.3	7.2	11.3	4.1
W Fk Mayfield Ck	3.9	4.6	8.2	3.6
Panther Ck	6.3	1.3	4.8	3.5
Elk Ck	11.3	12.6	15.7	3.1
Peshastin Ck	10.7	0.6	3.6	3.0
Chiwawa R	48.0	2.1	5.0	2.9
Little Naches R	15.6	1.7	4.6	2.9
N Fk Teanaway	12.2	3.1	5.9	2.8
Chewuch R	50.1	1.0	3.5	2.5
E Fk Lewis R	7.7	6.6	9.1	2.5
Rattlesnake Ck	18.7	1.6	4.0	2.4
Swauk Ck	9.7	1.1	3.4	2.3
Warm Springs Ck	24.5	5.9	8.0	2.1
White R	20.2	1.2	2.7	1.5
M Fk Teanaway	13.5	1.6	3.0	1.4
W Fk Methow	3.4	2.4	3.6	1.2
W Fk Camas Ck	3.3	0.3	1.5	1.2
Tieton R	12.9	0.2	1.3	1.1

Lost R	11.8	2.0	3.1	1.1
Pistol Ck	16.0	3.7	4.8	1.1
Greenhorn Ck	3.2	0.9	1.9	1.0
Marble Ck	15.0	3.2	4.1	0.9
Indian Ck	18.0	5.0	5.8	0.8
Panther Ck	10.0	5.8	6.5	0.7
Little Pistol Ck	16.0	2.8	3.4	0.6
Entiat R	42.2	2.1	2.6	0.5
Twisp R	13.2	5.8	6.1	0.3
Bumping R	26.0	1.1	1.1	0.0
Banner Ck	1.3	11.5	11.5	0.0
L Wenatchee R	16.3	5.9	5.8	-0.1
Tucannon R	24.3	2.4	2.2	-0.2
Mayfield Ck	5.7	1.1	0.9	-0.2
E Fk Mayfield Ck	2.9	11.0	10.7	-0.3
Rapid R	21.1	3.5	3.1	-0.4
Mission Ck	16.9	0.6	0.1	-0.5
Sulphur Ck	16.7	14.9	14.3	-0.6
N Fk Cispus R	9.7	13.9	13.3	-0.6
Naches R	8.8	1.5	0.8	-0.7
Loon Ck	46.7	4.1	3.4	-0.7
American R	24.5	3.4	2.5	-0.9
Grande Ronde R	14.9	3.0	1.8	-1.2
Meadow Ck	4.0	4.0	2.8	-1.2
Marsh Ck	19.2	9.9	8.3	-1.6
S Fk Brietenbush R	2.0	18.0	16.0	-2.0
Cispus R	41.2	5.0	2.6	-2.4
Horse Ck	24.0	7.1	4.7	-2.4
Gold Ck	10.9	3.9	1.2	-2.7
N Fk Catherine Ck	6.6	4.7	1.7	-3.0

Skate Ck	15.0	13.1	9.6	-3.5
Augusta Ck	3.2	8.1	4.4	-3.7
Panjab Ck	4.8	4.6	0.8	-3.8
McKenzie R	12.0	10.3	6.5	-3.8
Clear Fork	2.4	11.6	7.5	-4.1
Salmon Ck	14.5	7.0	2.8	-4.2
Beaver Ck	15.1	8.7	3.8	-4.9
Bear Valley Ck	24.5	8.7	3.7	-5.0
N Fk Brietenbush	9.6	10.6	5.5	-5.1
Trapper Ck	3.2	11.2	5.6	-5.6
Yellowjacket Ck	8.2	15.8	10.2	-5.6
Salmon R	28.1	7.9	1.9	-6.0
Lochsa R	22.4	10.1	4.1	-6.0
Fall Ck	15.3	10.3	4.1	-6.2
Knapp Ck	1.3	16.9	10.0	-6.9
S Fk McKenzie R	31.7	11.4	2.9	-8.5
S Fk Catherine Ck	3.3	11.2	1.5	-9.7
Cape Horn Ck	7.5	17.3	7.5	-9.8
M Fk Weiser R	15.0	15.7	5.2	-10.5
Lake Ck	3.1	19.6	8.5	-11.1
Trail Ck	0.8	11.2	0.0	-11.2
M Fk Willamette	32.5	22.2	7.6	-14.6
Iron Ck	4.3	28.5	11.3	-17.2
Camas Ck	3.6	25.6	6.1	-19.5
Brietenbush R	7.5	31.5	10.7	-20.8
Summary (n = 81)	1179.2	7.1	5.6	-1.5
	SD	6.8	3.7	

Changes in Large Pools on Private Lands.
BOF=Bureau of Fisheries, USFS=Forest Service Research.

Stream	Length km	BOF #/km	USFS #/km	Change
W Fk Grays R	5.1	4.5	10.3	5.8
Tucannon R	64.6	1.9	5.8	3.9
E Fk Elochoman	5.1	8.5	11.7	3.2
Elochoman R	24.0	2.8	5.6	2.8
L N Santiam	23.0	1.6	4.3	2.7
Wind R	17.2	2.6	5.3	2.7
Grays R	14.6	5.1	7.6	2.5
Rattlesnake Ck	8.1	2.0	4.4	2.4
Abernathy Ck	13.4	3.9	6.1	2.2
Chewuch R	14.0	1.1	3.2	2.1
Methow R	69.7	1.4	3.0	1.6
Coweeman R	42.5	5.1	6.6	1.5
Willamina Ck	16.1	4.4	5.8	1.4
Twisp R	29.3	1.5	2.9	1.4
Rock Ck	2.3	0.0	0.9	0.9
Chiwawa R	11.1	0.5	0.8	0.3
Big Ck	11.4	9.4	9.5	0.1
Five Points Ck	2.7	1.8	1.8	0.0
Rock Ck	8.8	7.6	7.6	0.0
Jordan Ck	3.1	0.0	0.0	0.0
Meadow Ck	14.7	2.0	1.8	-0.2
Asotin Ck	37.5	3.1	2.1	-1.0
Swift Ck	5.3	6.8	5.8	-1.0
Clatskanie R	24.9	7.0	5.9	-1.1
N Fk Grays R	9.2	7.7	5.9	-1.8
Lemhi R	94.9	4.2	1.8	-2.4
McKenzie R	110.1	7.5	5.1	-2.4

Agency Ck	7.2	10.2	7.6	-2.6
Umatilla R	27.7	8.3	5.5	-2.8
Orofino Ck	8.4	4.8	1.7	-3.1
Grande Ronde R	56.1	4.7	1.2	-3.5
S Fk Winberry Ck	12.9	8.7	4.7	-4.0
Thomas Ck	13.7	9.9	5.8	-4.1
Molalla R	26.2	9.1	5.0	-4.1
Lewis and Clark R	16.7	8.5	4.4	-4.1
Calapooia R	34.9	10.8	6.3	-4.5
Catherine Ck	30.7	9.1	3.5	-5.6
W Fk Elochoman R	5.5	11.9	5.7	-6.2
Crabtree Ck	14.5	10.0	3.4	-6.6
S Fk Klaskinine	15.8	14.3	7.6	-6.7
McCoy Ck	4.7	9.2	1.7	-7.5
Sheep Ck	9.2	14.8	6.9	-7.9
Beaver Ck	3.4	9.8	1.5	-8.3
Mosby Ck	22.7	15.0	5.5	-9.5
E Fk Grays R	4.3	16.8	6.9	-9.9
Summary (n = 45)	997.3	6.4	4.8	-1.6
	SD	4.3	2.6	

Changes in Deep Pools on Public Lands.
BOF=Bureau of Fisheries, USFS=Forest Service Research.

Stream	Length km	BOF #/km	USFS #/km	Change
White R	20.2	0.8	2.5	1.7
Staley Ck	5.3	3.0	4.5	1.5
Sulphur Ck	16.7	0.0	1.2	1.2
Tieton R	12.9	0.1	0.9	0.8
Loon Ck	46.7	0.7	1.4	0.7
Chiwaukum Ck	9.0	0.0	0.6	0.6
Rapid R	21.1	0.0	0.5	0.5
Early Winters Ck	18.3	0.1	0.5	0.4
Marsh Ck	19.2	0.3	0.7	0.4
Cispus R	41.2	2.3	2.6	0.3
W Fk Methow	3.4	0.3	0.6	0.3
Trout Ck	10.9	0.6	0.9	0.3
Pistol Ck	16.0	0.0	0.3	0.3
Mad R	37.2	0.1	0.3	0.2
Lost R	11.8	0.6	0.7	0.1
M Fk Weiser R	15.0	0.0	0.1	0.1
Little Naches R	15.6	0.7	0.8	0.1
Little Pistol Ck	16.0	0.0	0.1	0.1
Indian Ck	18.0	0.0	0.1	0.1
M Fk Teanaway	13.5	0.1	0.1	0.0
E Fk Mayfield Ck	2.9	0.0	0.0	0.0
Peshastin Ck	10.7	0.0	0.0	0.0
Swauk Ck	9.7	0.0	0.0	0.0
Panther Ck	6.3	0.0	0.0	0.0
Warm Springs Ck	24.5	0.0	0.0	0.0
Trail Ck	0.8	0.0	0.0	0.0

Grande Ronde R	14.9	0.0	0.0	0.0
Lake Ck	11.8	0.0	0.0	0.0
Bumping R	26.0	0.8	0.8	0.0
N Fk Catherine Ck	6.6	0.0	0.0	0.0
Greenhorn Ck	3.2	0.0	0.0	0.0
W Fk Mayfield Ck	3.9	0.0	0.0	0.0
Meadow Ck	4.0	0.0	0.0	0.0
Banner Ck	1.3	0.0	0.0	0.0
W Fk Camas Ck	3.3	0.0	0.0	0.0
S Fk Catherine Ck	3.3	0.0	0.0	0.0
Mayfield Ck	5.7	0.0	0.0	0.0
Entiat R	42.2	1.2	1.1	-0.1
Chiwawa R	48.0	1.6	1.5	-0.1
Tucannon R	24.3	0.2	0.1	-0.1
Marble Ck	15.0	0.1	0.0	-0.1
Beaver Ck	15.1	0.2	0.0	-0.2
Rattlesnake Ck	18.7	0.3	0.1	-0.2
Chewuch R	50.1	0.7	0.5	-0.2
Mission Ck	16.9	0.2	0.0	-0.2
Brietenbush R	7.5	10.7	10.4	-0.3
Fall Ck	15.3	2.8	2.5	-0.3
Naches R	8.8	1.1	0.8	-0.3
Salmon R	28.1	0.5	0.1	-0.4
Jack Ck	6.9	0.6	0.1	-0.5
N Fk Teanaway	12.2	1.3	0.7	-0.6
Knapp Ck	1.3	0.8	0.0	-0.8
Cape Horn Ck	7.5	0.8	0.0	-0.8
Wind R	15.6	1.0	0.2	-0.8
Gold Ck	10.9	0.9	0.0	-0.9
Bear Valley Ck	24.5	1.2	0.2	-1.0

E F Lewis R	7.7	2.8	1.7	-1.1
Panther Ck	10.0	1.6	0.4	-1.2
Trapper Ck	3.2	1.6	0.3	-1.3
Icicle Ck	14.2	2.2	0.8	-1.4
Horse Ck	24.0	2.0	0.4	-1.6
L Wenatchee R	16.3	4.6	2.9	-1.7
Twisp R	13.2	1.8	0.0	-1.8
Elk Ck	11.3	2.7	0.3	-2.4
Augusta Ck	3.2	2.5	0.0	-2.5
McKenzie R	12.0	3.2	0.7	-2.5
S Fk McKenzie R	31.7	3.1	0.3	-2.8
Lochsa R	22.4	5.4	2.5	-2.9
American R	24.5	3.6	0.4	-3.2
Panjab Ck	4.8	3.5	0.0	-3.5
Skate Ck	15.0	5.9	1.2	-4.7
M Fk Willamette	32.5	6.3	1.3	-5.0
Yellowjacket Ck	8.2	10.5	4.8	-5.7
Clear Fork	2.4	7.0	0.8	-6.2
Salmon Ck	14.5	7.9	1.6	-6.3
N Fk Cispus R	9.7	6.8	0.4	-6.4
Lake Ck	3.1	7.2	0.7	-6.5
Camas Ck	3.6	6.7	0.0	-6.7
Iron Ck	4.3	12.0	0.7	-11.3
SUMMARY (n = 79)	1167.5	1.9	0.8	-1.1
	SD	2.7	1.4	

Changes in Deep Pools on private Lands.
BOF=Bureau of Fisheries, USFS=Forest Service Research

	Length	BOF	USFS	
Stream	km	#/km	#/km	Change
Wind R	17.2	2.3	3.8	1.5
L N Santiam	23.0	1.0	2.4	1.4
Chiwawa R	11.1	0.1	0.4	0.3
Methow R	69.7	0.5	0.6	0.1
McCoy Ck	4.7	0.0	0.0	0.0
Beaver Ck	3.4	0.0	0.0	0.0
Jordan Ck	3.1	0.0	0.0	0.0
Five Points Ck	2.7	0.0	0.0	0.0
Rock Ck	2.3	0.0	0.0	0.0
Catherine Ck	30.7	0.2	0.2	0.0
Abernathy Ck	13.4	0.2	0.2	0.0
Meadow Ck	14.7	0.0	0.0	0.0
Sheep Ck	9.2	0.0	0.0	0.0
Grande Ronde R	56.1	0.3	0.1	-0.2
Tucannon R	64.6	0.2	0.0	-0.2
Chewuch R	14.0	0.5	0.0	-0.5
Twisp R	29.3	0.7	0.2	-0.5
Asotin Ck	37.5	0.7	0.0	-0.7
Swift Ck	5.3	0.9	0.2	-0.7
Mosby Ck	22.7	2.7	1.8	-0.9
Grays R	14.6	3.3	2.3	-1.0
Rattlesnake Ck	8.1	1.2	0.1	-1.1
Elochoman R	24.0	1.7	0.5	-1.2
W Fk Grays R	5.1	1.6	0.0	-1.6
Molalla R	26.2	4.4	2.8	-1.6
Calapooia R	34.9	4.2	2.5	-1.7

Willamina Ck	16.1	2.9	0.9	-2.0
W Fk Elochoman R	5.5	2.0	0.0	-2.0
Thomas Ck	13.7	3.1	1.1	-2.0
Crabtree Ck	14.5	2.7	0.6	-2.1
Lewis and Clark R	16.7	2.8	0.6	-2.2
Coweeman R	42.5	2.4	0.1	-2.3
S Fk Winberry Ck	12.9	3.5	0.9	-2.6
Rock Ck	8.8	4.9	1.7	-3.2
N Fk Grays R	9.2	3.4	0.0	-3.4
Umatilla R	27.7	4.2	0.7	-3.5
E Fk Grays R	4.3	4.1	0.0	-4.1
Clatskanie R	24.9	5.4	0.8	-4.6
McKenzie R	110.1	6.5	1.7	-4.8
Big Ck	11.4	6.8	0.9	-5.9
E Fk Elochoman	5.1	6.0	0.0	-6.0
Agency Ck	7.2	10.3	0.8	-9.5
S Fk Klaskinine	15.8	14.3	1.1	-13.2
SUMMARY (n = 43)	894.1	2.6	0.7	-1.9
	SD	2.9	0.9	

Changes in Large Pools by Ecoregion

MANAGED WATERSHEDS

Ecoregion	Length (km)	BOF #/km	USFS #/km	Change
NORTH CASCADES(n=13)	354.1	2.3	4.3	2.0
COAST RANGE (n=15)	182.1	8.2	7.2	-1.0
CASCADES (n=41)	756.1	9.2	6.1	-3.1
NORTHERN ROCKIES (n=19)	270.2	9.2	5.5	-3.7
BLUE MTS (n=16)	313.9	6.5	2.6	-3.9

UNMANAGED WATERSHEDS

Ecoregion	Length (km)	BOF #/km	USFS #/km	Change
CASCADES(n=2)	20.4	2.1	8.2	6.1
NORTH CASCADES(n=10)	180.1	1.6	4.8	3.2
NORTHERN ROCKIES (n=11)	171.4	5.3	6.6	1.3
BLUE MTS(n=2)	18.2	0.0	1.3	1.3
COAST RANGE (n=0)	NO DATA			

Changes in Deep Pools by Ecoregion				
MANAGED WATERSHEDS				
	Length	BOF	USFS	
Ecoregion	(km)	#/km	#/km	Change
NORTH CASCADES(n=13)	354.1	0.9	0.6	-0.3
BLUE MOUNTAINS (n=16)	313.9	0.7	0.1	-0.6
NORTHERN ROCKIES(n=17)	166.9	1.1	0.3	-0.8
CASCADES(n=39)	746.1	3.8	1.4	-2.4
COAST RANGE(n=15)	182.1	4.6	0.7	-3.9
UNMANAGED WATERSHEDS				
	Length	BOF	USFS	
Ecoregion	(km)	#/km	#/km	Change
NORTHERN ROCKIES(n=11)	171.4	0.2	0.5	0.3
NORTH CASCADES(n=10)	180.1	0.6	0.7	0.1
BLUE MOUNTAINS (n=2)	18.2	0.0	0.0	0.0
CASCADES(n=1)	18.8	0.4	0.1	-0.3
COAST RANGE(n=0)	NO DATA			