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Identification and Prioritization of Salmon Tributaries for Conservation in the Hoh River Basin, Washington State

June 2008

Published with the generous support of the Mountaineers Foundation

June 2008

Dear Friends and Colleagues:

I am pleased to send you Wild Salmon Center's new scientific report, *Identification and Prioritization of Salmon Tributaries for Conservation in the Hoh River Basin, Washington State*. A PDF version of the report is also available on our web site at: www.wildsalmoncenter.org/pubs/articles_reports.php.

We hope this report, representing seven years of intensive fish surveys, informs and accelerates efforts to protect the biologically outstanding Hoh River ecosystem and the fish and fisheries it supports. We also would like to pay tribute to the Hoh Tribe, the Hoh River Trust and other local stakeholders whose stewardship of the Hoh River and salmon fishery continues to contribute to the long-term health of this salmon stronghold.

Finally, we would like to thank the Mountaineers Foundation for their generous support, and the authors, scientists, and other contributors who made this report possible. Please see the complete list of acknowledgements on the inside cover of the report.

We look forward to discussing this report and its recommendations with you as we proceed together with efforts to conserve the Hoh River Watershed.

Sincerely,

Paula Burgess, Director
North America Programs
Wild Salmon Center

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Identification and Prioritization of Salmon Tributaries for Conservation in the Hoh River Basin, Washington State

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Acknowledgments
George Pess, Dr. Steve Katz, Dr. Xan Augerot, and Dr. Sam Chilcote provided critical reviews of the manuscript. We also gratefully acknowledge Bill Freymond (WDFW), Mike Gross (WDFW), Roger Moseley (WDFW), Jim Jorgensen (Quinault Tribe), and Tyler Jurasin (Hoh Tribe) for providing redd count data and smolt trap observations. This research was funded by the Wild Salmon Center, in addition to the National Marine Fisheries Service Northwest Fisheries Science Center which purchased some necessary field equipment. This report was published with the generous support of the Mountaineers Foundation.

Cover Photos
Front: Hoh River (John McMillan)
Back: Winfield Creek, Hoh River Watershed (James Starr)

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1.0 Executive summary

The rivers draining the west side of Washington State's Olympic Peninsula still contain large tracts of pristine temperate rainforest and continue to sustain a diversity of wild salmon and steelhead populations. These rivers' wild salmon populations are some of the healthiest remaining in the contiguous United States and represent core centers of salmon diversity, abundance, and productivity—they are Salmon Strongholds.

The purpose of this report is to prioritize Hoh River tributaries for conservation actions by identifying critical rearing and spawning habitat of salmon and steelhead. Successfully sustaining wild salmon will depend on the maintenance and improvement of current biological conditions in relatively healthy watersheds, as well as the restoration of altered freshwater habitats and implementation of improved regulatory measures that benefit overall ecosystem productivity. Explicit restoration and regulatory needs are beyond the scope of this document.

Our approach

In 2000, the Wild Salmon Center (WSC) initiated a watershed-scale conservation effort on the Olympic Peninsula with the goal of identifying and protecting salmon and their habitat in the Hoh River basin. With nearly 65 percent of its headwater habitat intact and anchored within protected lands of the Olympic National Park, the Hoh River basin was selected because it still supports relatively healthy and diverse salmon populations. Since that time, WSC and Western Rivers Conservancy have collaborated to purchase and protect 4,592 acres of mainstem Hoh River habitat. The ultimate goal of the project is to acquire a total of 10,000 acres, creating a conservation and recreation corridor that will protect most of the important habitat associated with the mainstem Hoh and will provide connectivity to most major tributaries.

Protection of the mainstem is vital, yet many major tributaries used for rearing and spawning are located outside of Park lands where current and historic land use practices continue to alter physical habitat conditions and processes. Protecting these tributaries is necessary to achieve ecological integrity, which is essential to conservation success.

Prioritization of tributaries- our method

To identify high value habitat for salmon rearing we collected 7 years of data on juvenile fish and their associated habitat conditions. Additionally, we analyzed existing agency data for adult fish and habitat during the sample time. We then generated metrics representing juvenile and adult salmon abundance and diversity, and habitat quantity and quality. To prioritize tributaries, we used a modified Watershed Index of Biotic Integrity (W-IBI) analysis to compare salmon and habitat metrics and separated tributaries into tiers (5) by their relative value. The top three tiers represent the best opportunities for conservation, with the uppermost tier warranting highest priority.

Results and recommendations

Our results indicate that all of the sub-basins we surveyed in the Hoh River basin are important to salmon to various degrees. Collectively, they provide unique services to a diversity of species across seasonal, annual and decadal time scales. We believe successful conservation efforts will utilize the sub-basins prioritized and described in this report as core areas or building blocks.

Tributaries with the highest scores (e.g., Tiers 1-3 out of 5) are assumed to have the greatest conservation potential, because they contain desirable salmon qualities and it often more cost-effective to conserve high quality habitat than it is to restore severely degraded habitat.

Tier 1

Winfield Creek was the only tributary we identified as critical salmon habitat and considered it to have excellent conservation potential. It was the most productive tributary with respect to the metrics and W-IBI salmon scores. The sub-basin represents only 3.5 percent of the Hoh watershed yet contains 15 percent of all fall Chinook redds observed, with spawning activity concentrated in the lower 1.6 km of the stream. Thus, the sub-basin represents the highest priority for conservation actions in the Hoh River basin.

Recommendations

Considering the unique salmon value, Winfield Creek is a priority for highly protective conservation actions such as acquisitions and easements. The feasibility of using acquisitions and easements to protect Winfield is high because private timber companies, which have liquidated large land parcels in recent years, own the majority of the sub-basin. To improve and maintain the quality and quantity of desirable stream characteristics (e.g., pool/riffle channel types) conifer regeneration in the riparian zone should be a priority land management activity.

Tier 2

Tier 2 tributaries supported a high level of salmon abundance and diversity for one species or life stage. They also have good habitat conditions and are considered to have good conservation potential. Nolan and Elk Creeks scored good for habitat and salmon. Despite a poor habitat score, Owl Creek is also a second tier level priority for conservation because it scored higher in terms of salmon metrics; its boulder-dominant substrate is particularly hospitable for rearing steelhead. The Elk creek sub-basin represents only 1.5 percent of the Hoh watershed yet supports 5 percent of all observed coho redds, with spawning concentrated in the lower 1 to 2 km of the stream.

Recommendations

The sub-basins are high priorities for increased regulatory protection focused on recovering the physical processes controlling habitat formation, including recruiting instream wood and spawning gravels. Additionally, privately owned tributaries, such as Elk and Nolan are good candidates for acquisitions and easements, while regulatory protection must occur through the 2001 Forest and Fish Plan for forest harvest. Such acquisitions are not possible in Owl Creek because it is owned and managed by Washington State, so conservation actions must be shaped through the regulatory process in this sub-basin. Actions should focus on slope stabilization, conifer regeneration, and recruitment of instream wood and spawning gravels. In Elk, Nolan, and Owl Creeks, maintaining a working landscape compatible with the needs of salmon conservation may be achievable through a gold-standard timber certification process, such as of the Forest Stewardship Council.

Tier 3

Tier 3 tributaries (Braden, Anderson, Alder and Willoughby) generally scored fair for salmon and good for habitat, except for Willoughby, which scored poor in terms of habitat conditions and Braden which scored excellent for habitat. Overall conservation potential is considered fair because the streams supported a less diverse population of spawning adults than Tier 2 streams. Interestingly, while the streams scored poorly for adult salmonids, they scored relatively high for juveniles. The life stage differences emphasize the importance of collecting juvenile data and suggest that the relative importance of different streams cannot be determined with a single life stage.

Recommendations

These sub-basins are priorities for regulatory actions through the Forest and Fish Plan on privately held timber land in Anderson and Braden Creeks, and through the 2005 Forest Practices Habitat Conservation Plan on State lands in Alder, Braden and Willoughby Creeks. Actions should focus on re-establishing connectivity to protected lands, slope stabilization, conifer regeneration, and recruitment of instream wood and spawning gravels. In Willoughby and Alder Creeks, maintaining a working landscape compatible with the needs of salmon conservation may be achievable through a gold-standard timber certification process, such as of the Forest Stewardship Council.

While conserving the above sub-basins is important to improving salmonid productivity and maintaining viable salmon fisheries in the Hoh, investments and actions in other sub-basins should not be overlooked. As loss and degradation of tributary habitat outside Olympic National Park continues, the impacts on Hoh River salmon should be studied and clarified so the appropriate conservation actions can be taken to protect an outstanding wild salmon ecosystem.

2.0 Introduction

Over the past decade the "salmon sanctuary" concept has reemerged as a strategy for conserving salmon at the watershed-scale across the Pacific Rim (Lichatowich et al. 2000; Rahr and Augerot 2005). Similar to the National Wildlife Refuge System that has benefited migratory birds, the strategy is to identify the healthiest remaining salmon watersheds in different salmon ecoregions and sustain those populations and their habitat through a series of collaborative conservation actions (Rahr and Augerot 2005). The approach emphasizes conserving an interconnected network of critical salmon rearing, spawning, and migration habitats that are essential to sustaining salmonids at the watershed-scale (Frissell 1993; Spence et al. 1996; Hauer et al. 2003).

The rationale for conserving critical habitat is that certain areas are disproportionately important for salmon within a watershed (Fausch et al. 2002), and this hierarchy of importance should guide the prioritization of habitat protection (Roni et al. 2002; Rosenfeld and Hatfield 2006). The term "critical habitat" as we use it, is consistent with the salmon "refugia" and "anchor habitat" terminology applied in similar conservation projects (Frissell 1993; Dewberry et al. 1998; May and Peterson 2003). Critical salmon habitat can exist at a variety of spatial scales, including mainstem river segments, floodplain patches, or entire tributaries. These areas support a disproportionate level of salmon abundance and diversity compared to non-critical habitats. They are salmon hotspots.

A key component in conserving critical habitat is prioritizing and identifying sub-basins for conservation actions ranging from acquisitions and easements to increased regulatory protection (Roni et al. 2002). Identifying critical habitat requires understanding how and when different salmon species use those tributaries across their freshwater life cycle and how those associations vary within the watershed (Roni et al. 2002; Rosenfeld and Hatfield 2006). Determining basic quantitative relationships between habitat and salmonid abundance is an important provisional step in the process (Frissell et al. 2000; Rosenfeld and Hatfield 2006).

Several approaches have been used to generate quantitative relationships between population size and habitat area. Most approaches are model based and rely heavily on previously collected data, such as stream surveys and adult redd counts (Pess et al. 2002). The models use the data to prioritize streams according to a suite of generalized habitat quality (e.g., pool and channel type frequency), habitat quantity (e.g., total pool surface area), and salmon metrics (e.g., abundance, distribution, productivity) (Lichatowich et al. 1995; Frissell et al. 2000; May and Peterson 2003; Martin et al. 2004). In watersheds where data is available to quantify habitat associations for all salmon life stages and generate metrics at appropriate scales, modeling can effectively prioritize salmon habitat (Frissell et al. 2000; Pess et al. 2002). However, adequate data for prioritizing salmonid streams for conservation does not exist in all watersheds.

In cases where data is limited to the adult life stage or habitat data is scarce, collecting watershed-scale juvenile and habitat data may be necessary to prioritize streams and identify critical habitat (McMillan et al., in prep). This requires collecting data at the appropriate spatial (e.g., 10's – 100's kilometers) and temporal scales (e.g., interannual, 5 - 50 years) necessary to bridge the gap between science and conservation (Fausch et al. 2002). One way to accomplish this task is to conduct intensive stream habitat and salmonid surveys over one to two salmonid life cycles (e.g., Dewberry 1995).

In 2000, the Wild Salmon Center (WSC) initiated a watershed-scale conservation project to sustain salmon and their habitat in the Hoh River basin, Washington State. The Hoh was selected because it supports a relatively healthy salmon population and roughly 65% of the landscape is considered pristine and protected within the Olympic National Park (Nehlsen et al. 1991; Huntington et al. 1994; McHenry and Lichatowich 1996).

To date, the Western Rivers Conservancy (WRC) and WSC have collaborated to purchase 4,592 acres of mainstem Hoh River habitat with an ultimate goal of acquiring 10,000 acres. If achieved, the project will protect the vast majority of the migration, rearing, and spawning habitat associated with the mainstem Hoh outside the Park (more than 85% of the habitat area) and will provide connectivity to most major tributaries. Although protection of the mainstem Hoh is critical, many major tributaries are located outside of the Park on industrial timberlands where land use practices continue to affect physical habitat conditions (Smith 2000; McHenry 2001). Conserving these tributaries is necessary to protect upslope processes that strongly influence habitat formation and to achieve ecological connectivity across physical and biological scales (Frissell 1993; ISG 1999).

The purpose of this report is to prioritize Hoh River tributaries for conservation actions and identify critical rearing and spawning habitat of salmon and steelhead. Successfully sustaining wild salmon will depend on the maintenance and improvement of current biological conditions, as well as the restoration of altered freshwater habitats and implementation of improved regulatory measures that benefit overall ecosystem productivity.

3.0 Study site

3.1 Watershed description

The headwaters of the Hoh River basin are located on Mt. Olympus at an altitude of 2,425 meters. The entire North Fork and majority of the South Fork Hoh Rivers are protected within the Olympic National Park and are considered pristine in condition (McHenry and Lichatowich 1996; Smith 2000) (Figure 1 – See Map Appendix, p 38). The Hoh is a large (481 km^2) glacially influenced river with an extensive floodplain that contains a diverse array of lateral riverine habitats that are critical to rearing salmonids (Sedell et al. 1984; Smith 2000; McHenry 2001). This river system is also comprised of several major non-glacial tributaries which provide temperate rearing and spawning areas for salmonids (Sedell et al. 1982; McHenry 2001). Most of the large tributaries drain commercial forestlands outside the Park where land use practices have degraded salmon rearing and spawning habitat and have altered the processes responsible for habitat formation (Smith 2000; McHenry 2001).

The wet, mild climate of the Hoh River is dominated by the influence of offshore marine air and is characterized by the highest precipitation levels in Washington State (U.S. Weather Bureau 1965). Average annual precipitation ranges from about 225cm (90 inches) near the Pacific Coast to 600cm (240 inches) per year in the Olympic Mountains (U.S. Weather Bureau 1965). The river's discharge fluctuations are highly dynamic and individual peak flows are greatest during winter months (e.g., November to February), while average monthly discharges are highest when snowmelt runoff occurs in June and July (USGS 1998).

The watershed lies within a temperate rainforest region and is dominated by Sitka spruce (*Picea sitchensis*), red alder (*Alnus rubra*), bigleaf maple (*Acer macrophyllum*), western red cedar (*Thuja plicata*), and Douglas fir (*Pseudotsuga mensiesii*) in the lowlands with western hemlock (*Tsuga* *heterophylla*) and silver fir (*Abies amabilis*) in the higher elevations (Smith 2000). Inside the Olympic National Park (ONP), where the forest is pristine, trees can reach up to 70 meters (200 feet) in height and are characterized by somewhat open canopies and low densities (Franklin and Dryness 1984). Outside the Park extensive timber harvest has altered the natural plant assemblages in the Hoh River basin resulting in higher densities of deciduous trees and smaller size conifer trees, especially in the riparian areas (Smith 2000).

3.2 Salmonid assemblage

The Hoh River supports a relatively healthy and diverse salmonid assemblage that includes five species of Pacific salmon, two species of trout, and one char species (McHenry and Lichatowich 1996). The spring/summer and fall chinook (*Oncorhynchus tshawytscha*), fall coho (*O. kisutch*), and winter steelhead (*O. mykiss*) are considered among the last remaining relatively healthy wild populations in the lower forty-eight (Nehlsen et al. 1991; Huntington et al. 1994; McHenry and Lichatowich 1996). The Hoh River bull trout (*Salvelinus confluentus*) population is listed as Threatened under the Endangered Species Act, but is generally considered to be relatively healthy and abundant (Mongillo 1992). The Hoh also contains unstudied populations of coastal cutthroat trout (*O. clarki*), resident rainbow trout and summer steelhead (*O. mykiss*), in addition to a few chum salmon (*O. keta*), sockeye salmon (*O. nerka*), and pink salmon (*O. gorbuscha*) (McHenry 2001). In addition to the native salmon, roughly 100,000 winter steelhead smolts from the Quinault Tribal hatchery are released into the Hoh each year.

Most salmon species utilize slightly different riverine habitats (Sedell et al. 1982; Sedell et al. 1984; McHenry 2001) and outmigrate at different ages during their freshwater lifecycle (Roger Moseley, WDFW, personal communication; Jim Jorgensen, Hoh Tribe, personal communication) (Table 1). Over 95% of the spring/summer and fall chinook outmigrate as juveniles at age-0, which contrasts sharply with the tendency of the other species to remain in freshwater for at least a full year. Spring/summer chinook spawn from August through September while fall chinook and coho spawn from October through December. Winter steelhead spawn from December through July. No information is available on the spawn timing of summer steelhead, which are believed to spawn in the North Fork and South Fork Hoh Rivers inside the ONP (McHenry 2001). Bull trout are believed to spawn primarily in the mainstem rivers or in tributaries of the ONP with active glaciers (Brenkman and Meyer 1999). The juvenile and adult life histories, and ecology, of coastal cutthroat and resident rainbow trout are completely unstudied.

Table 1. Description of salmon freshwater-saltwater rearing times and known stream types of juvenile rearing and adult spawning locations (Personal communication, Jim Jorgensen, Hoh Tribe). Habitat stream types include mainstem river (MR), mainstem river lateral habitat (MRL), and tributaries (TR).

Species	Fresh (yrs)	Salt (yrs)	Habitat	
			Rearing	*Spawning*
Spring/Summer chinook	< 1	2 - 6	MR	MR/MRL
Fall chinook	< 1	2 - 6	MR	MR/MRL
Fall coho	1.5	1 - 2	MRL/TR	MRL/TR
Winter steelhead	1 – 3	1 - 5	MR/ML/TR	MR/MRL/TR

4.0 Methods

4.1 Survey sites

We identified ten major tributaries outside of the Olympic National Park that redd count data indicate are important to salmon (1990-2004, Hoh Tribe and Washington Department of Fish and Wildlife [WDFW]). From the initial ten tributaries, we selected eight of the streams as survey sites, including Winfield, Elk, Nolan, Owl, Anderson, Braden, Willoughby, and Alder Creeks (Table 2). The two tributaries we did not survey, Pins and Hell Roaring Creeks, are highly tannic streams with inadequate visibility for snorkeling. In addition, the eight tributaries we surveyed supported 95% of the redds (coho, winter steelhead, fall chinook, spring/summer chinook) counted in tributaries outside of the Park (1990-2004, Hoh Tribe and WDFW, redd count data). Therefore we assumed the selected tributaries represent the most heavily used spawning and rearing tributaries outside of the Olympic National Park (McHenry 2001; Jim Jorgensen, Hoh Tribe, personal communication).

Table 2. Description of tributary survey sites, including total drainage area, the total stream length (*Stream* column) and the stream length surveyed during the summer months (*Survey* column), mean gradient, mean residual pool depth (RPD), mean bankfull width (BFW), mean bankfull depth (BFD), and dominant substrate (Sub) composition. Substrate (Sub) classes include pebble (P), cobble (C), and boulder (B).

Tributary	Drainage Area (km^2)	Stream length (km)		Gradient (%)	RPD (m)	BFW (m)	BFD (m)	Sub
		Stream	*Survey*					
Braden	15.2	5.1	3.6	1.1	0.6	11.4	1.2	C
Nolan	18.9	9.9	6.2	1.6	0.7	23.4	1.5	C
Anderson	5.5	3.6	3.0	2.0	0.6	13.8	1.3	P/C
Winfield	17.5	10.5	8.8	1.7	0.7	17.3	1.5	C
Alder	7.5	5.2	4.7	2.0	0.6	14.6	13	C
Elk	7.1	8.1	5.2	1.2	0.6	12.3	1.2	C
Willoughby	8.6	3.5	2.4	3.5	0.4	13.3	1.1	B/C
Owl	16.1	2.8	2.8	2.4	1.5	19.6	2.7	B/C

4.2 Extent of surveys

From the summer of 2000 to the winter of 2006 we conducted spatially and temporally extensive snorkel and stream habitat surveys to collect salmon and habitat information at the intermediate scales necessary to bridge the gap between conservation and science (Fausch et al. 2002; Jepsen 2005). Surveys were conducted twice a year over the study period, including once during the summer and again during the winter. During the summer we surveyed 64-100% of the stream length accessible to anadromous salmonids in each tributary for a total of 188 stream km. We surveyed from the mouth upstream until either water visibility became inadequate (Elk Creek), there was an anadromous barrier (Owl Creek), the stream went subsurface (Alder Creek) or the stream became consistently less than 0.2 m deep (Willoughby, Nolan, Anderson, Braden, and Winfield Creeks), which was too shallow to be snorkeled.

The length of stream surveyed was the same each year, except in 2002 when reaches were shorter in Anderson, Braden, and Alder Creeks, because the upper portions of each tributary went subsurface during a summer drought. Owl and Elk Creeks were not surveyed during the summer of 2005, because early fall freshets reduced water visibility below the snorkeling threshold (see section 4.4). The same two-person crew, including a diver and bank-walking recorder, conducted all surveys and covered 1-4 stream km/day.

Summer surveys were conducted from July through early September, which is when juvenile fish have typically selected their territorial habitats and migration is believed to be minimal (Hankin and Reeves 1988; Rodgers et al. 1992). We surveyed pools only during the summer because they serve as congregation points for several species of juvenile salmonids (Glova 1986; Hankin and Reeves 1988; Meehan and Bjornn 1991; Jepsen 2005). To cover the length of stream necessary to estimate juvenile abundance, we systematically surveyed every fourth pool starting at the mouth of each tributary.

We conducted winter snorkel surveys to identify potential seasonal shifts in habitat preferences (Bustard and Narver 1975; Campbell and Neuner 1985; Brown 1987; Cunjak et al. 1988; Cunjak 1996). During winter, we surveyed relatively short survey reaches (7-10 bankfull widths in length) that were selected according to road or trail access points. We could not survey Owl or Elk Creeks due to poor visibility. We sampled every habitat unit in the winter because survey reaches were relatively short.

4.3 Adult salmonid data

We used existing redd count data to estimate adult abundance. Redd counts from 1990-2004 provided adult estimates for spring/summer chinook, fall chinook, fall coho, and winter steelhead (Unpublished Data, Hoh Tribe, Natural Resources Department; Unpublished Data, WDFW). No information was available for other species. Redd counts for each species were conducted once every 10 days for the entire distribution of the spawning season (Table 3), although winter steelhead and spring/summer chinook surveys are limited to Winfield, Owl, Willoughby, and Nolan Creeks. The other creeks are assumed to support minimal steelhead and spring/summer chinook spawning activity. Some years did not allow the same survey frequency due to inadequate sampling conditions. Surveyors collected data in a spatially explicit manner by identifying the beginning and end-point of the surveys by kilometer markers (Jim Jorgensen, Hoh Tribe, personal communication).

Table 3. Monthly timing of redd count surveys conducted by Washington Department of Fish and Wildlife and Hoh Tribe. Calendar starts in September (S) an ends in June (J).

Species	S	O	N	D	J	F	M	A	M	J
Spring/summer chinook	■	■								
Fall chinook		■	■	■						
Fall coho		■	■	■						
Winter steelhead							■	■	■	■

4.4 Juvenile salmonid data

We conducted snorkel surveys to estimate the distribution, diversity, and abundance of juvenile salmonids during summer and winter months. We used a snorkel survey technique and several criteria described in previous studies (Thurow 1994; Roni and Fayram 2000). To reduce potential observational bias between divers, the same experienced diver and bank recorder sampled all survey sites (Hankin and Reeves 1988). Snorkel surveys were only conducted when visibility was bank to bank in tributaries and in pools greater than 0.2 m deep (Thurow 1994; Jepsen 2005). We implemented night surveys during winter months with the assistance of underwater lights to account for the nocturnal behavior of salmonids during cold water and low light periods (Roni and Fayram 2000).

The diver entered each pool at the downstream end and worked upstream through the unit in a single pass. Upon observation, juvenile salmonids were classified into age groups based upon size and morphology as coho, chinook, 0-age unidentifiable trout, steelhead parr, or coastal cutthroat trout (Hankin and Reeves 1988; Thurow 1994) (Table 4). 0-Age coho were not counted during winter surveys because they concentrate in high numbers along shallow channel margins, making accurate enumerations difficult.

We also conducted bounded counts, or three successive but separate counts of the same habitat unit, to attempt to quantify variation in our juvenile enumeration estimates at the individual pool scale (Hankin 1984). To determine if variation was greater between individual counts than pools we compared the mean number of fish to the corresponding standard deviation and the coefficient of variation.

Table 4. Classification scheme for juvenile salmonid surveys during winter and summer months. 0-Age and 1+ Age refer to year class, where all juvenile coho in summer were grouped as 0-Age fish regardless of size. Unidentifiable trout refers to unidentifiable cutthroat or steelhead trout. NC is not counted.

Species	Winter size (mm)		Summer size (mm)	
	0 age	*1+ age*	*0 age*	*1+ age*
Coho	NC	>100	>0	>0
Unidentifiable trout	<100		<100	
Steelhead parr		>100		>100
Cutthroat parr		>100		>100
Chinook	<100	>100	<100	

4.5 Habitat data

We defined stream habitat units as pools or non-pools and channel measurements were collected according to a modified Oregon Department of Fish and Wildlife habitat monitoring protocol, which is consistent with other protocols used in the Pacific Northwest (Moore et al 1998). Measurements collected at each pool include wetted width and length, residual depth, bankfull width, bankfull depth, floodprone width, floodprone depth, and substrate composition. The dominant substrate was visually estimated at each pool as pebble, cobble, boulder, or bedrock. Channel type was classified as pool/riffle, forced pool/riffle, plane bed, cascade, or step/pool according to Montgomery and Buffington (1993) at the stream reach scale. Stream gradient was measured with a clinometer for each different channel type reach. Data collection during the 2000 summer was limited to depth, wetted width and length, substrate composition, and large wood.

In addition to channel measurements, we visually estimated the frequency of functional large wood (LW) formations because it is an indicator of instream cover and channel complexity (Bilby and Ward 1991; Beechie and Sibley 1997). LW was defined as either single pieces, accumulations (2-4 pieces), or jams (> 4 pieces) and pieces were visually estimated as conifer or deciduous. We only counted LW when at least 50% of the LW was in the wetted channel during low flows, when the formation created a scour pool, and when the key piece was longer than three-quarters of the active channel width (Abbe 1996; Bilby and Ward 1989). Conifer pieces of LW are more stable and often larger than the smaller deciduous pieces; therefore, we calculated the cumulative composition of LW formations as either conifer dominant, deciduous dominant, or an even mix of both (Bilby and Ward 1991).

4.6 Data synthesis

We generated several metrics from the data that measure and describe different aspects of the salmon population and habitat conditions in each tributary (Table 5). Redd count data were used to generate the adult population composition and mean annual redd abundance metrics for each tributary. The adult population composition is the proportion of the cumulative abundance represented by individual species and life history types (e.g., fall vs. spring/summer chinook). We calculated the median annual redd abundance for all species combined and the 15-year cumulative redd abundance of each species to determine the population composition and diversity of each site (1990-2004). The period of record was longer for adults compared to our juvenile surveys, so we utilized all available data for redd counts. In addition, large scale mass wasting events in 1990 drastically altered adult spawning abundance and distribution in streams draining Owl and Willoughby ridges. Therefore, we decided to begin the data set in 1990 to better reflect the current status of adult populations and diversity.

We synthesized annual summer and winter juvenile snorkel data to generate the annual summer abundance of juvenile salmonids in pools, the six-year median summer juvenile abundance (all species combined) in pools, and the total summer juvenile population composition, which accounts for the percentage of the total juvenile population represented by each species. We used the winter survey data to calculate the annual winter juvenile density, the six-year median juvenile density (salmonids/m^2), and the winter juvenile population composition. Median metrics were compared between tributaries with box-whisker plots, which provide an effective way to initially compare the quartile distribution of the data and the medians among several groups. More detailed analysis of the data will be addressed in a forthcoming manuscript focused on identifying relationships between habitat and salmonids.

We calculated the six-year median (2000-2006 survey years) and annual pool quantity as the pool surface area (m^2/km), which is a surrogate for the availability of slow water habitat that is important to rearing juvenile salmon (Bisson et al. 1988; Rosenfeld et al. 2000; Sharma and Hilborn 2001). We also calculated the six-year median and annual LW frequency as LW formations/channel width. We used the LW metric because instream wood is an important source of cover for rearing juvenile salmon (Tschaplinski and Hartman 1983; Shirvell 1989; Sharma and Hilborn 2001) and is integral to pool formation in some channel types (Montgomery and Buffington 1997). Finally, we determined the channel type composition as a percent of the stream length in pool/riffle and forced pool/riffle channel types, which can also be viewed as a surrogate for adult and juvenile habitat quality (Montgomery et al. 1995, 1999; Pess et al. 2002). Channel type data was summed as the total length of each channel type measured along the entire survey reach from summers 2001 through 2005.

Table 5. Metrics used to prioritize tributaries, including the group that collected the data and time span.

Metrics	Data collector	Time span
Pool availability	Wild Salmon Center	2000-2005
Large wood frequency	Wild Salmon Center	2000-2005
Channel type	Wild Salmon Center	2000-2005
Adult abundance	Hoh Tribe Washington Department of Fish and Wildlife	1990-2004
Adult diversity	Hoh Tribe Washington Department of Fish and Wildlife	1990-2004
Summer juvenile abundance	Wild Salmon Center	2000-2005
Summer juvenile diversity	Wild Salmon Center	2000-2005
Winter juvenile density	Wild Salmon Center	2001-2006
Winter juvenile diversity	Wild Salmon Center	2001-2006

4.7 Identification and prioritization of critical tributary habitat

To identify and prioritize critical stream habitat, we rated each tributary using a modified Watershed Index of Biotic Integrity (W-IBI) developed for assessing watersheds and sub-basins (Moyle and Randall 1998). We used an ANOVA and a Dunn Test (non-parametric ANOVA) to determine significant differences between stream metrics. However, the ANOVA was inappropriate since the data were not normally distributed and displayed unequal variances. Additionally, the non-parametric Dunn Test had low power to detect differences given the small number of sample years for the juvenile and habitat data. Consequently, we decided *post hoc* to rely on the original W-IBI scoring because it provides a transparent analysis of our prioritization decisions and it is more broadly understood.

The W-IBI is a relative measure of sub-basin health that prioritizes areas for conservation by combining a suite of habitat and salmon metrics into an index. We modified the W-IBI by focusing the metrics on identifying critical salmon tributaries, rather than areas with high levels of biotic integrity, although the goals are essentially the same. It compared two major data groups, habitat and salmon. As previously described, the habitat group included three metrics that serve as surrogates for habitat quantity and quality (Table 5). The salmon group included six metrics that describe the diversity and abundance of salmonids across life stage and seasonal scales. The two broad-scale groups provide complementary information that can be used to help frame conservation efforts (May and Peterson 2003).

Each metric was rated as 1, 3, or 5 where 1 is low (poor) and 5 is high (good) according to the respective differences in salmon and habitat metrics between each tributary (Miller et al. 1988; Moyle and Randall 1998). The rating was associated with differences in metric medians. Streams were rated differently if: 1) metric ranges did not overlap (without outliers); and, 2) when ranges overlapped but median values of one stream were not within the quartile bounds of the other stream. While basic, the method is inclusive of many biological and physical variables, which is important when dealing with rich data sets.

The metrics were added and standardized to a 100-point scale for each tributary. For prioritization purposes, we divided the W-IBI values into quintile tiers (Table 6). Tributaries with the highest scores are assumed to have a high conservation potential, because they contain desirable salmon qualities and it is easier to conserve high quality salmon areas than it is to restore degraded habitat (Roni et al. 2002). Streams with salmon and habitat scores that fell into different tiers (e.g., good for habitat, fair for salmon) were ranked according to their salmon score, because we believe that the salmon score is a more direct indicator of biological integrity than physical characteristics.

Table 6. Description of prioritization tiers based on the W-IBI scores for each tributary and the associated conservation potential.

Tier	W-IBI Score	Conservation potential
1	80 – 100	Critical tributary habitat with excellent potential
2	60 – 79	Important tributaries with good potential
3	40 – 59	Moderately important tributaries with fair potential
4	20 – 39	Marginally important tributaries with poor potential
5	0 – 19	Inconsequential

5.0 Results
5.1 Adult salmon metrics
Between 1990 and 2004, salmonid species diversity was similar between streams and was higher in Winfield, Owl, and Elk Creeks due to the observation of a few spring/summer chinook redds. Over the same time period, the greatest cumulative abundance of redds was observed in Winfield Creek and the fewest in Willoughby Creek (Table 7). Winfield Creek also contained the greatest abundance of

redds for each individual species, including: fall coho, fall chinook, spring/summer chinook, and winter steelhead. In fact, Winfield Creek contained twice as many fall chinook redds as any other tributary and 15percent of all fall chinook redds counted in the entire watershed.

Winfield Creek, with 340 redds/year (SD = ± 111), supported the greatest median annual redd abundance and Willoughby Creek (8 redds/year; SD = ± 14), the lowest (Figure 2) (see Appendices for full data sets). Winfield was the only creek with a median annual redd abundance that did not overlap with Anderson and Willoughby Creeks, thus, the differences were significant. The only other stream with median abundance greater than 200 redds/year was Elk Creek (212 redds/year; SD = ± 87), although the annual variation overlapped extensively with Owl and Braden Creeks. Braden (102 redds/year; SD = ± 92) and Owl (108 redds/year; SD = ± 62) were the only other tributaries with a median annual abundance greater than 100 redds/year.

Annual variation in redd abundance was highest in Winfield and Braden Creeks and lowest in Willoughby and Anderson Creeks (Figure 2). Winfield ranged from an annual high of 527 redds in 2001, to a low of 122 redds in 1993. No other tributary contained over 400 redds in any single year and Winfield contained 450 redds in 1990 and 441 redds in 2002. Braden ranged from a low of 26 redds in both 1996 and 1997 to highs of 294 and 323 redds in 2001 and 2002, respectively.

Most tributary redd counts were dominated by coho (Figure 3). This was especially the case in Braden and Alder Creeks where they accounted for 98% and 91% of the redds, respectively. Fall chinook were the dominant species for redds in Nolan (53%), Winfield (52%), and Willoughby (81%) Creeks. Winter steelhead accounted for at least 10% of the redds in only two streams, Willoughby (11%) and Owl Creeks (13%).

Table 7. Cumulative number of redds (1990-2004) and the cumulative number of juveniles counted during snorkel surveys (2000-2005) for each species/race.

Tributary	Adult redds				Juvenile salmonids				
	Coho	*Fall Chinook*	*Spring/ Summer Chinook*	*Winter Steelhead*	*Coho*	*Unidentified Trout*	*Chinook*	*Steelhead parr*	*Coastal Cutthroat parr/adults*
Braden	1,546	28	0	0	4,939	195	2	37	47
Nolan	395	562	0	96	7,068	2,069	21	990	259
Anderson	425	188	0	0	5,074	671	3	241	118
Winfield	1,901	2,411	9	326	16,279	4,201	74	1,268	488
Alder	1,102	109	0	0	6,235	809	17	208	99
Elk	1,759	1,117	2	84	5,329	577	95	528	118
Willoughby	13	134	0	18	954	1,381	0	200	55
Owl	596	760	4	207	3,296	2,468	140	1,320	633

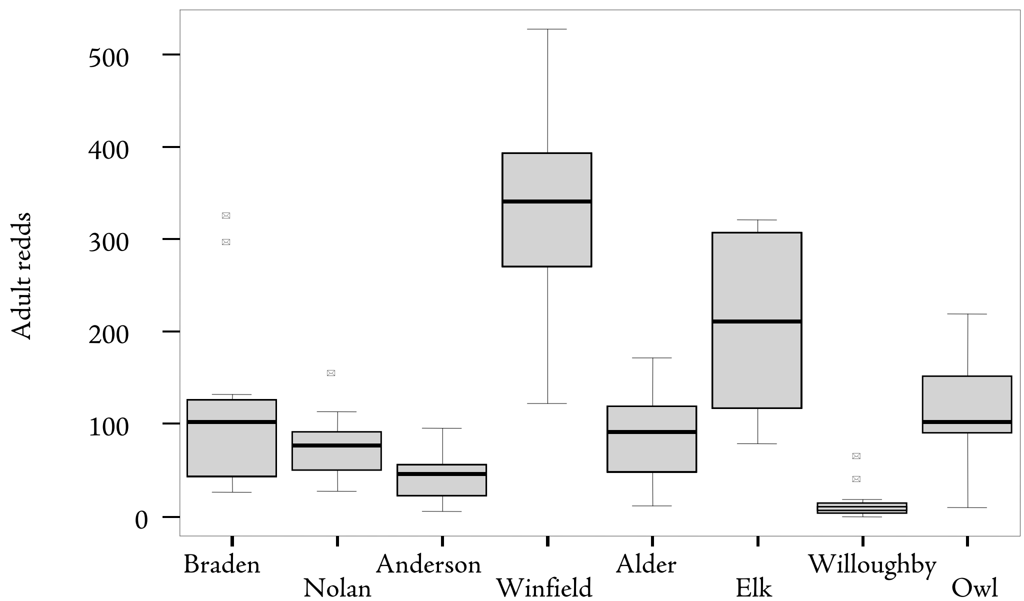


Figure 2. Box-whisker plot of adult redd abundance per tributary for all species combined from 1990-2004. Whiskers represent lines to data that are no more than 1.5 times the inter-quartile range and values beyond this range are indicated by asterisks. Top lines of boxes denote the 75th percentile, bottom lines the 25th percentile and middle lines the medians.

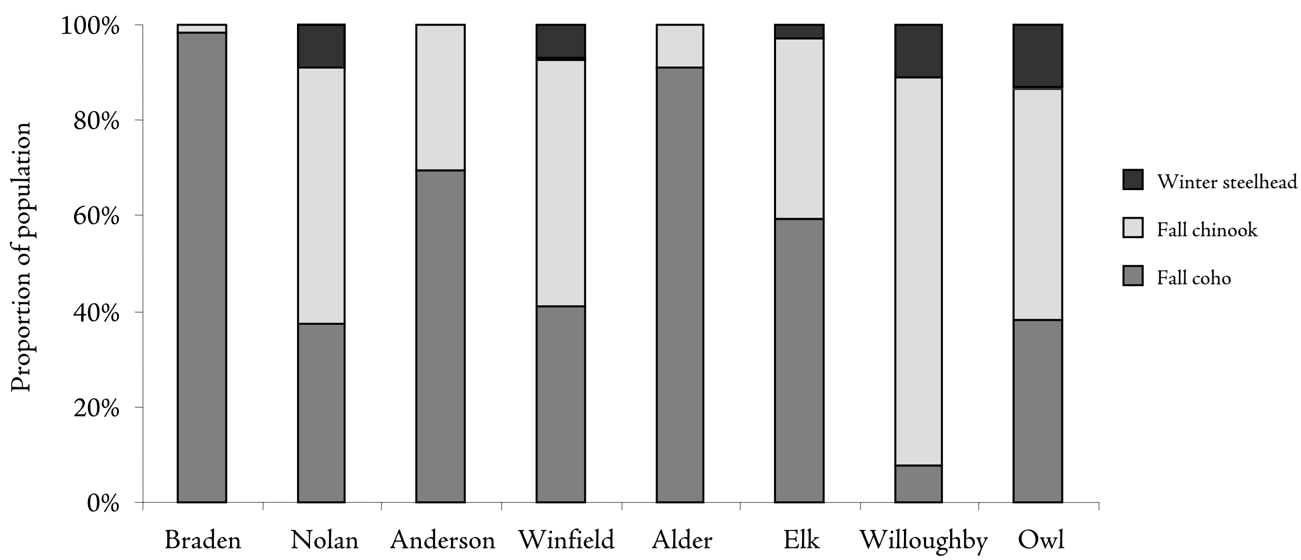


Figure 3. Cumulative population composition of adult redd counts in tributaries from 1990-2004.

5.2 Juvenile salmon metrics

From 2000 to 2005, we counted the greatest cumulative summer abundance of juvenile salmonids in Winfield Creek (22,310 fish) and the least in Willoughby Creek (2,590 fish) (Table 7). Winfield also contained the greatest abundance of juvenile coho (16,279 fish) and unidentifiable trout (4,201 fish). Owl Creek supported the greatest abundance of chinook (140 fish), steelhead parr (1,320 fish), and coastal cutthroat (633 fish). Full species diversity was distributed across all tributaries, except for Willoughby Creek which was the only site where we did not observe juvenile chinook.

Winfield Creek supported the greatest median annual abundance of juvenile salmonids at 3,795 fish/year (SD = ± 1,012), which was twice as many fish as any other tributary (Figure 4). The range of annual abundance in Winfield did not overlap with Braden, Anderson, Alder, Elk, or Willoughby Creeks; therefore, it was significantly greater than those tributaries. Except for Willoughby, which supported the lowest median annual abundance at 432 fish/year (SD = ± 190), and Winfield, all streams exhibited overlapping summer abundance values to differing degrees. Tributaries with a relatively high median annual abundance include Owl (1,219 fish/year; SD = ± 774), Elk (1,315 fish/year; SD = ± 206), Alder (1,224 fish/year; SD = ± 286), and Nolan Creeks (1,911 fish/year; SD = ± 491).

As expected, all streams exhibited annual variation in juvenile salmonid abundance. Annual variation was highest in Winfield Creek and lowest in Elk, Braden, and Willoughby Creeks (Figure 4). Winfield ranged from a high of 4,933 juveniles in 2003 to a low of 2,146 juveniles in 2004. Braden, Anderson, Winfield, Alder, and Owl Creeks all experienced their greatest annual juvenile abundance during the 2003 summer.

Some streams experienced their lowest abundance, or near lowest abundance, during a summer drought in 2002. In 2002, the Hoh River basin experienced the third driest summer on record (1931-2005) when rainfall from July through September was limited to 10.7 cm (City of Forks weather station, Washington State Climate Summaries). Previous low precipitation levels occurred in 1935 with 7.9 cm and 1987 with 8.9 cm, while the mean rainfall for those three months is 25.1 cm. Consequently, several tributaries went subsurface for long distances in stream segments where they did not go subsurface in any other year during our study. Despite the drought, Winfield, Elk and Anderson Creeks still supported abundant populations of juvenile salmonids, while Braden, Alder and Nolan Creeks, which went subsurface for 400- 1000 m, supported some of their lowest abundance levels.

The summer juvenile salmonid population composition was dominated by coho in most tributaries (Figure 5). Coho accounted for over 60% of the cumulative population enumerated from 2000-2005, with juvenile proportions comprising 95% in Braden, 68% in Nolan, 83% in Anderson, 73% in Winfield, 85% in Alder, 80% in Elk, and 42% in Owl Creeks. Unidentifiable trout dominated the population composition in Willoughby Creek (53%). Juvenile chinook existed at very low levels in most tributaries. Owl (17%) and Nolan Creeks (10%) were the only tributaries where at least 10% of the population consisted of steelhead parr. Owl Creek (8%) was the only site where more than 2% of the population consisted of coastal cutthroat.

From 2001-2006 median winter juvenile densities were relatively similar between most tributaries that included extensive overlap between annual values (Figure 6). Median winter density was greatest in

Braden Creek at 0.21 juveniles/m^2 (SD = ± 0.18), although it also exhibited the greatest level of annual variation that included a large outlier in 2002 that we could not explain. Densities were lowest in Anderson and Willoughby Creeks, at 0.11 juveniles/m^2 (SD = ± 0.06). Annual peak densities in Braden (0.60 juveniles/m^2), Anderson (0.16 juveniles/m^2), Winfield (0.22 juveniles/m^2), Alder (0.20 juveniles/m^2), and Willoughby Creeks (0.13 juveniles/m^2) were all documented during the 2002 winter. The lowest densities in Braden (0.11 juveniles/m^2), Nolan (0.06 juveniles/m^2), and Anderson Creeks (0.03 juveniles/m^2) occurred in 2003.

While the cumulative composition of juvenile fish was relatively similar between winter and summer, with coho being dominant, the relative proportion of species shifted over winter (Figure 7). Coho were still especially dominant in Braden (61%) and Alder Creeks (61%), while unidentifiable trout were dominant in Anderson Creek (48%) and steelhead parr in Willoughby Creek (22%). Chinook were largely limited to Winfield Creek (5%) and a single bull trout (approximately 200 mm in length) was observed in Nolan Creek during the winter of 2001. Historical records suggest Owl and Winfield Creeks also support bull trout, although we did not observe any during our surveys (Pacific Northwest Fishing and Hunting Guide 1956).

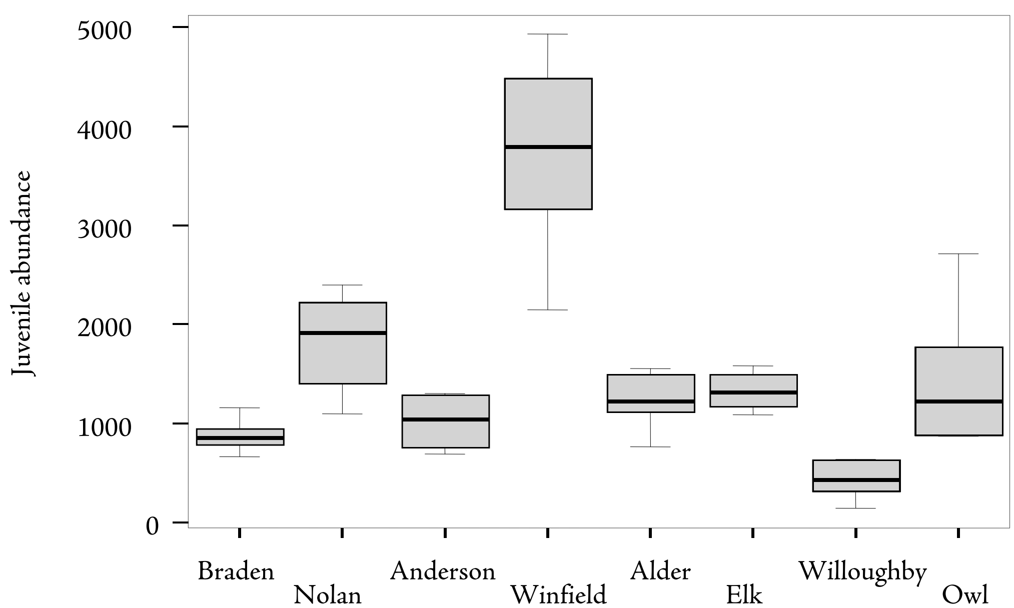


Figure 4. Box-whisker plot of annual juvenile salmonid abundance in sampled tributary pools (every fourth pool) during summer months (2000-2005). Whiskers represent lines to data that are no more than 1.5 times the inter-quartile range. Top lines of boxes denote the 75th percentile, bottom lines the 25th percentile and middle lines the medians.

Figure 5. Cumulative juvenile population composition in sampled tributary pools during summers 2000-2005.

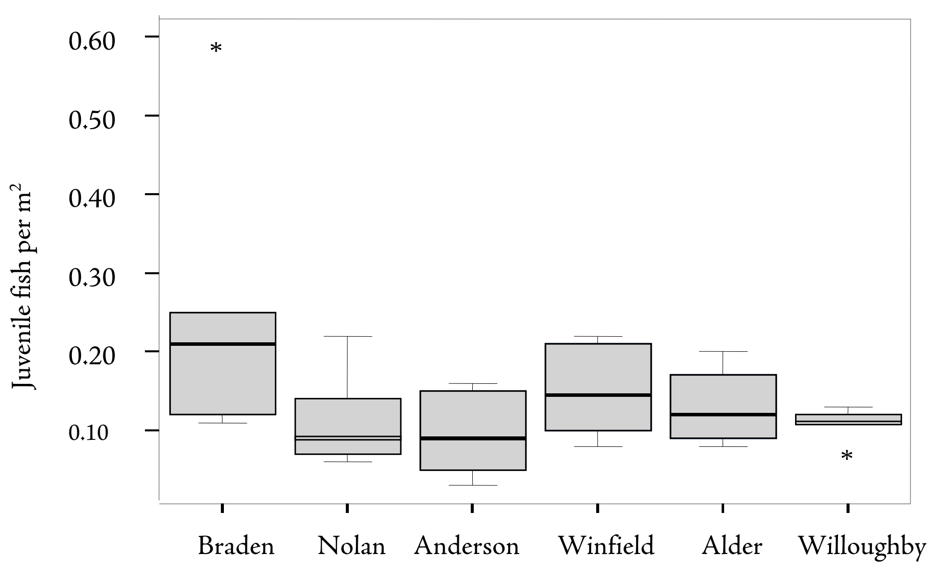


Figure 6. Box-whisker plot of winter juvenile salmonid density (fish/m^2) in selected tributaries (2001-2006). Whiskers represent lines to data that are no more than 1.5 times the inter-quartile range and values beyond this range are indicated by asterisks. Top lines of boxes denote the 75th percentile, bottom lines the 25th percentile and middle lines the medians.

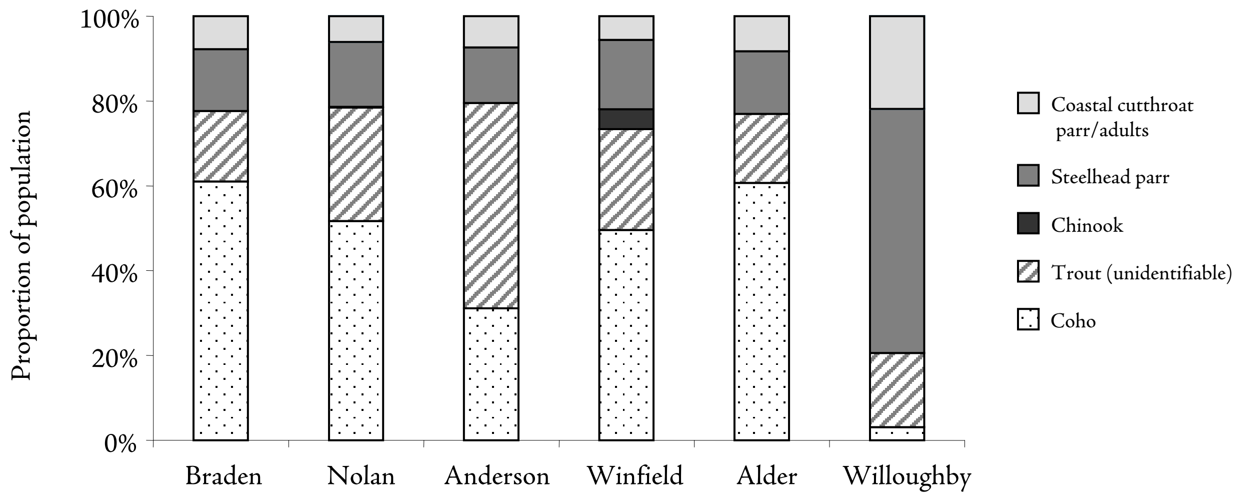


Figure 7. Cumulative juvenile population composition in tributaries during winters 2001-2006.

5.3 Habitat metrics

Nolan, Winfield, and Owl Creeks were the largest tributaries in terms of mean bankfull width and total basin area (Table 2). Braden Creek had the smallest mean bankfull width, but is a relatively large basin compared to other tributaries with similar sized channels and smaller basin areas (e.g., Elk, Anderson, and Willoughby Creeks).

We sampled 1,674 pools over six consecutive summers (2000-2005). The number of pools ranged from a high of 91 in Winfield Creek during the 2000 summer to a low of 8 in Owl Creek in 2002 (Table 8). Within each tributary, the range of pools sampled annually was greatest in Owl (8-21 pools) and Anderson (14-45 pools), although there was also a high level of variation in Winfield Creek in the year 2000 when we sampled 91 pools compared to a range of 62-72 in other years. The variability in all three tributaries from 2000 to 2001 was due to over-winter changes in channel structure, while the lower number of pools in 2002 in Owl was due to low flows that limited the availability of pool habitat. The annual number of pools sampled was most consistent in Willoughby (17-24 pools) and Braden Creeks (24-31 pools).

Tributary gradient was lowest in Braden (1.1%) and Elk Creeks (1.2%) and steepest in Willoughby (3.5%) and Owl Creeks (2.4%) (Table 2). At least 80% of the stream length consisted of pool/riffle or forced pool/riffle channel types, a surrogate for habitat quality, in Braden, Nolan, Anderson, Winfield, Alder, and Elk Creeks (Figure 8). Willoughby was the only stream dominated by the plane bed channel type (73%). Owl (12%) and Willoughby Creeks (10%) both contained the greatest proportion of the steeper cascade channel types, which is consistent with their boulder/cobble substrate.

The greatest amount of mean pool surface area (m^2) available per kilometer, our surrogate for habitat quantity, was found in Winfield (854 m^2/km) and Braden Creeks (805 m^2/km) (Figure 9). Elk (763 m^2/km) and Owl Creeks (713 m^2/km) were the only other tributaries to support more than 700 m^2/km of pool habitat. Willoughby Creek, with a mean of 185 m^2/km, contained significantly less pool habitat than all other tributaries.

Annual variability in pool habitat quantity was high for most sites, and was greatest in Braden, Elk, and Owl Creeks. The least amount of variability was observed in Willoughby, Alder, and Winfield Creeks. Owl Creek was notable because pool habitat quantity doubled from a low of 431 m^2/km in 2000 to a high of 867 m^2/km in 2005. Elk Creek shifted from a low of 457 m^2/km in 2000 to a peak of 1,154 m^2/km in 2002. The peak in 2002 was due to the presence of several large beaver ponds in the main channel, which greatly increased the amount of pool surface area. The ponds disappeared the following year.

Median large wood frequency (large wood/channel width [LW/cw]), a surrogate for habitat quality and complexity, was highest in Nolan Creek (0.10 LW/cw; SD = ± 0.03) and lowest in Willoughby Creek (0.02 LW/cw; SD = ± 0.03) (Figure 10). Median LW frequencies were similar between Elk, Anderson, Winfield, and Braden Creeks. Annual variation in LW frequency was extensive in Nolan Creek, especially when compared to the minimal variation in Braden and Elk Creeks. Alder and Willoughby Creeks exhibited two outliers recorded in the 2001 summer.

The composition of large wood formations was conifer dominant in Elk (85%), Alder (69%), Braden (67%), Owl (61%), and Anderson Creeks (57%) (Figure 11). Formations in the Nolan, Willoughby, and Winfield tributaries were deciduous dominant.

Table 8. Number of pools sampled in each tributary from summer 2000 to summer 2006. Some streams were not surveyed (N/S) in 2005.

Tributary	2000	2001	2002	2003	2004	2005
Braden	34	24	24	26	31	31
Nolan	45	34	30	28	25	25
Anderson	37	14	28	30	33	45
Winfield	91	66	65	62	72	72
Alder	41	44	38	50	43	43
Elk	46	51	37	42	69	N/S
Willoughby	23	22	20	18	17	24
Owl	21	10	8	19	16	N/S

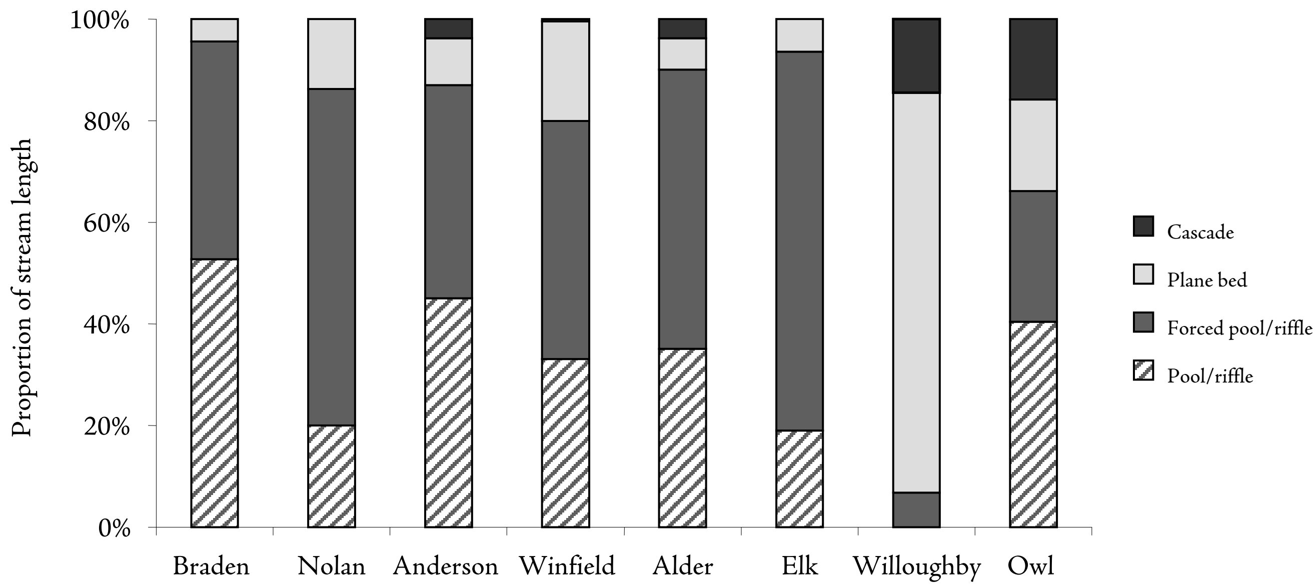


Figure 8. Composition of stream channel types in tributary sites during summers 2000- 2005.

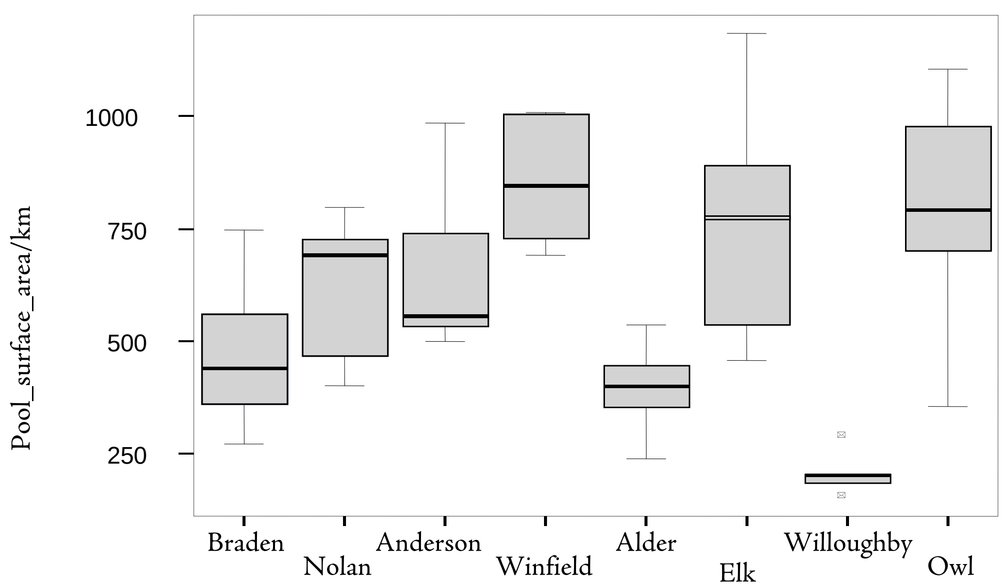


Figure 9. Range and mean of pool surface area (m^2) per stream kilometer during summers 2000-2005. Whiskers represent lines to data that are no more than 1.5 times the inter-quartile range and values beyond this range are indicated by asterisks. Top lines of boxes denote the 75^{th} percentile, bottom lines the 25^{th} percentile and middle lines the medians.

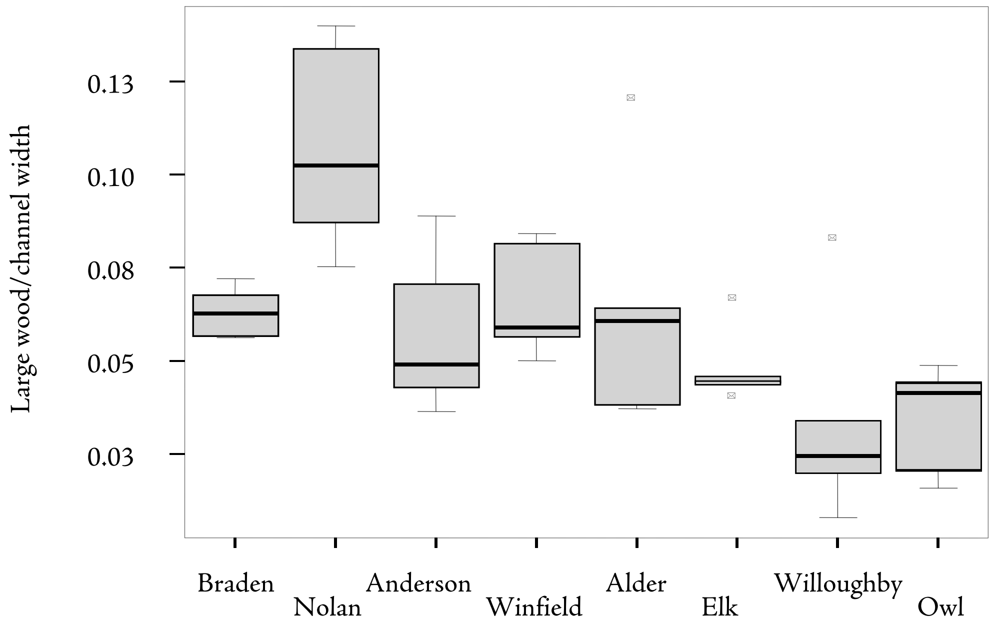


Figure 10. Range and mean of and large wood formations per channel width during summers 2001-2005. Whiskers represent lines to data that are no more than 1.5 times the inter-quartile range and values beyond this range are indicated by asterisks. Top lines of boxes denote the 75th percentile, bottom lines the 25th percentile and middle lines the medians.

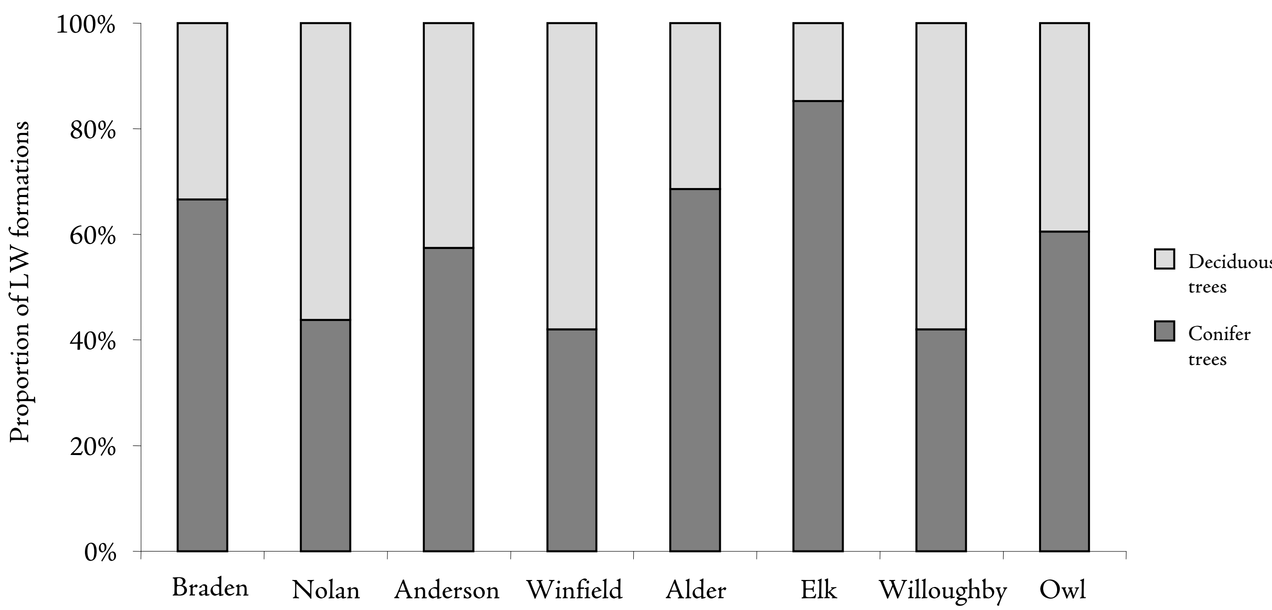


Figure 11. Composition of all large wood formations (LW) in tributaries during summers 2001- 2005.

5.4 Bounded counts

We conducted bounded counts in 36 pools during the summer of 2001 and 2002. We found that the variation of total abundance did not increase in relation to the mean number of salmonids in each pool (Figure 12). The greatest coefficient of variance generally occurred in pools with a lower mean number of salmonids. In contrast, the lowest variance often occurred in pools with a higher abundance. We also found that the variation between pools was 4 to 5 times greater than the variation between counts regardless of abundance level. Therefore, we assume that measurement error of overall abundance was minimal during summer surveys.

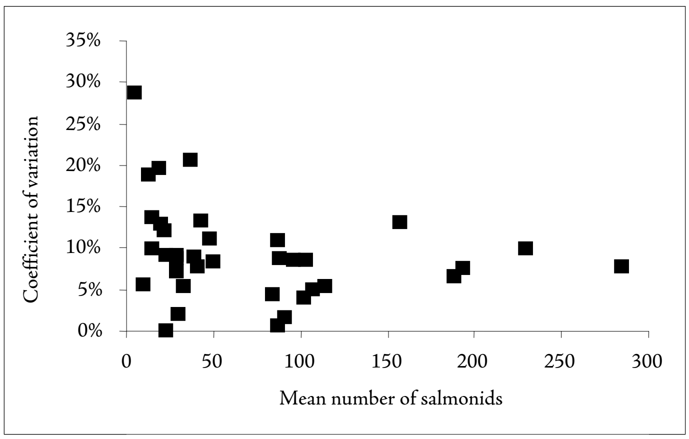


Figure 12. The coefficient of variation versus the number of fish for bounded counts conducted in pools during summer 2001 and 2002.

5.5 W-IBI scores

Braden and Elk Creeks scored highest among all tributaries in terms of habitat ratings (Table 9a). Standardized, they scored 80 each, just high enough to be considered to have excellent to very good conservation potential based on habitat (Figure13a). Habitat scores, including Winfield with a score of 73, suggest most streams have good conservation potential (Table 9a). Owl and Willoughby Creeks scored the lowest, which suggests fair and poor potential respectively.

Salmon scores prioritized streams differently than habitat scores in some cases. Winfield Creek scored a 93 and was the only tributary considered to have excellent to very good conservation potential in terms of salmon (Figure 13b). Elk and Owl Creeks scored higher than Nolan did, but all scored high enough to suggest they have good conservation potential. Winfield Creek was unique because it was the only stream to score a 5, the highest score possible, for every salmon metric except for winter juvenile density (Table 9b). Individual metric scores also varied between life stages in the same sub-basin. For example, Nolan, Anderson, and Alder Creeks scored a 1 for adult abundance, but a 3 for summer juvenile abundance.

Table 9. W-IBI metric ratings for Hoh River tributaries for habitat (**a.**) and salmon (**b.**) metric groups. Scores are as follows for habitat: 1 is poor, 3 is fair, and 5 is good. Scores are as follows for salmon: 1 is low, 3 is fair, and 5 is high.

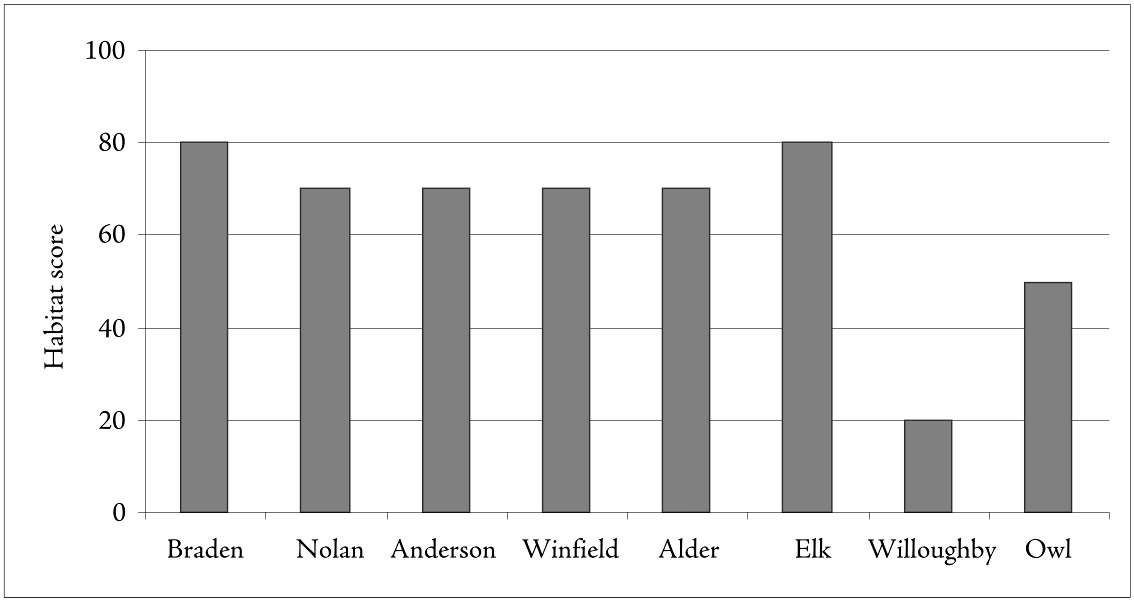
a.

Tributary	Channel type	Pool area	Large wood frequency	Large wood composition
Braden	5	5	3	3
Nolan	5	3	5	1
Anderson	5	3	3	3
Winfield	5	5	3	1
Alder	5	3	3	3
Elk	5	3	3	5
Willoughby	1	1	1	1
Owl	3	3	1	3

b.

Tributary	Adult		Juvenile			
			summer		winter	
	abundance	*diversity*	*abundance*	*diversity*	*abundance*	*diversity*
Braden	3	1	3	5	3	3
Nolan	1	3	3	5	3	5
Anderson	1	1	3	5	3	3
Winfield	5	5	5	5	3	5
Alder	1	1	3	5	3	3
Elk	3	5	3	5	3	3
Willoughby	1	3	1	3	3	3
Owl	3	5	3	5	3	3

a.



b.

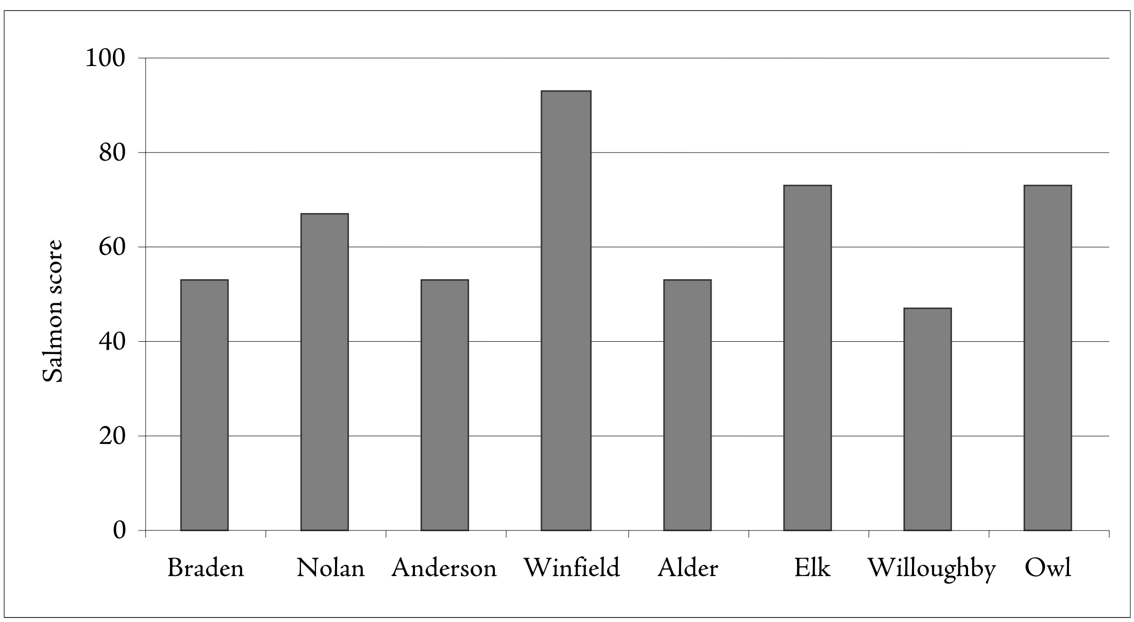


Figure 13. W-IBI scores for each tributary in the habitat (**a.**) and salmon (**b.**) metric groups. A score of 80–100 indicates excellent condition for either habitat or salmon; 60–79 indicates good condition; 40–59 indicates fair condition; and, 20–39 indicates poor condition.

6.0 Tributary Prioritization

6.1 Tier 1

Winfield Creek was the only tributary we designated as critical salmon habitat and considered to have excellent conservation potential (Table 10). It was the most productive tributary with respect to the metrics and W-IBI salmon scores; therefore, the sub-basin represents the highest priority for conservation actions in the Hoh River basin. Considering the unique salmon value, Winfield Creek is the top priority for highly protective conservation actions such as acquisitions and easements (Lucchetti et al. 2005). The feasibility of using acquisitions and easements to protect Winfield is high because private timber companies, which have liquidated large land parcels in recent years, own the majority of the sub-basin. Winfield was also identified as an important salmon tributary in a recent watershed analysis (McHenry 2001) and limiting factors analysis (Smith 2000).

Table 10. Conservation potential for each tributary, with a brief description of the most abundant salmonids. Tier 1 represents the highest conservation potential and Tier 3 the least—no scores fell into bottom two quintile tiers (e.g., 4 and 5).

Tributary	Tier	Conservation potential
Winfield	1	Critical habitat for all salmonids and life stages
Elk	2	Important habitat for all salmonids, especially juvenile and adult coho
Nolan	2	Important habitat for all salmonids, especially juvenile steelhead
Owl	2	Important summer rearing habitat, especially for steelhead and cutthroat
Braden	3	Important winter rearing habitat for coho; moderately important for other species and life stages
Anderson	3	Moderately important for all salmonids
Alder	3	Moderately important for all salmonids
Willoughby	3	Moderately important for juvenile steelhead

Winfield supported a disproportionate level of adult and juvenile salmon abundance that included coho, fall and spring/summer chinook, winter steelhead, and coastal cutthroat trout (Table 10). Two metrics in particular highlight the importance of Winfield Creek. First, the basin area of Winfield Creek represents only 3.5% of the watershed yet the tributary contained 15% of all fall chinook redds counted in the entire watershed, with most spawning activity occurring in the lower 1.6 km of stream. Perhaps no other stream segment is used more intensively by any salmonid species. Importantly, the lower 1.0 km of Winfield was recently acquired and put into protective status by Wild Salmon Center (WSC) and Western River's Conservancy (WRC). Second, Winfield is a stronghold for juvenile coho, steelhead, and coastal cutthroat. The stream contained 6% of all fall coho redds in the watershed and served as juvenile refugia during harsh conditions, as evidenced by the high juvenile abundance during the 2002 drought summer.

Habitat conditions were rated as good in Winfield Creek. The stream meanders across glacial terraces and contains a high percentage of the pool/riffle channel type preferred by spawning and rearing salmon (Montgomery et al. 1995, 1999; Pess et al. 2003). Winfield exhibited a relatively consistent level of pool surface area across the study period and because it was the largest sub-basin we surveyed, it supported the greatest overall pool surface area. The stream channel is also relatively stable when compared to Owl, Willoughby, Anderson, and Alder Creeks since it is not associated with steep and unstable slopes that deliver debris flows directly to the main channel (McHenry 2001). However, there is a lack of large conifer trees in the riparian zone, which are critical to shaping channel morphology, and some of the channel appears to be shifting to plane bed (McHenry 2001). Conservation actions should focus on regeneration of large conifers in the riparian zone to sustain and increase the extent of pool/riffle channel morphology into the future.

6.2 Tier 2

Tier 2 tributaries tended to support a disproportionate level of salmon abundance and diversity for one species or life stage, in addition to having good habitat conditions, and are considered to have good conservation potential. Nolan and Elk Creeks scored good for habitat and salmon (Table 10). Despite a poor habitat score, Owl Creek is also a second tier level priority for conservation because it scored higher than Nolan and Braden Creeks in terms of salmon metrics.

The sub-basins are high priorities for increased regulatory protection focused on recovering the physical processes controlling habitat formation (McHenry 2001). Additionally, privately owned tributaries, such as Elk, Nolan, and Braden, are good candidates for acquisitions and easements, while regulatory protection must occur through the Forest and Fish Plan (2001) for forest harvest. Such acquisitions are not possible in Owl Creek because it is owned and managed by the Washington State DNR, so conservation actions must be shaped through the regulatory process.

Elk Creek

Elk Creek had the second highest W-IBI salmon score and the highest habitat score (Table 10). Considering it was the second smallest sub-basin we surveyed, Elk Creek was especially productive for adult and juvenile coho. Similar to Winfield Creek, Elk is capable of supporting juvenile salmonids during periods of adversity as we observed its greatest juvenile abundance during the drought of 2002. Furthermore, the sub-basin represents only 1.5% of the area in the Hoh River basin yet it accounted for 5% of the coho redds observed in the entire watershed. Most coho spawning occurs in the lower 1-2 km of stream where the stream braids into a series of channels across the mainstem Hoh River migration zone (Jim Jorgensen, Hoh Tribe, personal communication). A recent purchase of the lower 0.5 km of Elk Creek by the WSC and WRC in 2001 provides permanent protection for a small portion of this important creek.

Physically, Elk Creek is a low gradient tributary formed by a series of springs, wetlands, and cedar bogs. The channel contains an abundant amount of pool surface area and the main channel is strongly influenced by beaver ponds, all factors that might help explain why the area is a coho stronghold (Tschaplinksi and Hartman 1983; Brown 1987; Rot 1996; McHenry 2001). In addition Elk has an abundant supply of conifer dominated large wood formations, which are important to long-term channel complexity (Bilby and Ward 1991; Montgomery and Buffington 1997). Despite the relative habitat quality, clearing of wood in the channel (above stream-km 3) by management agencies in the 1970's has resulted in localized channel incision and high levels of embeddedness in those areas (McHenry 2001; Wild Salmon Center, unpublished habitat data, 2000-2006). The problem is bad enough that instream large wood structures may be necessary to reduce the rate of incision, which has locally disconnected the main channel from its floodplain (Smith 2000; McHenry 2001).

Nolan Creek

Nolan Creek was the largest sub-basin we surveyed. W-IBI scores rate the tributary as good for salmon and good for habitat (Table 10). Nolan is a stronghold for juvenile salmonids, especially steelhead parr and coastal cutthroat, and was the only tributary in which we observed bull trout. The bull trout was observed during the 2001 winter and suggests Nolan, and potentially other large tributaries, may serve as rearing or feeding areas for juvenile char from late fall through early spring. In contrast to our single observation, bull trout were not found using tributaries in a bull trout radio telemetry project (Brenkman and Corbett 2005). However, the study was limited to specimens longer than 40 cm, and the bull trout we observed was relatively small (25 cm in length), so there is the potential for greater tributary usage by smaller juveniles. While important for juveniles, the sub-basin supported relatively few adult redds compared to Winfield, which exhibited a similar channel morphology and basin size. Moreover, the survey reach in Nolan was twice as long as Elk and Owl and yet it contained fewer redds in most years.

Nolan flows most of its distance over glacial terraces and, similar to Winfield Creek, the channel is not directly impacted by debris flows (McHenry 2001). However, the stream was cleaned of wood and the channel was used as a skid trail in the late 1970's (Bob Howell, Hoh Tribe, personal communication). Subsequently, Nolan has experienced channel broadening, channel simplification, and erosion of forested floodplain habitat (Jill Silver, 10,000 Years Institute, personal communication; Wild Salmon Center, unpublished data, 2000-2006). Interestingly, the stream had the highest large wood densities, apparently because channel broadening has increasingly accessed riparian trees. Fortunately, conservation actions have been initiated in Nolan Creek, as the WSC and WRC recently purchased over 1,000 acres of land that includes approximately 800 m of riparian forest. Considering the high large wood density, recovery of forested floodplains and improved channel stabilization in Nolan Creek requires a long-term focus on processes, rather than a short-term focus on attempts to manipulate instream structure.

Owl Creek

Owl Creek is a large sub-basin with a 4.1 m high falls at river-km 2.8 that represent an anadromous barrier, above which there is an abundant population of resident coastal cutthroat (Wild Salmon Center, unpublished data, 2000-2006). W-IBI scores for Owl indicate the stream is in fair condition for habitat and good condition for salmon (Table 10). Owl supports a high level of species diversity, with an especially high proportion of steelhead and coastal cutthroat, and exhibited the third highest mean annual redd abundance and the second highest mean juvenile abundance. Historical records suggest the stream may contain bull trout, a species we did not observe (Pacific Northwest Fishing and Hunting Guide 1956). Although debris flows have removed much of the gravel that once made Owl Creek a critical spawning tributary, it still contained more juvenile steelhead and coastal cutthroat trout than any other survey site.

The relatively steep gradient and boulder/cobble dominated channel make Owl a unique stream compared to the other tributaries, and may help explain the high proportion of juvenile steelhead (Everest et al. 1985; Bjornn and Reiser 1991). However, channel conditions are a conservation concern since much of the tributary and its steep valley walls are prone to frequent landslides that deliver directly to the channel (McHenry 2001). In the spring of 1990 a rain-on-snow event unleashed a series of debris flows that tracked from its headwaters through the mouth, drastically widening the channel and flushing out most of the wood and spawnable gravel (McHenry 2001). The altered conditions and variable nature of its channel could limit over winter survival of juveniles, which would suggest the stream is essentially a summer stronghold. Our observations of dramatic annual fluctuations in pool surface area and juvenile abundance, combined with the lack of large wood appear to reflect the legacy of this large event.

Protecting the steep and unstable slopes of Owl Ridge is critical to sustaining salmonids in Owl Creek and for maintaining habitat in the adjacent mainstem Hoh River channel migration zone (McHenry 2001). Currently, the Hoh Indian Tribe has over 30 years remaining on a Memorandum of Understanding (MOU) with the Washington State Department of Natural Resources (WA DNR) limiting harvest on the sensitive valley walls flanking the Owl, Huelsdonk, and Willoughby Ridge areas (Jim Jorgensen, Hoh Tribe, personal communication). If protection for valley slopes is secure, Owl Creek may benefit from engineered instream wood structures capable of increasing gravel aggradation and the restoration of pool/riffle channel morphology.

6.3 Tier 3

Tier 3 tributaries generally scored fair for salmon and good for habitat, except for Willoughby, which scored poor in terms of habitat conditions and Braden which scored excellent for habitat (Table 10). Overall conservation potential is considered fair because the streams supported a less diverse population of spawning adults than Tier 2 streams. Interestingly, while the streams scored poorly for adult salmonids, they scored relatively high for juveniles. The life stage differences emphasize the importance of collecting juvenile data. These sub-basins are priorities for regulatory actions through the Forest and Fish Plan (2001) on privately held timber land in Anderson Creek, and through the Forest Practices Habitat Conservation Plan (2005) on WA DNR land in Alder and Willoughby Creeks.

Braden Creek

Braden Creek is a large sub-basin with a relatively small channel size. Braden scored on the borderline of good to excellent for habitat and fair for salmon. Braden is essentially a single species stronghold for adult and juvenile coho, and is notable for a high juvenile density during winter. The WSC and WRC recently acquired part of the main channel where Highway 101 crosses the tributary. The stream reach is approximately 500 m long and provides important summer and winter rearing habitat.

Braden Creek was the lowest gradient stream we surveyed and exhibited channel characteristics similar to Elk Creek, including the highest proportion of the pool/riffle channel type. The stream also contained the single highest annual large wood density value; however, annual density levels were highly variable. Braden has experienced localized channel incision and substrate embeddedness, which appears to limit the availability of spawning gravel and juvenile rearing habitat quality in the uppermost reaches (Wild Salmon Center, unpublished data, 2000-2006). Conservation actions should focus on increasing the availability of functional large wood and spawning gravel in the upper sub-basins. Increasing large wood might also help reduce stream substrate embeddedness, which appears to be exacerbated by inability of the low gradient channel to flush pulses of fine sediment that occur annually during the winter months. We could not account for embeddedness in our study, but this is an issue that requires further analysis.

Alder and Anderson Creeks

Alder and Anderson Creeks shared the same W-IBI scores, good for habitat and fair for salmon (Table 10). Both tributaries supported a similar level of juvenile abundance and diversity compared to higher rated sub-basins, including Elk and Braden Creeks. In fact, Alder supported a greater level of adult abundance than Nolan did in some years. Despite the similarities, adult diversity was limited to coho and fall chinook according to the redd counts and Anderson had the lowest mean winter juvenile density. The relatively higher level of juvenile abundance compared to the adult life stage may reflect high juvenile survival rates, undercounting of redds, or juvenile migration patterns—none of which we could account for with our study.

Alder and Anderson also exhibited similarities in channel morphology and channel gradient. Both are dominated by a low gradient pool/riffle channel type in their lower and upper reaches that are bound in the middle by a short (0.6 -1.5 km) section of the steeper cascade channel type. Annual pool surface area was highly variable in Anderson Creek and we observed extensive bedload movement, which may help explain the low juvenile salmonid density we recorded during the winter. The upper floodplain of Alder Creek often goes subsurface each year, leaving behind a few pools that serve as critical summer refugia to juvenile coho and coastal cutthroat trout. The lower 0.5 km of Alder and Anderson Creeks are associated with extensive floodplain streams located in the Hoh River channel migration zone and have been acquired by the WSC/WRC partnership. Conservation actions should focus on steep and unstable slopes in the headwaters of both sub-basins, in addition to road abandonment in sensitive areas and increased regulatory protection for riparian zones.

Willoughby Creek

Willoughby Creek scored fair for salmon and poor for habitat conditions (Table 10). The tributary supported the lowest annual adult and juvenile salmonid abundance. However, the stream is important to juvenile steelhead, which is consistent with its relatively steep channel and boulder/cobble dominated substrate. Because Willoughby lacks an adequate supply of spawnable size substrate it supports only a few spawning fall chinook and winter steelhead (Jim Jorgensen, Hoh Tribe, personal communication).

Willoughby Creek scored poorly for habitat because it exhibits a plane-bed dominated channel. The main channel suffered a debris flow during a 1992 storm, which explains the lack of instream wood and low level of pool habitat. The headwaters of the sub-basin are located on Willoughby ridge and are protected through a current MOU between the Hoh Tribe and WA DNR that limits forest harvest on steep and unstable slopes. Willoughby was once an important winter steelhead spawning tributary, and recovery will be related to the ability of conservation actions to retain protection for sensitive upslope areas over the long-term. In the short-term, the main channel of Willoughby Creek is a good candidate for engineered large wood structures capable of retaining spawnable size gravel and increasing the availability of pool/riffle channel types.

7.0 Discussion and conclusions

7.1 Findings

Our results indicate that all of the sub-basins we surveyed in the Hoh River basin are important to salmon to various degrees. W-IBI scores prioritized half of the sub-basins in the Tier 1 and Tier 2 categories as having excellent to good potential for conservation, respectively, with the other half in Tier 3 with fair conservation potential (Figure 14). We identified Winfield Creek as critical habitat with excellent conservation potential, followed by Elk, Owl, and Nolan Creeks in the Tier 2 category, and Braden, Alder, Anderson, and Willoughby Creeks in the Tier 3 category. The terms "excellent," "good," and "fair" only describe conservation potential between sub-basins and they do not necessarily reflect a standard of ecological health or recovery status.

We found that differences in salmon metrics between sites were fairly represented in the W-IBI scoring system. The differences between adult and juvenile abundance metrics between the top scoring stream (Winfield Creek) and all Tier 3 streams were significant. Winfield clearly supported the greatest abundance of salmonids across the adult and juvenile life stages. On the other hand, differences in salmon metrics between all Tier 2 and Tier 3 tributaries were not significant for all life stages. Elk, Owl, and Nolan did support a disproportionate level of salmonid abundance and diversity for one life stage (e.g., adult or juvenile), which is why they scored lower than Winfield and above the Tier 3 tributaries. That some streams scored lower despite not exhibiting truly significant values highlights the inherent grey area associated with scoring bins and should be considered when making conservation decisions. Nonetheless, we have a high confidence level in this analysis as a first step toward identifying critical habitat since we generated our quantitative habitat and salmonid associations with spatially and temporally intensive field data.

7.2 Approach revisited

We are confident in our results that Winfield Creek is Tier 1 critical salmon habitat, because the differences in metrics were significant. However, we acknowledge the decision to sample only pools was a limitation in our sample design and may affect some W-IBI scores. For example, juvenile coho tend to prefer low gradient streams and use deep slow-water areas (pools > 0.2 m deep) while juvenile steelhead often prefer steeper streams and use a combination of deep slow- and fast-water habitats (Bisson et al. 1998; Hicks and Hall 2003). Usage of shallow (< 0.2 m deep) pool and fast-water areas is generally limited to age-0 trout and smaller age-0 coho (Quinn 2005). During our surveys, low-gradient channels in Braden, Elk, and Anderson Creeks were dominated by shallow riffles between pools. In contrast, we observed numerous deep, fast riffles and pockets in the higher gradient channel of Owl Creek, and in Nolan and Winfield Creeks to lesser degrees.

If we had sampled all habitat units, juvenile steelhead abundance may have increased proportionally more in Owl, Nolan, and Winfield Creeks compared to shallower streams, because there appeared to be a far greater abundance of deep fast-water habitats. Despite the potential for higher juvenile abundance, their low adult abundance relative to Winfield Creek would still probably prevent them from being placed in the Tier 1 category. In addition, we only collected instantaneous daily water temperatures in each creek during the days we conducted surveys and did not collect discharge data. A more thorough collection of these data may have helped explain specific species usage in particular sites and streams. Future monitoring should include an improved sample design that continuously samples all habitat units that meet minimum depth criteria to test this assumption.

7.3 Conservation actions

Many of the land use practices and processes responsible for degrading habitat conditions in the Hoh River basin have diminished as regulations have improved over the last twenty years. Despite these trends, current conditions are still closely tied to the legacy of land use practices that have and will continue to alter the physical processes controlling habitat formation (Smith 2000). Among the sub-basins we identified as productive for salmon, many include significant road networks and were logged without riparian buffers (McHenry 2001). The clear-cut upslopes and mass-wasting areas cannot be restored faster than natural vegetative recovery, but roads and culverts are essentially permanent sources of impact that require physical removal or obliteration to reduce risks associated with erosion, sediment delivery, and hydrologic alterations (Frissell et al. 1992; Doppelt et al. 1993; FEMAT 1993).

While we provide only general conservation actions, future conservation and management objectives must ensure the sub-basins remain functional as productive long-term habitat for salmonids in the Hoh River basin (Table 11; Figure 14 – See Map Appendix, p 39). We suggest that all management and conservation objectives occur within the framework of a watershed-scale conservation plan that identifies areas and actions based on information in this report, the Hoh River Limiting Factors Analysis (Smith 2000), Middle Hoh River Watershed Analysis (McHenry 2001), Watershed Resource Inventory Area 20 plan (WRIA 20 ongoing) and the North Pacific Coast Lead Entity group prioritization strategy (NPCLE ongoing). Assessing the socio-economic, regulatory, physical, and biological factors associated with conserving salmon and their habitat is necessary to determine exactly what might be required of local tribal, state, federal, non-profit, and private stakeholders on the ground to accomplish this task (Frissell et al. 2000).

7.4 Conclusions

The prioritization of sub-basins in this report represents a first step towards identifying critical salmon tributaries and evaluating those areas for conservation actions (Figure 14 – See Appendix). Our goal was to prioritize streams in a manner that provides a new and useful perspective for stakeholders (Frissell et al. 2000) and fills data gaps at appropriate scales for conservation decisions (Fausch et al. 2002). We also recognize evaluating habitat for conservation is not a static process, because salmon and habitat conditions change over time. For example, habitat conditions will likely continue to decline unless specific conservation actions are taken to protect steep and unstable slopes, regenerate conifer trees in the riparian zones, and reduce channel incision associated with a lack of functional size large wood (Smith 2000; McHenry 2001).

We believe successful conservation efforts will utilize the sub-basins described in this report as foundational building blocks for improving and securing salmonid productivity in the Hoh River basin. However, conservation and recovery efforts in the remaining sub-basins should not be overlooked in their overall contribution to watershed processes that support a full diversity of species. The role and net effect of protecting priority sub-basins alone should be examined through specific analyses of local population dynamics and detailed studies of ecosystem change, but this is outside the scope of this report. Nevertheless, continued loss and degradation of habitat in tributaries, especially in the face of significant climatic change, will have negative biological consequences for salmonids and is likely to compromise viable fisheries into the future.

Table 11. Conservation recommendations by tier for eight tributaries to the Hoh River, Washington. Tier 1 represents the highest conservation potential and Tier 3 the least—no scores fell into bottom two quintile tiers (i.e., 4 and 5).

Tributary	**Tier**	**Key conservation recommendations**				
		Acquisitions/ Easements	*Stream buffer increase*	*Forest Stewardship Council Certification*	Locations	Purpose
Winfield	1	x			River mile 0.1 to 3.5; river mile 0.1 to 1.2 of north branch	Connectivity, conifer regeneration
Elk	2	x		x	Private lands from floodplain complex to State lands; headwater slopes State lands	Connectivity, instream wood recruitment
Nolan	2	x		x	River mile 0.1 to 3.8; headwater slopes State lands	Connectivity, confier regeneration
Owl	2		x	x	State lands (steep and unstable slopes)	Slope stabilization and prevention of mass wasting, conifer regeneration, instream wood and gravel recruitment
Braden	3	x	x		Private lands from floodplain complex to State lands; headwater slopes State lands	Connectivity, slope stabilization and prevention of mass wasting, conifer regeneration, instream wood and gravel recruitment
Anderson	3	x	x		Private lands from floodplain complex to State lands; headwater slopes	Connectivity, slope stabilization, instream wood recruitment, failing infrastructure removal
Alder	3		x	x	Floodplain complex to headwater slopes State lands	Connectivity, slope stabilization, instream wood recruitment, failing infrastructure removal
Willoughby	3		x	x	Floodplain complex to headwater slopes State lands	Connectivity, slope stabilization and prevention of mass wasting, conifer regeneration, instream wood and gravel recruitment

8.0 References

Published

Abbe, T. B., and D. R. Montgomery. 1996. Large woody debris jams, channel hydraulics, and habitat formation in large rivers. Regulated Rivers: Research and Management 12:201-221.

Beechie, T. J., and T. H. Sibley. 1997. Relationships between channel characteristics, woody debris, and fish habitat in Northwestern Washington streams. Transactions of the American Fisheries Society 126:217–229.

Bilby, R.E., and J.W. Ward. 1989. Changes in characteristics and function of woody debris with increasing size of streams in Western Washington. Transactions of the American Fisheries Society 118:368-379.

Bilby, R. E., and J. W. Ward. 1991. Characteristics and function of large woody debris in streams draining old-growth, clear-cut, and second-growth forests in southwestern Washington. Canadian Journal of Fisheries and Aquatic Sciences 48:2499-2508.

Bisson, P.A., Sullivan, K., and Nielsen, J.L. 1988. Channel hydraulics, habitat use, and body form of juvenile coho salmon, steelhead, and cutthroat trout in streams. Trans. Am. Fish. Soc. 117: 262-273.

Bjornn, T.C., and D.W. Reiser. 1991. Habitat requirements of salmonids in streams. Pages 83-138 in W.R. Meehan, editor. Influences of forest and rangeland management on salmonid fishes and their habitats. Special Publication 19. American Fisheries Society, Bethesda, MD.

Brenkman, S. J. and S. C. Corbett. 2005. Extent of anadromy in bull trout and implications for conservation of a threatened species. North American Journal of Fisheries Management 25:1073-1081.

Brown, T. 1987. Characterization of salmonid over-wintering habitat within seasonally flooded land on the Carnation Creek floodplain. Land management report, ISSn 0702-9861; no. 44, Research Branch, Ministry of Forests and Lands, Victoria, B.C.

Bustard, D.R., and D.W. Narver. 1975. Aspects of winter ecology of juvenile coho salmon (Oncorhynchus kisutch) and steelhead trout (Salmon gairdneri). Journal Fisheries Research Board of Canada 32:667-680.

Cambell, R.F., and J.H. Neuner. 1985. Seasonal and diurnal shifts in habitat utilized by resident rainbow trout in western Washington Cascade Mountain streams. Pages 39-47 in Proceedings of the symposium on small hydro and fisheries. Symposium held 1-3 May. American Fisheries Society, Denver, CO.

Cunjak. R.A. 1996. Winter impacts of selected stream fishes and potential impacts from land-use activity. Canadian Journal of Fisheries and Aquatic Science 53:267-282.

Cunjack, R.A., R.G. Randall, and E.M.P. Chadwick. 1988. Snorkeling versus electrofishing: A comparison of census techniques in Atlantic Salmon rivers. Canadian Naturalist 115:89-93.

Dewberry, T.C., L. Hood, and P. Burns. 1998. After the flood: the effects of the storm of 1996 on a creek restoration project in Oregon. Restoration and Management Notes 16(2):174-182.

Doppelt, B., M. Scurlock, C. Frissell, and J. Karr. 1993. Entering the watershed: a new approach to save America's river ecosystems. Island Press, Washington, D.C.

Everest, R.H., N.B. Armantrout, S.M. Keller, W.D. Parante, J.R. Sedell., T.E. Nickleson, J.M. Johnston, and G.N. Haugen. 1985. Salmonids. Pages 199-230 in E. R. Brown, editor. Management of wildlife and fish habitats in forests of western Oregon and Washington. Publication R6-F&WL-192-1985. U.S. Department of Agriculture, Forest Service, Pacific Northwest Region, Portland, OR.

Fausch, K.D., Torgersen, C.E., Baxter, C.V., and Li, H.W. 2002. Landscapes to riverscapes: bridging the gap between research and conservation of stream fishes. Bioscience 52: 483-496.
FEMAT (Forest Ecosystem Management Assessment Team). 1993. Forest ecosystem management: an ecological, economic and social assessment, Report of the Forest Ecosystem Management Assessment Team. U.S. Government Printing Office 1993-793-071. U.S. Government Printing Office for the U.S. Department of Agriculture, Forest Service; U.S. Department of the Interior, Fish and Wildlife Service, Bureau of Land Management, and National Park Service; U.S. Department of Commerce, National Oceanic and Atmospheric Administration and National Marine Fisheries Service; and the U.S. Environmental Protection Agency.
Franklin, J., and C. Dyrness. 1984. Natural vegetation of Washington and Oregon. Oregon State University Press, Corvallis.
Frissell, C. A. 1993. A new strategy for watershed restoration and recovery of pacific salmon on the Pacific Northwest. Report prepared for The Pacific Rivers Council, Eugene, OR.
Frissell, C. A., P. H. Morrison, S. B. Adams, L. H. Swope, and N. P. Hitt. 2000. Identifying priority areas for salmon conservation in the Puget Sound Basin. Pacific Biodiversity Institute Open File Report Number 2000-1.
Frissell, C. A., R. K. Nawa, and R. Noss. 1992. Is there any conservation biology in "New Perspectives"?: A response to Salwasser. Conservation Biology 6:461-464.
Glova, G.J. 1986. Interaction for food and space between experimental populations of juvenile coho salmon and coastal cutthroat in a laboratory stream. Hydrobiologia 132: 155-168.
Hankin, D.G. 1984. Multistage sampling designs in fisheries research: applications in small streams. Canadian Journal of Fisheries and Aquatic Science 41:1575-1591.
Hankin, D.G., and G.H. Reeves. 1988. Estimating total fish abundance and total habitat area in small streams based on visual estimation methods. Can. J. Fish. Aquat. Sci. 45: 834-844.
Hauer, F. R., C. N. Dahm, G. A. Lamberti and J. A. Stanford. 2003. Landscapes and ecological variability of rivers in North America: factors affecting restoration strategies, pp 81-105. In: Wissmar, R. C. and P. A. Bisson (eds.). Strategies for Restoring River Ecosystems: Sources of Variability and Uncertainty in Natural and Managed Systems. American Fisheries Society, Bethesda, MD.
Hicks, B. J., and J. D. Hall. 2003. Rock type and channel gradient structure salmonid populations in the Oregon Coast Range. Transactions of the American Fisheries Society 132:468-482.
Huntington, C., W. Nehlsen and J. Bowers. 1994. Healthy stocks of anadromous salmonids in the Pacific Northwest and California. Oregon Trout, Portland, OR.
Independent Scientific Group (ISG). 1999. Scientific issues in the restoration of salmonid fishes in the Columbia River. American Fisheries Society 24(3):10-21.
Jepsen, D.B. 2005. Smith River Steelhead and Coho Monitoring Verification Study, 2004. Monitoring Program Report Number ODFW-2005-6, Oregon Department of Fish and Wildlife, Salem.
Lichatowich, J. A., G. R. Rahr III, S. M. Whidden, and C. R. Steward. 2001. Sanctuaries for Pacific salmon. Sustainable Fisheries Management: Pacific Salmon. pp. 675-686.
Lichatowich, J.A., L. Mobrand, L. Lestelle, and T. Vogel. 1995. An approach to the diagnosis and treatment of depleted Pacific salmon populations in Pacific Northwest watersheds. Fisheries 20(1):10-18.
Lucchetti, G. 2005. Salmonid use of the Snoqualmie River – Tolt Delta Reach. King County Department of Natural Resources and Parks Water and Land Resources Division, Seattle, WA.

Martin, D., L. Benda, and D. Shreffler. 2004. Core Areas: A Framework for Identifying Critical Habitat for Salmon. Presented to: King County Department of Natural Resources and Parks, Development of Salmonid Conservation Strategies Phase I, Project No. T01426T.

May, C., and G. Peterson. 2003. Landscape assessment and conservation prioritization of freshwater and nearshore salmonid habitat in Kitsap County: Kitsap salmonid refugia report. Kitsap County, WA.

McHenry, M.L., J. Lichatowich, and R. Hagaman. 1996. Status of Pacific Salmon and their habitats on the Olympic Peninsula watersheds. Washington Department of Ecology, Olympia.

Meehan, W.R., and T.C. Bjornn. 1991. Salmonid distributions and life histories. Pages 47-82 in W.R. Meehan, editor. Influences of forest and rangeland management on salmonid fishes and their habitats. Special publication 19. American Fisheries Society, Bethesda, MD.

Miller, D. L., P. M. Leonard, R. M. Hughes, J. R. Karr, P.B. Moyle, L. H. Schrader, B. A. Thompson, R. A. Daniels, K. D. Fausch, G. A. Fitzhigh, J. R. Gammons, D. B. Halliwell, P. L. Angermeier, and D, J. Orth. 1988. Regional applications of an index of biotic integrity for use in water resource management. Fisheries 13(5):12-20.

Mobrand, L. E., J. A. Lichatowich, L. C. Lestelle, and T. S. Vogel. 1997. An approach to describing ecosystem performance "through the eyes of salmon". Canadian Journal of Fisheries and Aquatic Science 54(12):2964-2973.

Mongillo, P.E. 1992. The distribution and status of bull trout/Dolly Varden in Washington State. Washington Department of Fish and Wildlife, Olympia.

Montgomery, D.R., Beamer, E.M., Pess, G.R., and Quinn, T.P. 1999. Channel type and salmonid spawning distribution and abundance. Canadian Journal of Aquatic Science, 56: 377-387.

Montgomery, D.R., and J.M. Buffington. 1993. Channel classification, prediction of channel response, and assessment of channel condition. Olympia, Washington Department of Natural Resources, TFW-SH10-93-002.

Montgomery, D.R., and J.M. Buffington. 1997. Channel-reach morphology in mountain drainage basins. GSA Bulletin, V.109, no. 5; p.596-611. Department of Geological Sciences, University of Washington, Seattle, WA.

Montgomery, D. R., J. M. Buffington, R. Smith, K. M. Schmidt, and G. R. Pess. 1995. Pool spacing in forest channels. Water Resources Research 31:1097-1105.

Moore, L., K. Jones, and J. Dambacher. 1998. Methods for Stream Habitat Surveys Aquatic Inventory Project, version 8.1. Corvallis, OR: Oregon Department of Fish and Wildlife, Natural Production Program.

Moyle, P. B., and P. J. Randall. 1998. Evaluating the biotic integrity of watersheds in the Sierra Nevada, California. Conservation Biology 12:1318-1326.

Nehlsen, W., J.E. Williams, and J. Lichatowich. 1991. Pacific salmon at the crossroads: Stocks at risk from California, Oregon, Idaho, and Washington. Fisheries 16:4-21.

Pacific Northwest Hunting and Fishing Guide 1956. Editor Gordon S. Frear. Published by Wood and Reber, Inc. Seattle, WA.

Pess, G. R., T. J. Beechie, J. E. Williams, D. R. Whithall, J. I. Lange, and J. R. Klochak. 2003. Chapter 8. Watershed assessment techniques and the success of aquatic restoration activities. Pages 185-201 in R. C. Wissmar and P. A. Bisson, editors. Strategies for restoring river ecosystems: sources of variability and uncertainty in natural and managed systems. American Fisheries Society, Bethesda, MD.

Quinn, TP. 2005. The Behavior and Ecology of Pacific Salmon and Trout. University of Washington Press, Seattle, WA.

Rodgers, J.D., M.F. Solazzi, S.L. Johnson, and M.A. Buckman. 1992. Comparison of three techniques to estimate juvenile coho salmon populations in small streams. North American Journal of Fisheries Management 12:79-86

Roni, P. and A. Fayram. 2000. Estimating Winter Salmonid Abundance in Small Western Washington Streams: A Comparison of Three Techniques. North American Journal of Fisheries Management 20:683-692.

Roni, P., T. J. Beechie, R. E. Bilby, F. E. Leonetti, M. M. Pollock, and G. R. Pess. 2002. A Review of Stream Restoration Techniques and a Hierarchical Strategy for Prioritizing Restoration in Pacific Northwest Watersheds. North American Journal of Fisheries Management 22:1–20

Rosenfeld, J. M. Porter, and E. Parkinson. 2000. Habitat factors affecting the abundance and distribution of juvenile cutthroat trout (Oncorhynchus clarki) and coho salmon (Oncorhynchus kisutch). Canadian Journal of Fisheries and Aquatic Sciences 57:766774.

Rosenfeld, J. S, and T. Hatfield. 2006. Information needs for assessing critical habitat of freshwater fish. Canadian Journal of Fisheries and Aquatic Science 63:683-698

Rot, B. 1996. The importance of floodplain backchannels to overwintering salmonids: a literature review with specific references to the floodplain at river mile 19 on the Hoh River, Washington. Unpublished report, Hoh Indian Tribe, Forks, WA.

Sedell, J.R., P.A. Bisson, J.A. June, and R.W. Speaker. 1982. Ecology and habitat requirements of fish populations in South Fork Hoh River, Olympic National Park. In: Starkey, Edward, editor. Ecological Research in National Parks of the Pacific Northwest. Oregon State University, Corvallis, OR.

Sedell, J., R.W. Speaker, and J.E. Yuska. 1984. Habitat and salmonid distribution in pristine sediment-rich river valley systems: S. Fork Hoh and Queets River, Olympic National Park. Pages 47-63, Vol.7 in Proceedings of the Second Conference on Scientific Research in National Parks. National Park Service, NPS/ST-80/02-7, Wash., D.C.

Sharma, R., and R. Hilborn. 2001. Empirical relationships between watershed characteristics and coho salmon (Oncorhynchus kisulch) smolt abundance in 14 western Washington streams. Canadian Journal of Fisheries and Aquatic Sciences 58: 1453-1463.

Smith, Carol J. 2000. Salmon and Steelhead Habitat Limiting Factors in the North Coastal Streams of WRIA 20. Washington State Conservation Commission, Lacey, WA.

Spence, B. C., G. A. Lomnicky, R. M. Hughes, and R. P. Novitzki. 1996. an ecosystem approach to salmonid conservation. TR-4501-96-6057. ManTech Environmental Research Services Corp., Corvallis, OR.

Thurow, R.F. 1994. Underwater Methods for Study of Salmonids in the Intermountain West. United States Forest Service. General Technical Report INT-GTR-307.

Tschaplinski, P.J., and G.F. Hartman. 1983. Winter distribution of juvenile coho salmon (Oncorhynchus kisutch) before and after logging in Carnation Creek, British Columbia, and some implications for overwinter survival. Canadian Journal of Fisheries and Aquatic Sciences 40:452-461.

U.S.G.S. 1998. Water Resources Data Washington Water Year 1998. Water-Data Report WA-98-1.

U.S. Weather Bureau. 1965. State of Washington, mean annual precipitation, 1930-1957: Portland, Oregon, Soil Conservation Service, map M-4430.

Washington Department of Fish and Wildlife. 2002. Salmonid Stock Inventory. Olympia, WA.

Washington State Forest Practices Board. 2001. Forest and Fish Plan. Washington Department of Natural Resources, Olympia, WA. Available online at: http://www.forestsandfish.com

Washington State Forest Practices Board. 2005. Forest Practices Habitat Conservation Plan (FPHCP). Washington Department of Natural Resources, Olympia, WA. Available online at: http://www.dnr.wa.gov/htdocs/agency/federalassurances/final_fphcp/index.html

Personal Communication and Unpublished

Brenkman, S., and J. Meyer. 1999. Spawning migrations of bull trout (Salvelinus confluentus) in the Hoh River and South Fork Hoh River, Washington. Unpublished Report. Olympic National Park, Port Angeles.

City of Forks weather station, Washington State Climate Summaries. Available online at: http://www.wrcc.dri.edu/summary/climsmwa.html

Hoh Tribe Natural Resources. 1990-2004. Unpublished redd count data. Hoh River, WA.

Howell, Bob. 2001. Personal Communication. Hoh Tribe Geomorpholgist. Hoh River, WA.

Jorgensen, Jim. 2001. Personal Communication. Hoh Tribe Fisheries Manager. Hoh River, WA.

McHenry, M.L. 2001. Fisheries habitat module. Middle Hoh River Watershed Analysis, Washington State Department of Natural Resources. Forks, WA.

McMillan, J. M., J. C. Starr, G. R. Pess, X. Augerot, and S. Chilcote. [In prep.] A comparison of salmon habitat prioritization metrics in a coastal Pacific Northwest watershed.

Mosely, Roger. 2001. Personal communication. Fisheries Biologist, Washington Department of Fish and Wildlife, Forks Office, Forks, WA.

North Olympic Peninsula Lead Entity. 2004. NOPLE Hoh Basin Project Prioritization Strategy. Available online at: http://www.noplegroup.org/NOPLE/pages/watersheds/HohBasinWatershedPage.htm

Rahr, G., and X. Augerot. 2005. Salmon 2100: A strategy to Anchor and Expand the Remaining Wild Salmon Strongholds. In: Lackey, Robert T., and Denise H. Lach. Editors. [2006]. Salmon 2100 Project: Alternative Futures for Western North American Salmon. American Fisheries Society, Bethesda, MD. [In Preparation].

Silver, Jill. 2001. Personal Communication. 10,000 Years Institute. Forks, WA.

Washington Department of Fish and Wildlife. 1990-2004. Unpublished redd count data.

Map Appendix

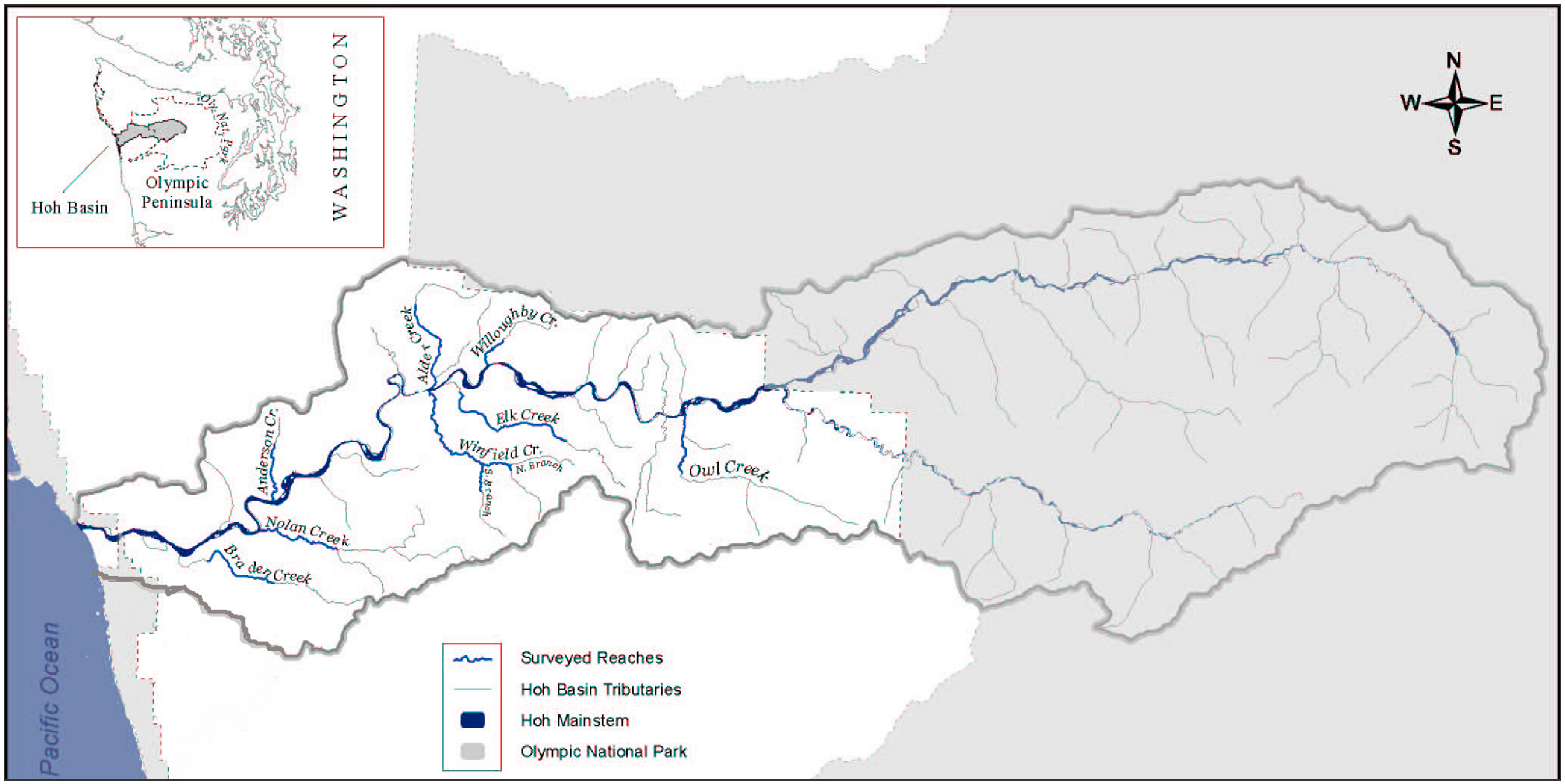


Figure 1. Map of the Hoh River basin in relation to Washington State, including major tributary survey sites and the proportion of land within the Olympic National Park

Map Appendix

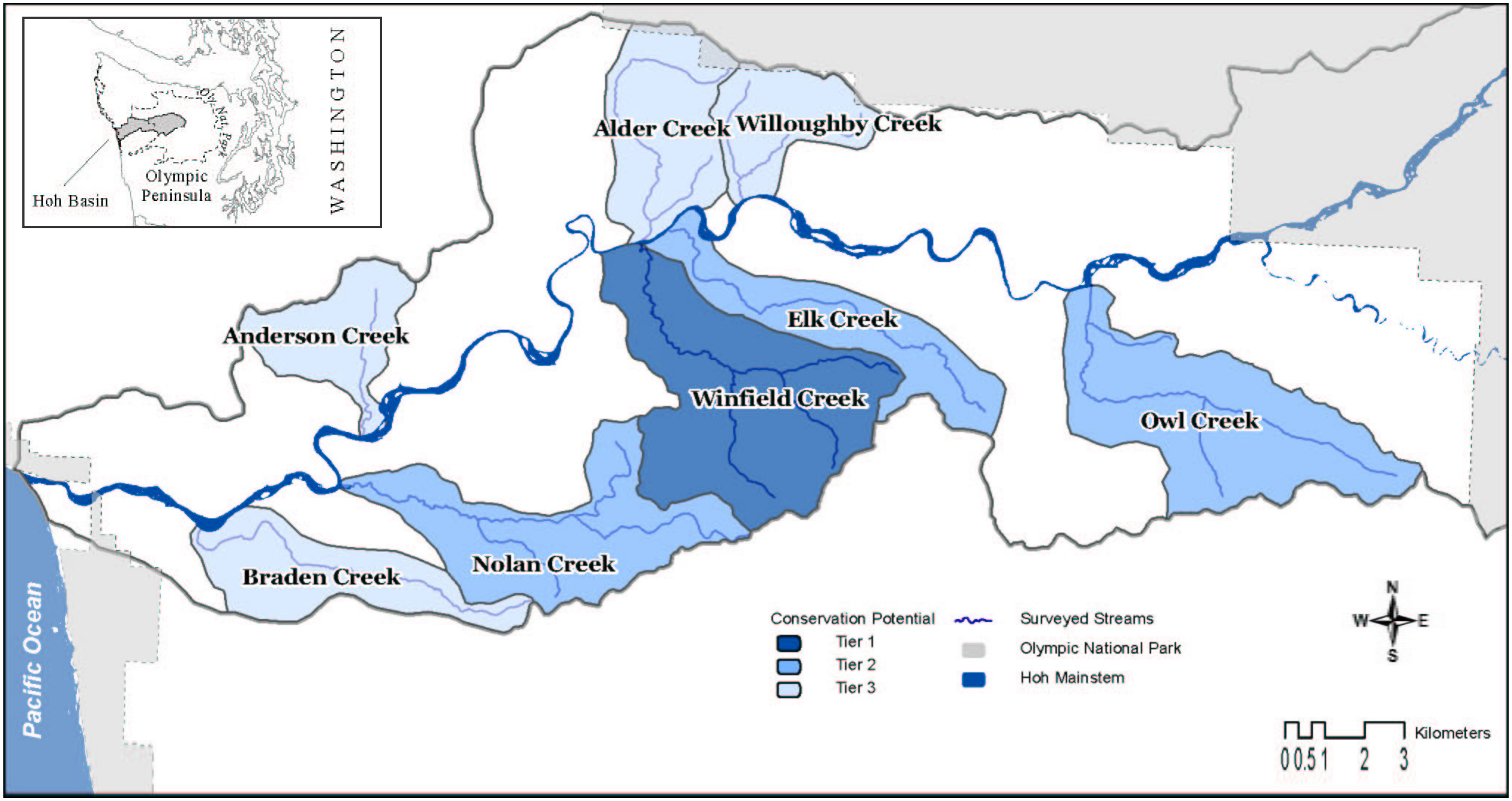
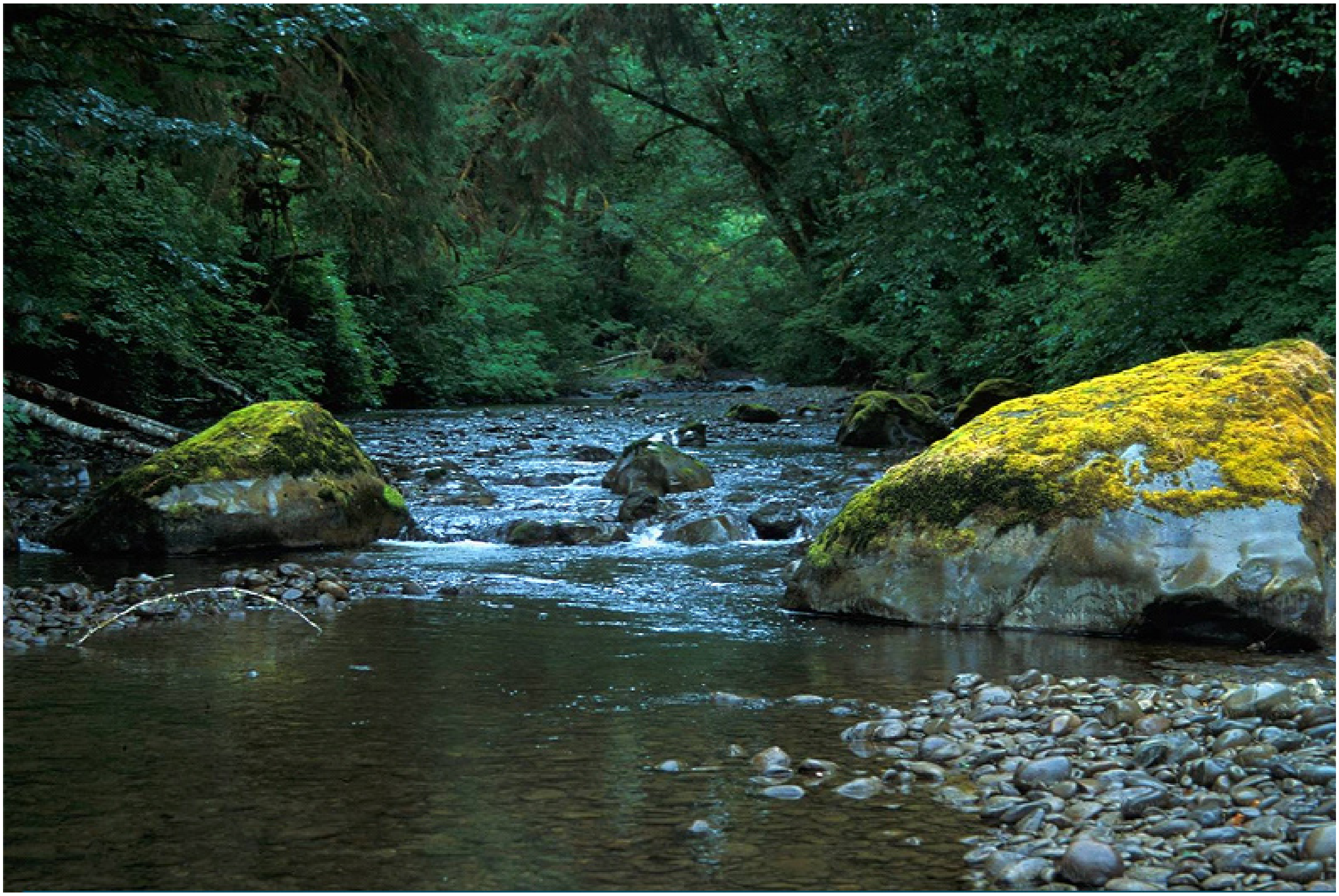


Figure 14. Map of tributary prioritization by conservation potential as determined by W-IBI scores and tier ranking.



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