Salmon Habitat Limiting Factors in Washington State
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Acknowledgements

This statewide document is a summary of all individual Habitat Limiting Factors reports developed for 45 basins in Washington State from 1998 through 2003, and could not have been written without the efforts of the many people who developed these original documents. The primary authors of these reports include Donald Haring, John Kerwin, Carmen Andonaegui, Mike Kuttel Jr., Gary Wade, Ginna Correa, Mary Wilkosz, Brian Cowan, Kevin Lautz, and Carol Smith with leadership from Ed Manary and additional support from Randy McIntosh (NWIFC), Kurt Fresh (NOAA Fisheries), Jennifer Cutler (NWIFC), Devin Smith (SRSC), and Ron McFarlane (NWIFC). This statewide report closely follows the outline used in the basin reports including some of the same text in introductory sections that was developed by the above-mentioned individuals, and this project would not have been possible without their vast expertise. All of the individual reports are listed in the Literature Cited section even though some are not directly cited because data within each of these reports was used in the accompanying Excel habitat ratings spreadsheet, which formed the basis for further analyses.

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Cover pictures feature the upper Skagit River (top photo) and Ruby Beach (bottom photo).

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EXECUTIVE SUMMARY

From 1998 through 2003, salmon habitat limiting factors analysis (LFA) reports were developed for all basins in Washington State that produced salmon or steelhead in addition to one Watershed Resource Inventory Area (WRIA) that produced only bull trout as an anadromous species. This is a summary report of those 45 individual reports that provides an overview of the results on a state, regional, and WRIA scale. Habitat results are also related to land ownership and land use. The purposes of this report are to provide a broader perspective of salmon habitat conditions and provide information across the state by habitat category, which is useful for those who are more interested in a particular type of habitat parameter rather than a specific stream. It shows how different habitat conditions vary by category across the state, and how land use and land ownership may play a role in habitat conditions. This report provides the following products: 1) a spreadsheet that provides at a glance all habitat ratings for the streams in all LFA reports, 2) maps and discussion of WRIA-scale ratings developed from the most frequent habitat ratings by category, 3) A discussion of the extent of data gaps for salmon habitat throughout Washington State, 4) the relationship of WRIA-wide habitat ratings results to land use and land ownership, and 5) a summary of salmonid stocks and stock status by basin.

Fish Stocks and Status Conclusions

Salmonid production, stocks, and status vary greatly across Washington State. Out of 161 independent salmon-producing drainages, three (Chehalis, Quillayute, and Skagit) produce 14% of the total, 17% of the wild, and 19% of the native salmon and steelhead stocks in the state. Twelve out of 161 drainages produce 35% of the total, 45% of the wild, and 38% of the native salmon and steelhead stocks in the state. These twelve drainages are the Chehalis, Quillayute, Skagit, Snohomish, Cowlitz, Nooksack, Queets, Stillaguamish, Puyallup, Quinault, Lewis, and Dungeness basins, which combined produce much of the genetic diversity of salmon and steelhead populations in the state.

The percent of healthy stocks also differs widely (stocks of unknown status are not included in the percentage). The Snake River, upper Columbia, and lower Columbia regions have very low percentages of healthy wild salmon and steelhead stocks (0%, 0% and 11% respectively), while the mid-Columbia has 40%, Puget Sound 56%, and the coast has 78% healthy wild salmon and steelhead stocks. Results are similar for native and total stocks. It is noteworthy that even the area with the healthiest stocks (the Washington Coast) still has wild stocks that are not healthy.

General Salmon Habitat Conditions in Washington State

Habitat types and conditions also vary across the state. Washington ranks 20th in the nation in size and 15th in human population with ¾ of the state’s human population located in the Puget lowlands. Coniferous forest covers 37%, agriculture accounts for 21%, and urban lands comprise 2.5% of the state (Cassidy et al. 1997). There is much that we don’t know about habitat conditions, and where we have information, the majority suggests degraded habitat. Most (43%) of the WRIA-scale habitat ratings are data gaps followed by poor habitat conditions (38%). Only 13% of the ratings are good and 7% are fair.

Only one WRIA (Upper Skagit) had overall good habitat ratings in all categories that were not data gaps. Methow, Naches, and Nisqually had an overall fair-good rating with 11 additional basins rating fair overall. Nine basins rated poor-fair, but more (21) basins rated poor than any other rating.

Data gaps are especially prevalent for water quality (particularly for water quality parameters other than temperature), sedimentation other than road density, and low flow categories. Data on pool habitat are even less common, but poor ratings in this category are often the result of impacts in landscape processes such as sedimentation, LWD supply, flow and riparian conditions, and measuring conditions of processes rather than symptoms (pools) is of greater value because it identifies the source(s) of the problem.

Land Ownership and Freshwater Habitat Conditions

Habitat ratings in nine categories (access, floodplain, sedimentation, riparian, large woody debris (LWD), pool, water temperature, high flow and low flow) were related to land ownership, but most of the ratings were poor across all land ownership percentages and types with a low number of good or fair ratings. This coupled with a lack of parcel-specific information of habitat conditions and land use/land ownership resulted in an inability to produce correlations with p-values of .05 or less (statistically significant). However, some broad conclusions can be made.

Basins with higher percentages of federal land had generally better ratings for nearly all of the habitat categories including: access, floodplain, LWD, riparian, high flow, and sedimentation conditions. The remaining three categories (low flows, pools, and water temperature) were not associated with any specific extent of federal land ownership. Lower percentages of state-owned land had typically better ratings for access, floodplain, and LWD conditions. Habitat data in other categories were too scattered to suggest a relationship with various percentages of state-owned land. Lower percentages of private land ownership were generally associated with better ratings for floodplain, sedimentation, LWD, pool, and high flow conditions. Data in other categories were too scattered to suggest a relationship.

Land Use and Freshwater Habitat Conditions

Forestry dominated WRIAs had generally better ratings for riparian, water temperature, and pool conditions, and nearly all of the fair to good rated WRIAs for access, floodplain, and LWD were in forestry dominated WRIAs. WRIAs with significant urban land use and/or higher human population densities had overall poor ratings in all but one habitat category. These poor rated categories include: access, floodplain, LWD, riparian, sedimentation, low flow, high flow, and pool conditions. The one category without a poor rating was water temperature, and this was due to widely scattered results. WRIAs dominated by agricultural lands had generally poor access, floodplain, and LWD conditions, while riparian and pool condition results were scattered across all percentages of agricultural land. Lower percentages of agricultural land were associated with better water temperature conditions.

Conclusions

Habitat categories with the greatest percentage of poor ratings were floodplain, LWD, and riparian, while access (culverts), high flows (land cover), and water temperatures had the greatest percentage of good ratings. Data coverage was better for riparian conditions than any other category due to broad scale data from Lunetta et al. (1997). However, newer data are needed to continue to assess conditions in the future. Data collection programs exist for water quality data as well as for basic flow data in certain streams, but assessments are needed to monitor trends and relate flows to salmon use and production. At this time, there are no programs that are funded on a regular basis to monitor and assess access, floodplain, sedimentation, riparian, and instream habitat conditions.

When habitat conditions are related to land use, urbanized basins had generally worse habitat conditions in most categories. Basins dominated by forestry had the best habitat ratings compared to other land uses. WRIAs dominated by agriculture had ratings that were not as good as forestry-dominated basins, but generally not as bad as the overall ratings in more urbanized drainages.

It is important to recognize that these results are based upon the individual limiting factors reports, which are snapshots in time of habitat conditions. New data at the local level is constantly evolving and readers are encouraged to check with local salmon recovery planning organizations for the most up-to-date information. In addition, the summarization of data to a broad statewide level results in a necessary loss of variability and sense of data gaps or uncertainty within a basin. A review of information at the local level is important to retain that perspective.

HABITAT LIMITING FACTORS BACKGROUND AND INTRODUCTION

How to Use This Document

This report is made available in a portable document format (pdf). This allows anyone with a computer and free Adobe Acrobat Reader® software to read and print the document. Adobe Acrobat Reader is available at: http://www.adobe.com/products/acrobat/readstep.html. The Adobe software has several useful features to aid your use of this document. The zoom feature allows you to magnify details, which is particularly useful for maps. Blue underlined text appears throughout the document as hyperlinks that can take you directly to the referenced item. Also, the Acrobat software allows you to search for your topic of interest, and has bookmarks to quickly access a desired chapter.

Habitat Limiting Factors Background

The successful recovery of naturally spawning salmon populations depends upon directing actions simultaneously at harvest, hatcheries, habitat and hydro; the four H's. The 1998 state legislative session produced a number of bills aimed at salmon recovery. Engrossed Substitute House Bill 2496 (now 77RCW) was a key piece of the 1998 Legislature's salmon recovery effort with the focus directed at salmon habitat issues.

Engrossed Substitute House Bill (ESHB) 77RCW in part:

- Directed the Conservation Commission in consultation with local government and the tribes to invite private, federal, state, tribal and local government personnel with appropriate expertise to act as a technical advisory group.

- Directed the technical advisory group to identify limiting factors for salmonids to respond to section 8 sub 2 of this act.

- Defined limiting factors as "conditions that limit the ability of habitat to fully sustain populations of salmon."

- Defined salmon as all members of the family Salmonidae, which are capable of self-sustaining, natural production.

The overall goal of the Conservation Commission's limiting factors project was to identify habitat factors limiting production of salmon in the state. In waters shared by salmon, steelhead trout and bull trout were also included. One area (WRIA 62, Pend Oreille) was included as bull trout only waters.

It is important to note that the responsibilities given to the Conservation Commission in 77RCW do not constitute a full limiting factors analysis. The hatchery, hydro and harvest segments of limiting factors are being dealt with in other forums.

New Products in this Report

Several products are the result of this effort.

- Detailed Spreadsheet. In a separate file to this report, there is a large spreadsheet with ratings for all habitat categories by stream and stream reach (when available) that were in each of the Conservation Commission's Limiting Factors Analyses (LFA). This includes most salmon-producing streams in Washington State. It is provided as an Excel file instead of a PDF so that others can easily work with the data, and it puts all of the habitat ratings for salmon-producing streams in one place. The information in the spreadsheet is also the foundation for subsequent analyses in this report. In addition, it shows finer scale data to provide readers with a greater sense of variability and data gaps or uncertainty within a basin, which can be overlooked when examining coarser scale data. Readers are encouraged to keep these factors in mind and refer back to the spreadsheet to see the original results by stream.

- Salmonid Stock Status. Information summarizing salmonid stock status is also included and this information is presented by WRIA and by salmon recovery region. Such information includes the number of wild, native, and total stocks as well as the status of those stocks.

- Summary of LFA Ratings by WRIA. The individual LFA ratings were combined to form a WRIA-wide rating for each habitat parameter. This provides a snapshot of the extent of habitat degradations and data gaps by category across Washington State. It also illustrates the geographic range and locations of conditions and data gaps. This summary data were based directly on the detailed spreadsheet discussed above.

- Maps of Habitat Ratings by WRIA. Numerous maps are provided to quickly illustrate the extent of habitat conditions across the state for each habitat category. Categories include access, floodplain, sediment quantity, sediment quality, road density, stability, riparian, LWD, pools, water temperature, dissolved oxygen, other water quality issues (nutrients, pH, toxins), high flow conditions, impervious surfaces, and low flow conditions.

- Habitat Ratings and Land Ownership/Land Use. Lastly, this report includes a summary of the habitat ratings by WRIA and discusses how those ratings relate to land ownership and land use.

ANADROMOUS SALMONID STOCKS AND THEIR STATUS IN WASHINGTON STATE

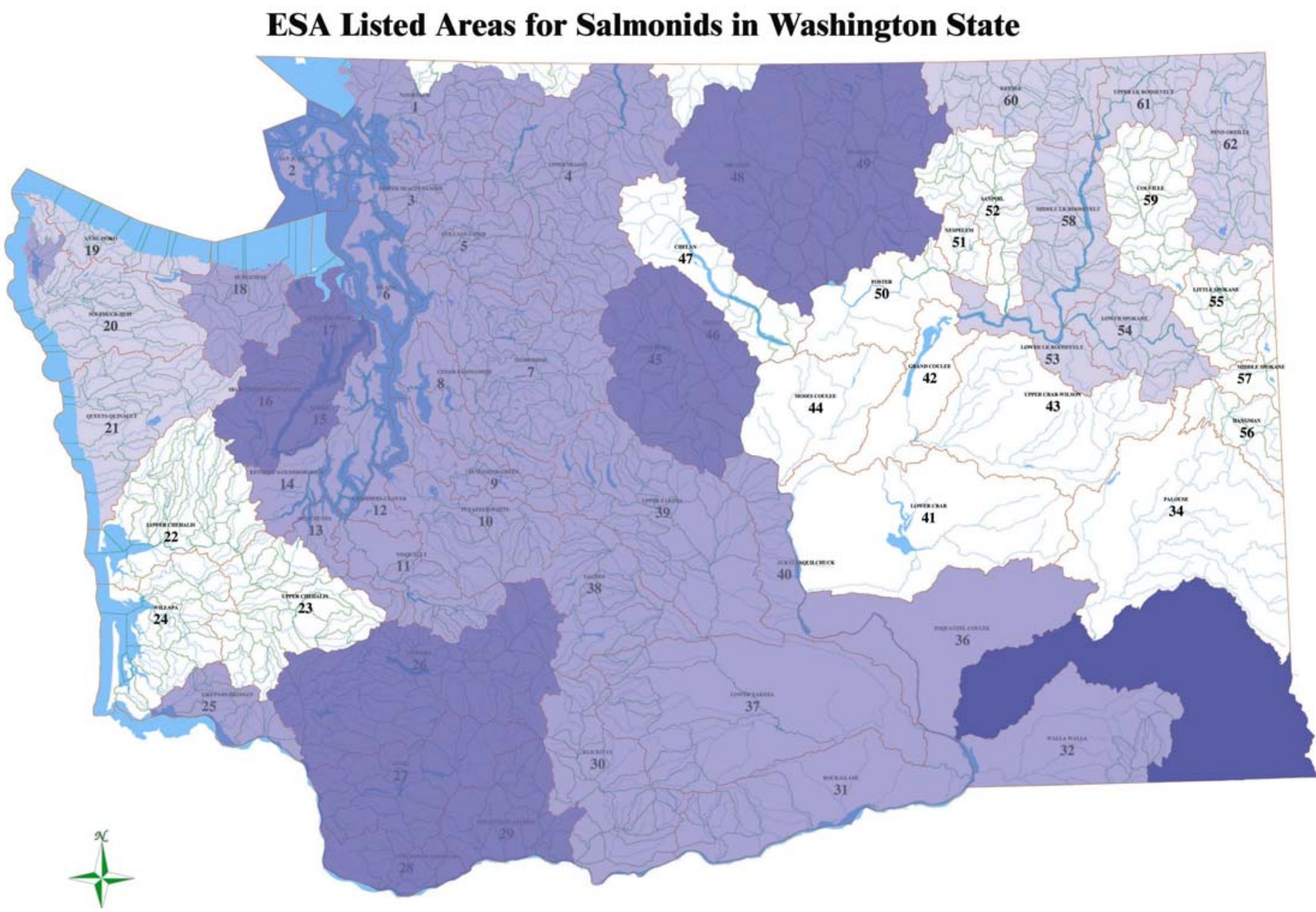
Anadromous Salmonid Species in Washington State

Washington State provides habitat for five different native species of anadromous salmon and three native species of anadromous trout or char. The most abundant salmon species in Washington is pink salmon with a 2003 forecast run size of 2.3 million adults (WDFW 2003). Washington State pink salmon return as adults generally every odd year, and are found throughout Puget Sound streams. All Washington pink salmon production is wild with the exception of hatchery supplementation in the Dungeness River to recover a critical stock (WDFW 2002). Pink salmon are irregularly found along the coast and in Columbia River streams, but these are not considered self-sustaining populations (Heard 1991; WDFW 2002). Small runs of pink salmon may exist in California, but Washington is the southern most extent of significant populations of this species (Heard 1991). No Washington State pink salmon populations are on the Endangered Species List (Hard et al. 1996).

Chum salmon are the second most abundant species of salmon in Washington State. They are found throughout Puget Sound with a total 2003 forecast run size of 835,000 adults (WDFW 2003). Large populations also return to the south coastal streams with a 5-year mean return of 23,600 to the Willapa Basin and 4,300 to the Chehalis Basin (Johnson et al. 1997). Little is known about the numbers of chum salmon that return to the north coastal streams. Historically, the Columbia River supported abundant chum with catches in the hundreds of thousands of fish through the 1940s, and spawning extending as far as the Walla Walla River (Johnson et al. 1997). However, now only three small populations exist, and they are located in three lower Columbia River tributaries (Johnson et al. 1997). Most chum stocks are wild, but some hatchery production occurs in the Samish, Green, Kitsap, Hood Canal, and Quinault watersheds in addition to supplementation for recovery purposes in the lower Columbia and eastern Strait of Juan de Fuca (WDFW 2002). Small numbers of chum salmon can be found in Oregon and California, but Washington State is the southern most extent of abundant chum populations (Salo 1991). Two populations of Washington State chum salmon are listed as threatened on the Endangered Species List (Figure 1). These include lower Columbia chum and Hood Canal summer chum (Johnson et al. 1997).

Wild coho salmon stocks are numerous throughout most streams in Puget Sound and along the coast, and comprise the third most abundant species of salmon in Washington State. The wild forecast estimate for 2003 was 530,000 adult coho returning to Puget Sound and 216,000 to the coastal streams (WDFW 2003). Wild coho stocks no longer exist in the Columbia Basin, although a mix of natural and hatchery production likely occurs in many streams with stocks of mixed origin (Weitkamp 1995; WDFW 2002). No populations of coho salmon are listed as threatened or endangered on the Endangered Species List, but Puget Sound and southwest Washington (including the lower Columbia) stocks are described as candidate stocks, indicating that sufficient concern exists to potentially list them in the future (Weitkamp 1995).

Figure 1. Number of salmonid stocks on the Endangered Species List in Washington State. Color intensity relates to the number of listed stocks. The more intense the color, the greater number of listed stocks.



Wild chinook salmon runs are found throughout much of the state, and this species is the fourth most abundant species. The 2003 forecasted wild run size to Puget Sound was 50,000 adults with 17,500 returning to the north coast, 13,900 to the south coast, 24,600 to the lower Columbia streams in Washington, and 280,400 to the mid and upper Columbia River system (WDFW 2003). Five populations of Washington State chinook salmon have been included on the Endangered Species List (Figure 1). These include the upper Columbia spring stocks, which are listed as endangered, and the Snake River fall, Snake River spring/summer, Puget Sound, and lower Columbia chinook, which are listed as threatened (Meyers et al. 1998). Only three groups of chinook populations in Washington are not on the Endangered Species List. These are upper Columbia summer/fall chinook, mid-Columbia spring chinook, and Washington Coast chinook (Meyers et al. 1998).

Although sockeye salmon are the third most abundant species in the Pacific Rim (Burgner 1991), they are presently the least abundant salmon species in Washington State, limited to areas with appropriate, accessible habitat. In the early 1900s, the Columbia River had sockeye salmon runs numbering greater than 1 million adults, but of eight historic lake systems in the Columbia Basin, only three are currently accessible and produce sockeye salmon today (Burgner 1991). In terms of lake area, the remaining stocks of Columbia River sockeye occupy only 4% of the historic lake habitat (Gustafson 1997). Presently, the larger populations are found in the Baker River of the Skagit Basin (7,800 forecast for 2003), Lake Washington (104,000 forecast for 2003), Quinault (39,000 mean runsize). Wenatchee (11,000 forecast), and Okanogan (11,000 forecast) Rivers. Small (less than 1000 returns/year) runs are found in the Ozette and Lake Pleasant (Quillayute) watersheds. The Ozette population is listed as threatened (Figure 1) (Gustafson 1997). Snake River sockeye are listed as endangered, but their spawning and rearing areas are primarily outside of Washington State.

Steelhead trout have a broad distribution throughout streams in Puget Sound, along the coast, and throughout much of the Columbia River Basin. While none of the populations along the coast and in Puget Sound are on the Endangered Species List, all of the Columbia River populations are listed. Upper Columbia steelhead are listed as endangered, and lower Columbia, middle Columbia, and Snake River steelhead are listed as threatened (Figure 1) (Busby et al. 1996). Only summer-run steelhead are found upstream of the Klickitat River in the Columbia.

Bull trout throughout the state are listed as threatened (U.S. Fish Wildlife Service 1999), and bull trout/Dolly Varden char are found in nearly all the same river systems as salmon and steelhead with the following exceptions. Char are absent in the Willapa streams, questionable in the Chehalis system, and they are present in a few areas lacking salmon and steelhead, such as Pend Oreille, Franklin D. Roosevelt Lake, South Salmo, and Granite Creek in the upper Columbia (WDFW 1998). Little is known about the Washington State char populations; 72% have an unknown status in SaSI (WDFW 1998). All char populations in this state are native origin with wild production.

Coastal cutthroat are found throughout Puget Sound, the coastal streams, and in the Columbia River tributaries to Celilo Falls (the Dalles Dam) (Johnson et al. 1999). Little is known about these populations, as 80% have an unknown stock status (WDFW 2000). They appear to be generally more abundant in north Puget Sound compared to southwest Puget Sound (Johnson et. al. 1999).

Comparison of Stocks Between Drainages

In the most recent SaSI report (WDFW 2002), salmon and steelhead stocks have been categorized three different ways: by origin, production type, and status. Origin can be either native to that watershed, non-native, mixed, or unknown/unresolved. Production type refers to the extent of hatchery versus natural production, and can be wild (natural production), hatchery, composite (mixed hatchery and wild), or unknown/unresolved. Stock status is listed as healthy, depressed, critical, extinct, or unknown/unrated. Detailed definitions of these classifications can be found in WDFW et al. 1993 and http://wdfw.wa.gov/fish/sassi/intro.htm, and in brief, WDFW definitions are as follows:

- “A stock is a group of fish that return to spawn in a given area at the same time.”

- “Critical stocks are those that have declined to the point that the stocks are in danger of significant loss of genetic diversity, or are at risk of extinction.”

- “A depressed stock is one whose production is below expected levels, based on available habitat and natural variation in survival rates, but above where permanent damage is likely.”

- “The term "healthy" covers a wide range of actual conditions, from robust to those without surplus production for harvest.”

Using this information, drainages within Washington State are compared by the number of salmon and steelhead stocks, the types of those stocks (native and wild), and the stock status within that drainage. Wild stocks spend all phases of their life in the natural environment and are more dependent upon habitat conditions, providing a better indicator of the link between stock status and habitat. Native stocks were included because these are assumed to be more locally adapted to that particular basin, and would also serve as an important indicator of habitat health. A drainage is defined in this report as a basin with its tributaries that directly drains into either saltwater or the Columbia River. For example, the Skagit River, Samish River, and Joe Leary Slough are all separate drainages from each other even though they are in the same Watershed Resource Inventory Area (WRIA). This criterion was chosen because within a basin, there is a continuity of habitat and salmonid stocks, and salmonids from one basin do not frequently use freshwater habitat from another basin.

The comparison is presented in two different formats. Statewide maps have been colored to easily compare the relative number of stocks by drainage (Figures 2-4). The intensity of the color is proportional to the relative number of stocks, the darker the color, the greater number of stocks. In addition to the maps, the numerical data are listed in Table 1 next to a colored indicator that describes the health of the stocks within that drainage.

Cutthroat and char stocks are not included in this comparison. There are much fewer data available for these species, particularly for stock status and the location of different stocks, and this would greatly decrease the accuracy of the analysis. Also, these species are widely distributed, so that inclusion of these stocks would likely change the analysis by very little and in only a few areas.

In addition to the abundance of salmon and steelhead stocks, a coarse comparison of overall abundance of salmon is important to consider because a basin can have few stocks, yet be a very important area of overall salmonid abundance. However, this sort of measurement is problematic as estimates for each species often use different methodologies, and the production from some drainages is merged together for management purposes, especially in the Columbia River. Also, the Columbia River watersheds do not produce pink salmon and have very depressed or extinct levels of chum and coho salmon, which reduces the overall abundance of salmon compare to other areas of the state. Because of these problems, the abundance of chinook salmon by drainage was chosen for comparisons between drainages. This allows for the inclusion of the Columbia River watersheds, but underestimates the importance of small streams that produce primarily other species. Also, it overestimates Columbia River production compared to coastal and Puget Sound areas that produce many other species.

Number of Total, Wild, and Native Salmon and Steelhead Stocks by Drainage

No matter how the data are sorted (total stocks, wild stocks, or native stocks), the results are similar. The Chehalis basin has the greatest number of salmon and steelhead stocks, ties with the Quillayute for the greatest number of wild stocks, and ties with the Quillayute and Skagit basins for the greatest number of native stocks (Table 1, Figures 2-4). These three basins are the top sources of total stocks, native stocks, and wild stocks of salmon and steelhead in Washington State. Together, the Chehalis, Quillayute, and Skagit drainages produce nearly 14% of the total number of salmon and steelhead stocks, 17% of the wild stocks, and 19% of the native salmon and steelhead stocks in the state.

The stock health varies between these three drainages with mostly healthy stocks in the Quillayute, generally healthy total and native stocks in the Chehalis, and nearly equal healthy to depressed/critical/extinct total and native stocks in the Skagit. There are less healthy wild stocks in the Chehalis and Skagit than total or native stocks, suggesting greater habitat impacts to those stocks that spend all life history phases in their natural environment.

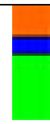
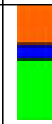
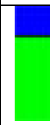
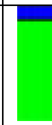
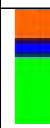
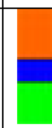
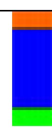
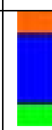
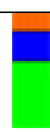
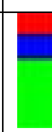
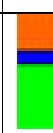
Other basins with large numbers of total stocks include the Snohomish, Cowlitz, Nooksack, Queets, Stillaguamish, Puyallup, Quinault, Lewis, and Dungeness. There are more divergent results between these drainages when native and wild stock numbers are compared. The Snohomish, Nooksack, Queets, and Stillaguamish basins have more native and wild stocks than the Cowlitz, Puyallup, Quinault, Lewis, and Dungeness drainages. In most of these basins, less of the native-origin stocks were healthy compared to total and wild stocks within the same basin with notable exceptions of the Stillaguamish and Quinault (Table 1). A greater percentage of healthy stocks were found in the Snohomish and Queets drainages, while the greater percentage of depressed/critical/extinct stocks were found in the Cowlitz, Puyallup, and Dungeness basins.

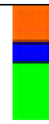
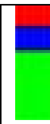
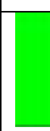
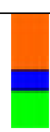
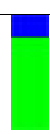
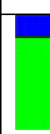
Together the top twelve drainages with the greatest number of stocks produce 35% of the total number of salmon and steelhead stocks, 45% of the wild stocks, and 38% of the native-origin stocks out of a total of 161 examined drainages in the state.

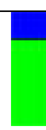
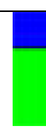
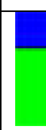
Basins with moderate numbers of salmon and steelhead stocks include the Dosewallips, Duckabush, Skokomish, Wenatchee, Elwha, Green, Hamma Hamma, Hoh, Klickitat, Methow, Snake, Yakima, Kalama, Nisqually, and Wind drainages (Table 1, Figures 2-4). Of these, predominantly depressed/critical/extinct stocks were found in the Dosewallips, Duckabush, Wenatchee, Elwha, Methow, Snake, and Yakima basins, while mostly healthy stocks were found in only one of these, the Hoh drainage.

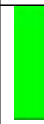
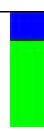
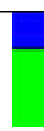
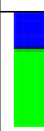
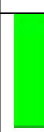
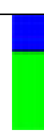
It is also interesting that in the Green River basin, there is only one wild stock and it is depressed, whereas there are two native stocks with hatchery production support, and they are healthy.

Table 1. Number of total, wild, and native salmon and steelhead stocks by drainage with the percentage of healthy stocks (green), unknown status stocks (blue), and depressed, critical, or extinct stocks (red) shown in bars (raw data from WDFW 2002).

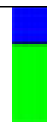
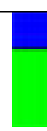
Drainage	Total Number of Stocks	Stock Health: Total Stocks	Number of Wild Stocks	Stock Health: Wild Stocks	Number of Native Stocks	Stock Health: Native Stocks
Chehalis	28		18		17	
Quillayute	22		18		17	
Skagit	19		16		17	
Snohomish	17		15		11	
Cowlitz	12		4		3	
Nooksack	12		9		10	
Queets	12		8		10	
Stillaguamish	12		11		9	
Puyallup	11		6		6	

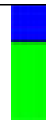
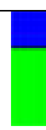
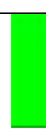
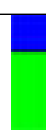
Quinault	10		6		5	
Lewis	9		6		6	
Dungeness	8		3		5	
Dosewallips	7		4		3	
Duckabush	7		4		3	
Skokomish	7		3		2	
Wenatchee	7		4		4	
Elwha	6		3		3	
Green	6		1		2	
Hamma Hamma	6		4		4	
Hoh	6		6		5	

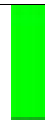
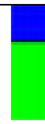
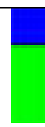
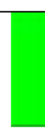
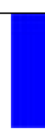
Klickitat	6		3		2	
Methow	6		3		3	
Snake	6		3		3	
Yakima	6		4		4	
Kalama	5		2		2	
Nisqually	5		3		3	
Wind	5		2		2	
Blackjack	4		3		3	
Cedar	4		3		2	
Dewatto	4		2		1	
Grays	4		2		2	

Hammersley: John, Mill	4		3		2	
Hammersley: Goldsborough, Shelton	4		3		3	
Hoko	4		3		3	
Naselle	4		2		1	
North	4		3		3	
North Lake Washington tribs	4		2		1	
Ozette	4		3		4	
Quilcene	4		0		1	
Rocky, Coulter, Sherwood	4		3		3	
Samish	4		2		1	
Skookum	4		3		2	

Sooes	4		1		2	
Tahuya	4		3		1	
Washougal	4		2		2	
White Salmon	4		2		1	
Willapa	4		2		2	
Abernathy	3		1		1	
Anderson	3		2		1	
Bear	3		2		2	
Big Beef	3		1		0	
Burley, Minter, Purdy	3		1		1	
Chambers	3		2		2	

Clallam	3		2		1	
Coweeman	3		2		2	
Dakota	3		2		1	
Deep/Twin	3		2		1	
Dyes/Liberty	3		1		2	
Elochoman	3		1		1	
Finch	3		2		1	
Germany	3		1		1	
Gig Harbor/Olalla	3		1		1	
Hamilton	3		1		2	
Issaquah	3		2		1	

Jimmycomelately	3		2		2	
Kennedy	3		2		2	
Lilliwaup	3		1		1	
Lyre	3		2		1	
Macdonald	3		2		1	
Mill (Lower Col)	3		1		1	
Morse	3		2		1	
Nemah	3		2		2	
Okanogan	3		2		1	
Palix	3		2		2	
Perry, Swift, McLane	3		2		2	

Pysht	3		2		1	
Sekiu, Sail	3		3		2	
Sinclair Inlet Tribs	3		2		2	
Skamokawa	3		1		1	
Snow, Salmon	3		1		2	
Union	3		1		1	
California, Sequalicum, Whatcom, Padden, Chuckanut, Oyster, Colony	2		1		0	
Chimicum	2		1		1	
Clark, Hill, Sund, Miller (Hood Canal)	2		1		0	
Copalis	2		2		1	
Deschutes	2		2		0	

Eagle, Jorstad, Little Gamble, Lake, Kinman	2		1		0	
Entiat	2		0		0	
Goodman	2		2		2	
Hardy	2		0		1	
Henderson Inlet Tribs	2		1		0	
Hylebos	2		0		0	
Kalaloch	2		2		2	
Moclips	2		1		1	
Mosquito	2		2		2	
Raft	2		1		0	
Rendsland, Caldervin, Twana, Alderbrook, Mission	2		1		0	

Salmon (Lower Col.)	2		1		1	
Salt	2		2		1	
Stavis, Seabeck	2		1		0	
Sumas, Chilliwack	2		2		2	
Waatch	2		1		1	
Walla Walla	2		0		0	
Cascade Cr. (Orcas)	1		1		0	
Duncan	1		0		0	
Ennis	1		1		0	
Jim, Joe	1		1		1	
Johnson, Glerin	1		1		1	

Lake Chelan	1		1		0	
Niawiakum	1		0		0	
Rock (Mid-Columbia)	1		1		1	
Siebert	1		0		0	
Spencer, Jackson, Donovan, Tarboo	1		0		0	
Whidbey/Maxwelton	1		1		0	
Whiskey, Colville, Field	1		1		1	

Figure 2. Total number of Washington salmon and steelhead stocks by drainage (raw data from WDFW 2002). Increased color intensity indicates a greater number of stocks in that basin.

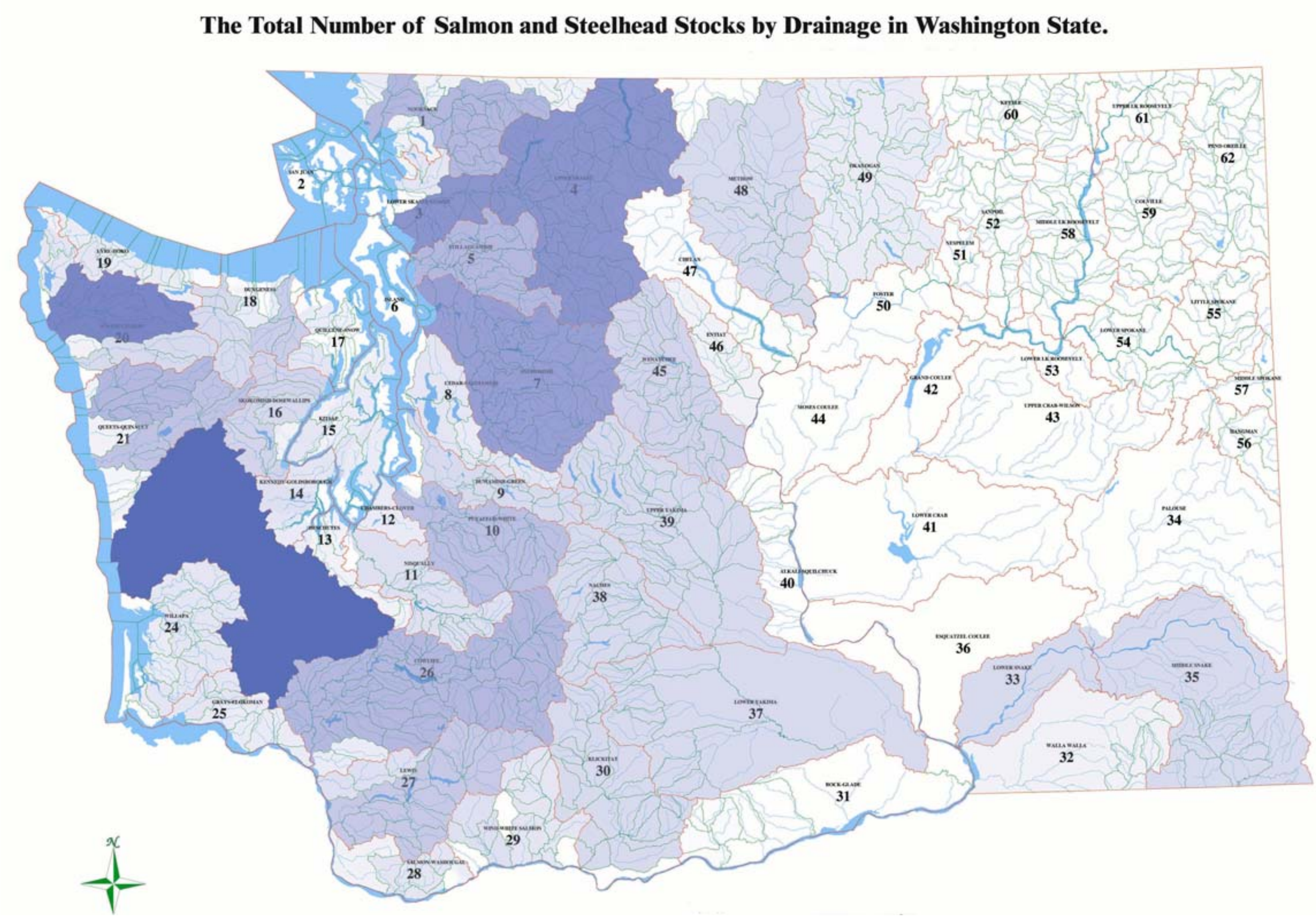


Figure 3. Total number of wild (naturally spawning) Washington salmon and steelhead stocks by drainage (raw data from WDFW 2002). Increased color intensity indicates a greater number of stocks in that basin.

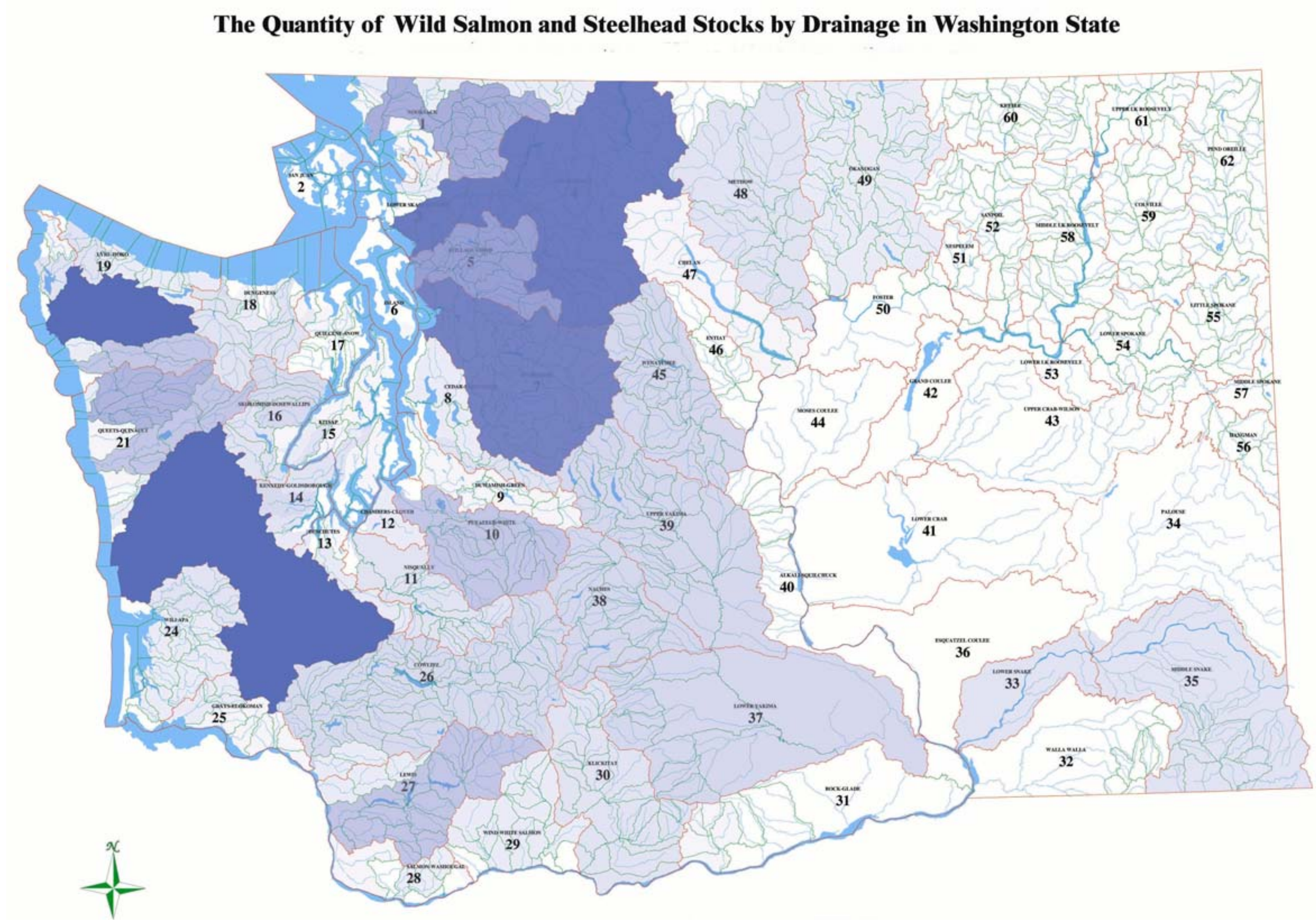
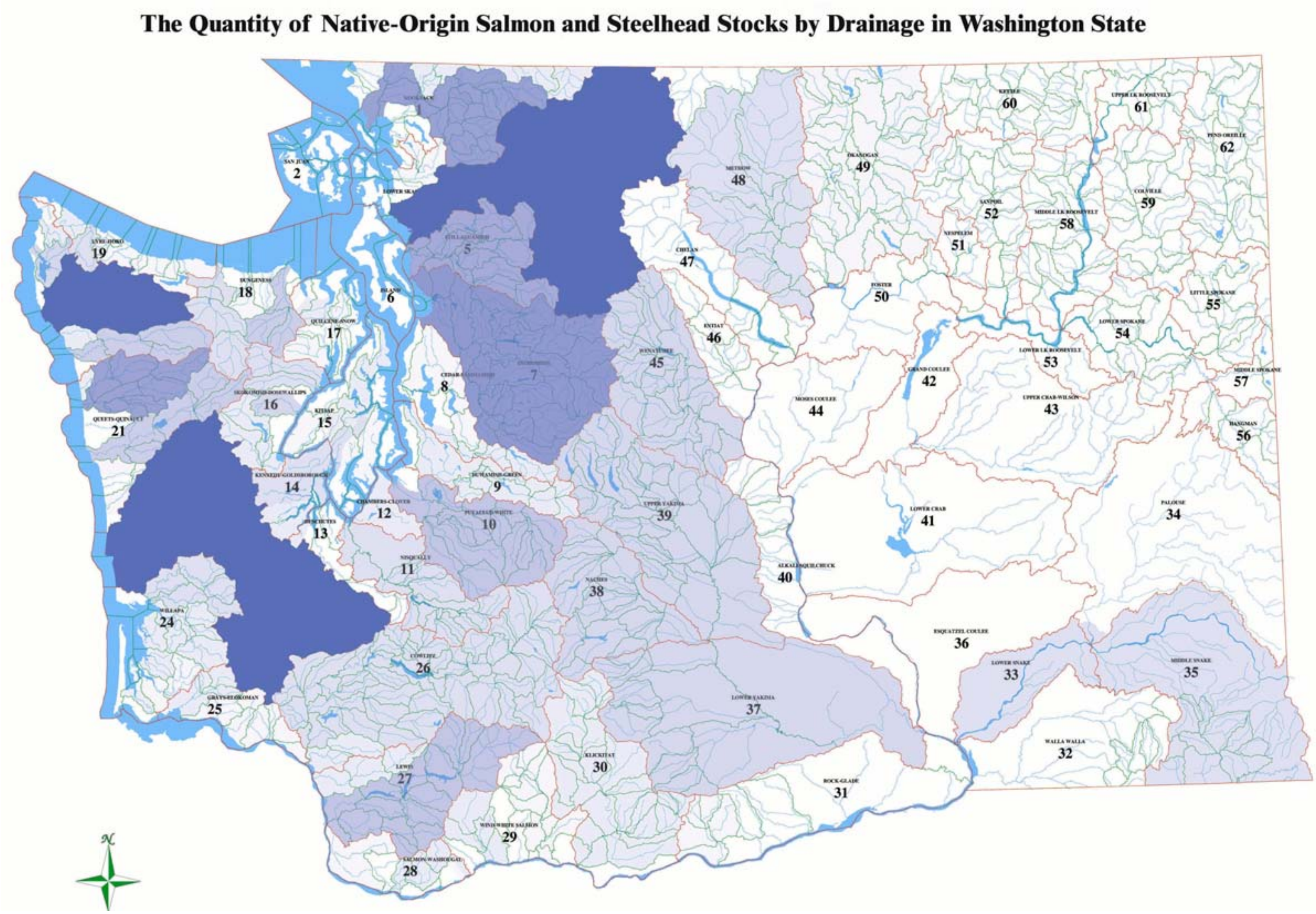


Figure 4. Total number of native-origin Washington salmon and steelhead stocks by drainage (raw data from WDFW 2002). Increased color intensity indicates a greater number of stocks in that basin.



Chinook Salmon Abundance by Basin

As stated earlier, it is important to also examine the relative abundance of naturally produced (wild) salmonids by basin regardless of stock. However, estimates across the entire state are not available for some species, and the accuracy varies by species and by area. Because of this, chinook abundance is used with the caveat that this will underestimate the importance of drainages that produce little to no chinook, but do produce considerable amounts of chum, coho, or other species. This limitation should be considered when reading this section. Even for chinook salmon, accurate estimates of escapement or run size are not available for all of the drainages, and the quality of the estimates varies widely. Because this analysis is focusing on habitat conditions, estimates of wild chinook were used as they spend their entire life history in the natural environment and are better indicators of habitat health.

The primary data source for the relative abundance of wild chinook salmon was the NMFS Chinook Status Review which included 5 year geometric means of escapement (Meyers et al. 1998). The estimates for the wild production from the Yakima and Snake drainages came from other sources that provided a better separation of wild versus hatchery stocks (Fast et al. 1989, 1991). Run size information, while a better indicator, was not used because the data were not separated adequately by drainage. Escapement goals were considered because they are often based upon habitat quantity and better represent potential production than escapement estimates. However, escapement goals have not been developed for many of the drainages, especially in the middle and upper Columbia River basins.

When sorted by wild/natural chinook escapement abundance, many of the same drainages that have the greatest number of stocks, also have the greatest abundance of chinook salmon spawners. These include the Chehalis, Lewis, Snake, Skagit, Wenatchee, Quillayute, Snohomish, and Green Basins (Table 2). Within this group, the Wenatchee and Green Rivers had lesser numbers of stocks than the others, but are important salmon producers when abundance is considered, especially for chinook salmon. It should be noted that these are known underestimates in the Chehalis, Snake, and Quillayute drainages because mixed hatchery/wild units were not included, and data were not available to separate hatchery from natural production.

Moderate producers of wild chinook salmon based upon these estimates include Yakima, Hoh, Queets, Quinault, Kalama, Washougal, Cowlitz, Puyallup, North, Elwha, and Okanogan drainages (Table 2). Chinook spawners are likely greatly underestimated in the Puyallup Basin due to water turbidity preventing accurate counts, and are somewhat underestimated in the Yakima, Quinault, and Cowlitz basins due to the exclusion of mixed units and the inability to distinguish hatchery from natural production in these basins.

A few basins that rated well for the number of stocks did not rank high for chinook abundance. These include the Nooksack, Dosewallips, Duckabush, and Hamma Hamma Rivers. This is due to several reasons. The chinook stocks in the Nooksack basin are important stocks for genetic diversity, but the wild production has declined to critical levels. The Dosewallips, Duckabush, and Hamma Hamma Rivers are considered to be chinook-producing rivers, but the abundance is very low for unknown reasons. These basins are important for other species such as pink and chum production.

As another partial comparison, natural coho escapement goals are provided where known. Escapement goals are generally based upon available habitat and are good measurements of a basin's potential production for that species. In order of abundance, the areas with high escapement goals for natural coho are the Snohomish, Chehalis, Skagit, Hood Canal, Stillaguamish, Quillayute, Queets, and Hoh Basins. These generally correspond with the abundance for chinook salmon, considering that out of 161 drainages, the same basins generally rate towards the top. However, the Hood Canal streams are an exception. Many of these streams are smaller than the large basins with abundant stocks and chinook production, yet together they comprise the state's fourth largest natural coho escapement goal. They, among other smaller streams, are also important producers of chum and pink salmon, which are not included in the abundance estimates (but are included in the stock number estimates).

Table 2. Recent average natural (wild) chinook escapement levels. See text for data sources.

Chinook Stock	Recent Mean Escapement
Chehalis*	20817
Lewis	10892
Snake*	10320
Skagit	8735
Wenatchee	7340
Quillayute*	6854
Snohomish	6348
Green	5053
Yakima*	4389
Hoh	4297
Queets	4137
Quinault*	3881
Kalama	3732
Washougal	3184
Cowlitz*	3034
Puyallup	2991
North	2223
Elwha	1768
Okanogan	1486
Stillaguamish*	953
Skokomish	937
Methow	877
Hoko	800
Nisqually	699
Coweeman	679
Wind	533
Abernathy	418
Cedar	377
Nooksack*	317
Elochoman	317
Klickitat*	214
Germany	183
Skamokawa	148
N. Lake WA Tribs	145
White Salmon*	127
Mill	117
Dungeness	105
Entiat	89
Dosewallips	82
Grays	39
Hamma Hamma	32
Duckabush	7
Willapa*	Not Available

Stocks and Abundance by Region

The Governor's Salmon Recovery Office, in coordination with regional planning groups, has subdivided the state into six regions with further subdivision of Puget Sound into three sub-regions (Governor's Salmon Recovery Office 2003). The stock and abundance results are sorted by these regions and discussed below.

<u>Puget Sound Salmon and Steelhead Stocks and Abundance</u>

The Puget Sound region comprises all watersheds draining into Puget Sound, bounded by the Nooksack to the north, and including Hood Canal streams and the streams draining into the Strait of Juan de Fuca as far west as the Elwha River. The region is subdivided into three areas: North Puget Sound, Central Puget Sound, and Southwest Puget Sound.

North Puget Sound

North Puget Sound includes the streams in Whatcom, San Juan, Skagit, and Island Counties (Governor's Salmon Recovery Office 2003). The WRIAs include Nooksack (1), San Juan (2), Lower Skagit (3), Upper Skagit (4), and Island (6). The tribes involved in this sub-region are the Lummi, Nooksack, Stillaguamish, Samish, Sauk-Suiattle, and Upper Skagit tribes.

The North Puget Sound sub-region produces 44 stocks, 77% of which are wild spawning stocks and 70% are native-origin stocks (Table 3). The most common stock status designation is an "unknown" status, and a data need is to monitor population abundance and trends for these unknown stocks, especially in the larger basins such as the Nooksack and Skagit.

Central Puget Sound

Central Puget Sound includes all or part of Snohomish, King, Pierce, and Thurston Counties (Governor's Salmon Recovery Office 2003). The WRIAs include Stillaguamish (5), Snohomish (7), Cedar/Sammamish (8), Green/Duwamish (9), Puyallup/White (10), Nisqually (11), and Chambers/Clover (12). The tribes involved in this sub-region are the Stillaguamish, Tulalip, Muckleshoot, Puyallup, and Nisqually tribes.

This sub-region covers a broader area and has a correspondingly larger number of stocks (67). Most of the different stocks are found in three basins, the Stillaguamish, Snohomish, and Puyallup (Table 3). Within the entire sub-region, 67% of the stocks are wild and 55% are native-origin. However, there are differences between the northern section of this sub-region compared to the remaining area. Within the Stillaguamish and Snohomish, 90% of the stocks are wild and 69% are native-origin (Table 3). From Lake Washington through the Nisqually Basins, 50% of the stocks are wild and 45% are native-origin.

Most (52%) of the stocks in the Stillaguamish/Snohomish Basins are healthy, but a considerable percentage (31%) is depressed or critical (Table 3). However, a greater percentage (47%) of unhealthy stocks are found from Lake Washington through the

Nisqually Basins. This area has 37% healthy stocks when all types of stocks are considered. When only wild or native stocks are analyzed, a much higher percentage of unhealthy stocks are found in the Lake Washington to Nisqually area. For wild stocks, 32% are healthy and 63% are not healthy, and this is the greatest percentage of unhealthy wild stocks in all of Puget Sound and the Coast. For native stocks, only 29% are healthy with 64% depressed/critical/extinct (Table 2). The Stillaguamish and Snohomish Basins do not show the divergent stock health percentages for wild and native stocks as they have similar percentages of stock status between total, native, and wild stocks.

Southwest Puget Sound

The Southwest Puget Sound area includes all or part of Thurston, Pierce, Kitsap, Mason, Jefferson, and Clallam Counties, encompassing the eastern Strait of Juan de Fuca streams along with Hood Canal and south west Puget Sound (Governor's Salmon Recovery Office 2003). The WRIAs consist of all or part of Deschutes (13), Kennedy-Goldsborough (14), Kitsap (15), Skokomish/Dosewallips (16), Quilcene/Snow (17), and Elwha/Dungeness (18) drainages. The tribes involved in this sub-region are the Squaxin Island, Skokomish, Suquamish, Jamestown S' Klallam, Port Gamble S' Klallam, and the Lower Elwha S' Klallam tribes.

When streams in southwest Puget Sound excluding Hood Canal and the Strait are examined separately, most (64%) of the total stocks are healthy with only 5% not healthy (Figure 5). The wild and native-origin stocks in this area also fare well with less than 10% of depressed/critical/extinct stocks (Figures 6 and 7). The Kitsap, Mason, and Thurston County streams have the highest percentage of healthy total and native stocks in the entire Puget Sound and the Columbia River regions (Figures 5 and 7). Only stocks in the coastal streams have a greater percentage of healthy stocks.

Hood Canal stocks consist of 46% unhealthy and 40% healthy total stocks, and wild stocks have an even better status with 58% healthy and 35% not healthy. However, native stocks are not as robust with 68% depressed/critical/or recently extinct (Figures 5-7).

Most (58%) of the total stocks in the eastern Strait and Port Townsend areas are depressed, critical, or recently extinct (Figure 5). This area has the greatest percentage of unhealthy total stocks outside of the Columbia River Basin. Half of its wild and native-origin stocks are also unhealthy with a large component of unknown stocks in these categories (Figures 6 and 7). Given the high percentage of unhealthy stocks, monitoring of the unknown status stocks should be a priority data need. Many of the unknown status stocks are steelhead, coho, and chum populations.

<u>Coastal Salmon and Steelhead Stocks and Abundance</u>

The coastal streams are Washington State streams north of the Columbia River that drain into the Pacific Ocean. It also includes the watersheds that drain into the western Strait of Juan de Fuca. In this analysis, the north coastal and Strait streams are separated from the lower coastal streams due to environmental differences such as precipitation, landform, and to some degree, land use.

North Coast Streams

The North Coast area includes streams in the western Strait of Juan de Fuca and streams that drain north of the Chehalis River. These include the WRIAs of Lyre-Hoko (19), Soleduck-Hoh (20), and Queets-Quinault (21). For total stocks, this area has a low percentage (7%) of depressed/critical/extinct stocks, but a considerable percentage (47%) of unknown status stocks (Figure 5). A similar pattern exists for its wild and native stocks, and this represents a data need, especially in the Ozette and Sooes drainages where all stocks are listed as having an unknown status (Figures 6 and 7).

South Coast Streams

The South Coast area includes streams within the Chehalis and Willapa WRIAs such as Lower Chehalis (22), Upper Chehalis (23), and Willapa (24). The Chehalis also includes the Humptulips and South Bay streams because they drain into a single well-defined estuary and fish mixing from these different areas during various life history stages is likely.

The South Coast streams have the greatest percentage (66%) of known healthy total and native-origin stocks within the entire State of Washington, but 20% of total and 24% of native stocks are unhealthy; a greater level than seen in the North Coast and Southwest Puget Sound. Wild stocks are generally healthy (51%), but a higher percentage is not healthy (26%) compared to total and native stocks in the same area (Figures 5-7).

Lower Columbia Salmon and Steelhead Stocks and Abundance

The lower Columbia region comprises the WRIAs of the Chinook and Wallicut Rivers (part of WRIA 24), Grays-Elokoman (25), Cowlitz (26), Lewis (27), Salmon-Washougal (28), and Wind/White Salmon (29). However, no salmon stocks were included in the SaSI report for the Chinook and Wallicut Rivers, probably because of uncertainty that salmon in these areas are distinct self-sustaining stocks (WDFW 2002).

Many stocks of salmon and steelhead have become extinct within the Columbia River Basin, and these extinctions are not included in the depressed/critical/recently extinct category. Because of this, the stock statuses for all of the Columbia River drainages are biased towards a greater stock health than really exists. In spite of the positive bias, stock health is generally poor throughout the Columbia River.

In the Lower Columbia, more salmon and steelhead stocks are described as depressed or critical than any other classification with very low (15% or less) percentages of healthy wild, native, and total stocks (Figures 5-7). Most of the unknown status stocks in the total stock category are coho salmon (WDFW 2002), which are a mix of hatchery and wild production and are difficult to separate.

Middle Columbia Salmon and Steelhead Stocks and Abundance

The middle Columbia region extends from the Klickitat (30) and Rock-Glade (31) WRIAs to the lower Yakima (37), Naches (38), Upper Yakima (39), and Alkali-Squilchuck (40) WRIAs.

This region has a mix of stock status for the total and wild stock categories with a higher percentage (57%) of unhealthy stocks in the native-origin type (Figures 5-7). However, this is a positively biased stock status summary because extinctions of stocks and species have occurred and were not included in the SaSI report upon which this summary is based. Also, the mainstem Columbia River chinook stocks are not included in this summary because the Habitat Limiting Factors program examined only the drainages to the mainstem Columbia. The mainstem Columbia River is highly regulated by dam operations and the legislation creating the Habitat Limiting Factors Program specifically excluded analysis from dam (hydro) impacts.

The Yakima River Basin is the largest basin in this area and currently supports natural production of spring chinook, fall chinook, bull trout, summer steelhead, and coho. The coho have naturalized from hatchery plants. From 1982 to 2000, spring chinook escapement averaged 3591 fish (Haring 2001). Fall chinook mean 3159 from 1988 to 1992. Extirpated stocks include native coho, Yakima sockeye, and Yakima summer chinook. Since 1989, steelhead abundance has fluctuated around 1000 fish per year except for 1992. Summer steelhead and bull trout are on the Endangered Species List as threatened (Busby 1996; U.S. Fish Wildlife Service 1999). Thirteen separate bull trout populations have been identified in the Yakima Basin; no anadromous char are known (USFWS 2001 draft).

Upper Columbia Salmon and Steelhead Stocks and Abundance

The upper Columbia region includes the WRIAs of Moses Coulee (44), Wenatchee (45), Entiat (46), Methow (48), Okanogan (49), and Foster Creek (50). This region is the second worst region for salmon and steelhead stock health in Washington State. All of the native-origin stocks in this region are not healthy, and nearly all of the total and wild stocks are not healthy (Figures 5-7). Even as poor as the current stock statuses are, this summary is positively biased because extinctions of stocks and species have occurred and were not included in the SaSI report upon which this summary is based.

Snake River Salmon and Steelhead Stocks and Abundance

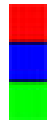
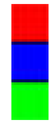
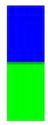
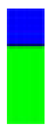
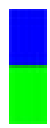
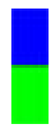
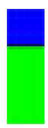
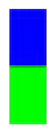
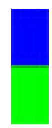
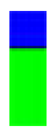
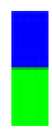
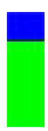
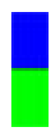
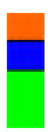
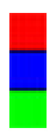
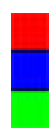
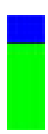
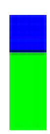
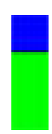
The Snake River area includes the Washington State portion of the Snake River and its tributaries. It also includes the Walla Walla drainage, which is independent of the Snake River. At the time of the last SaSI update, this region had the lowest level of healthy stocks in Washington State. All of the native-origin and wild stocks in this region are not healthy, and nearly all of the total stocks are not healthy (Figures 5-7). This is a positively biased stock status summary because extinctions of stocks and species have occurred and were not included in the SaSI report upon which this summary is based.

However in recent years, adult returns of steelhead have rebounded to higher levels in the Snake Region and are supporting local fisheries and hatchery supplementation needs. Asotin Creek wild steelhead returns are currently above TRT viability levels without hatchery intervention, and spring chinook adult spawners throughout the region have increased in abundance (Glen Mendel, WDFW, personal communication. This analysis did not include these recent increases because of time and budget constraints, but readers are encouraged to review the most recent information at: http://www.snakeriverboard.org/index.php.

Table 3. Number of total, wild, and native salmon and steelhead stocks by drainage sorted by region with the percentage of healthy stocks (green), unknown status stocks (blue), and depressed, critical, or extinct stocks (red) shown in bars (data from WDFW 2002).

Drainage by Region	**Total Number of Stocks**	**Stock Health: Total Stocks**	**Number of Wild Stocks**	**Stock Health: Wild Stocks**	**Number of Native Stocks**	**Stock Health: Native Stocks**
North Puget Sound						
Cascade Cr. (Orcas)	1		1		0	
Dakota	3		2		1	
Sumas, Chilliwack	2		2		2	
Nooksack	12		9		10	
California, Sequalicum, Whatcom, Padden, Chuckanut, Oyster, Colony	2		1		0	
Samish	4		2		1	

Skagit	19		16		17	
Whidbey/Maxwelton	1		1		0	
Central Puget Sound:						
Stillaguamish	12		11		9	
Snohomish	17		15		11	
North Lake Washington tribs	4		2		1	
Issaquah	3		2		1	
Cedar	4		3		2	
Green	6		1		2	
Hylebos	2		0		0	
Puyallup	11		6		6	

Chambers	3		2		2	
Nisqually	5		3		3	
Southwest Puget Sound:						
Henderson Inlet Tribs	2		1		0	
Deschutes	2		2		0	
Perry, Swift, McLane	3		2		2	
Kennedy	3		2		2	
Skookum	4		3		2	
Hammersley: John, Mill	4		3		2	
Hammersley: Goldsborough, Shelton	4		3		3	
Rocky, Coulter, Sherwood	4		3		3	

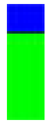
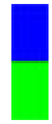
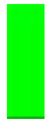
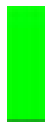
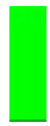
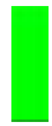
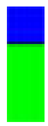
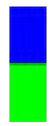
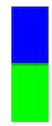
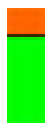
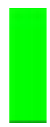
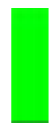
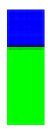
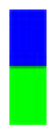
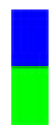
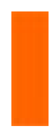
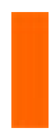
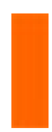
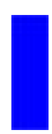
Burley, Minter, Purdy	3		1		1	
Gig Harbor/Olalla	3		1		1	
Blackjack	4		3		3	
Sinclair Inlet Tribs	3		2		2	
Dyes/Liberty	3		1		2	
Hood Canal:						
Union	3		1		1	
Tahuya	4		3		1	
Rendsland, Caldervin, Twana, Alderbrook, Mission	2		1		0	
Dewatto	4		2		1	
Anderson	3		2		1	
Stavis, Seabeck	2		1		0	

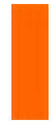
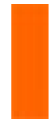
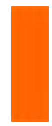
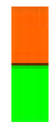
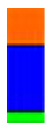
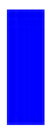
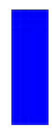
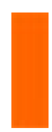
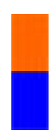
Big Beef	3		1		0	
Skokomish	7		3		2	
Finch	3		2		1	
Clark, Hill, Sund, Miller (Hood Canal)	2		1		0	
Lilliwaup	3		1		1	
Eagle, Jorstad, Little Gamble, Lake, Kinman	2		1		0	
Hamma Hamma	6		4		4	
Duckabush	7		4		3	
Dosewallips	7		4		3	
Spencer, Jackson, Donovan, Tarboo	1		0		0	
Quilcene	4		0		1	

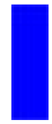
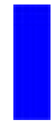
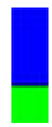
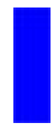
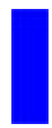
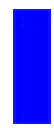
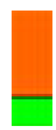
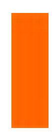
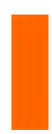
Chimicum	2		1		1	
Snow, Salmon	3		1		2	
Jimmycomelately	3		2		2	
Johnson, Glerin	1		1		1	
Dungeness	8		3		5	
Macdonald	3		2		1	
Siebert	1		0		0	
Morse	3		2		1	
Ennis	1		1		0	
Elwha	6		3		3	
Western Straits:						
Salt	2		2		1	

Whiskey, Colville, Field	1		1		1	
Lyre	3		2		1	
Deep/Twin	3		2		1	
Jim, Joe	1		1		1	
Pysht	3		2		1	
Clallam	3		2		1	
Hoko	4		3		3	
Sekiu, Sail	3		3		2	
North Coast:						
Waatch	2		1		1	
Sooes	4		1		2	
Ozette	4		3		4	

Quillayute	22		18		17	
Goodman	2		2		2	
Mosquito	2		2		2	
Hoh	6		6		5	
Kalaloch	2		2		2	
Queets	12		8		10	
Raft	2		1		0	
Quinault	10		6		5	
Moclips	2		1		1	
Copalis	2		2		1	
South Coast:						
Chehalis	28		18		17	

North R. (Willapa)	4		3		3	
Willapa	4		2		2	
Niawiakum	1		0		0	
Palix	3		2		2	
Nemah	3		2		2	
Naselle	4		2		1	
Bear	3		2		2	
Lower Columbia:						
Grays	4		2		2	
Skamokawa	3		1		1	
Elochoman	3		1		1	
Mill (Lower Col)	3		1		1	

Abernathy	3		1		1	
Germany	3		1		1	
Cowlitz	12		4		3	
Coweeman	3		2		2	
Kalama	5		2		2	
Lewis	9		6		6	
Salmon (Lower Col.)	2		1		1	
Washougal	4		2		2	
Duncan	1		0		0	
Hardy	2		0		1	
Hamilton	3		1		2	

Wind	5		2		2	
White Salmon	4		2		1	
Mid-Columbia:						
Klickitat	6		3		2	
Rock (Mid-Columbia)	1		1		1	
Yakima	6		4		4	
Snake Region:						
Walla Walla	2		0		0	
Snake	6		3		3	
Upper Columbia:						
Wenatchee	7		4		4	
Entiat	2		0		0	

Lake Chelan	1		1		0	
Methow	6		3		3	
Okanogan	3		2		1	

Figure 5. Stock health by region based upon total number of stocks listed in WDFW 2002. "Not healthy" includes depressed, critical, and recently extinct. The "not healthy" category is under-represented in the Columbia Basin because extinct stocks in that region were not listed in the SaSI report although they were included for other regions when known.

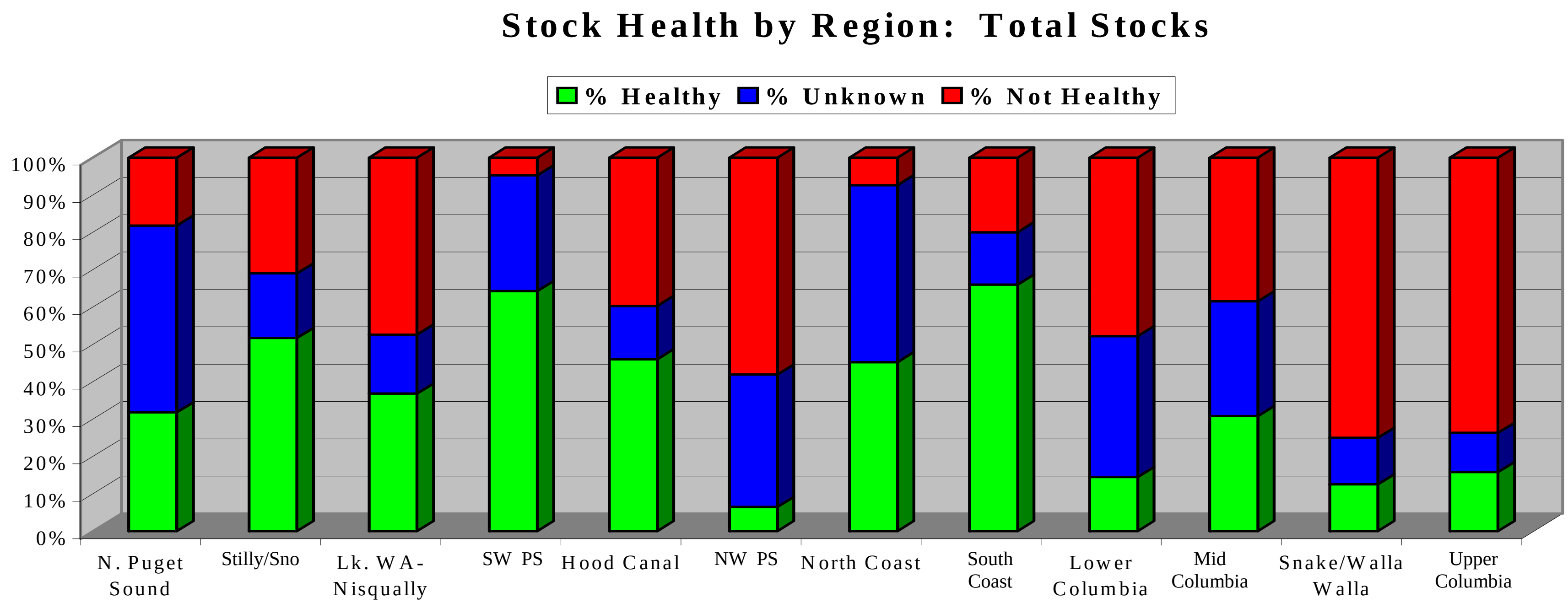


Figure 6. Stock health by region based upon the number of wild or naturally-spawning stocks listed in WDFW 2002. "Not healthy" includes depressed, critical, and recently extinct. The "not healthy" category is under-represented in the Columbia Basin because extinct stocks in that region were not listed in the SaSI report although they were included for other regions when known.

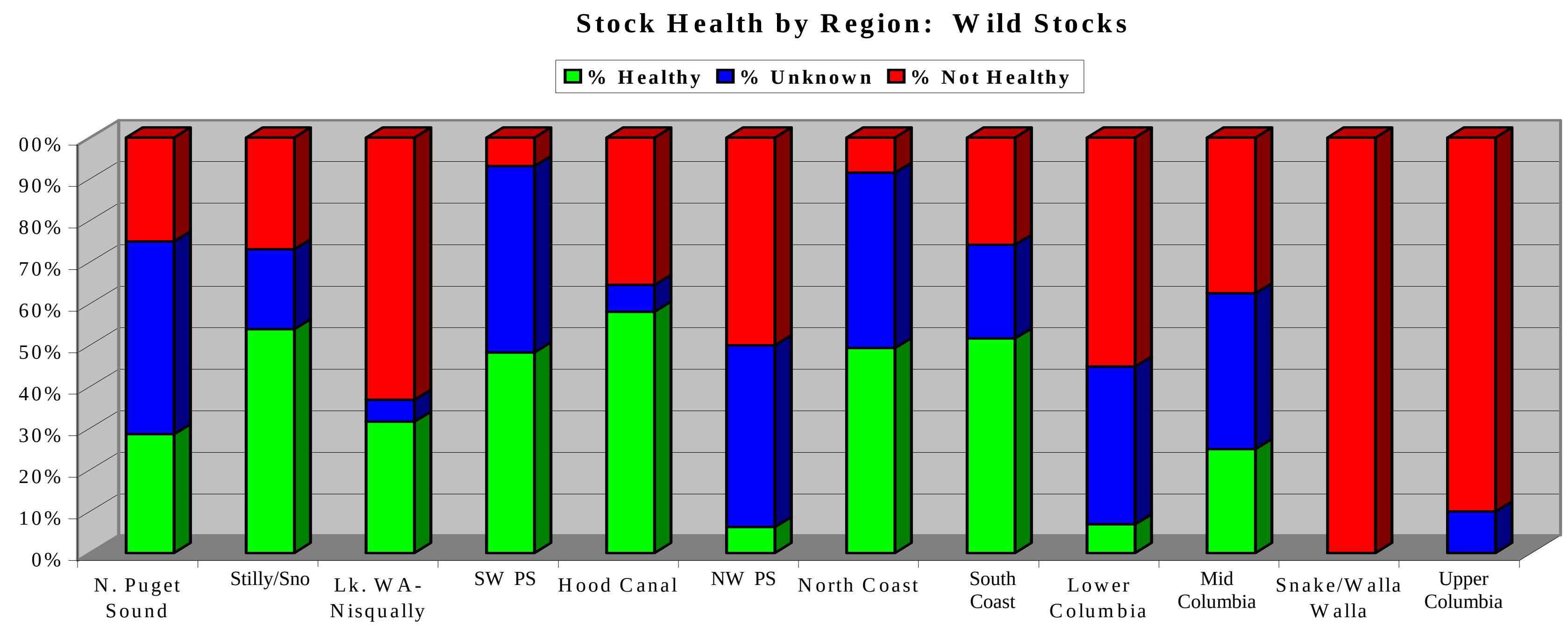
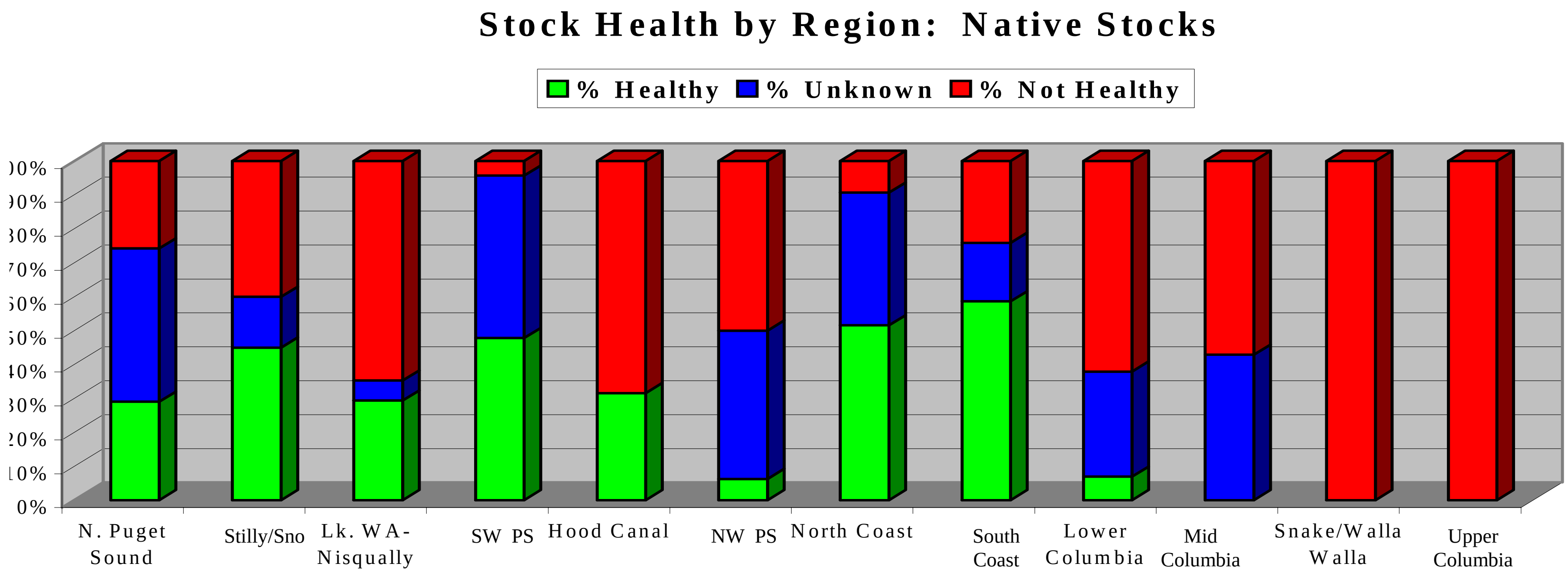


Figure 7. Stock health by region based upon total number of native-origin stocks listed in WDFW 2002. "Not healthy" includes depressed, critical, and recently extinct. The "not healthy" category is under-represented in the Columbia Basin because extinct stocks in that region were not listed in the SaSI report although they were included for other regions when known.



ECOREGIONS AND LAND USE IN WASHINGTON STATE

Introduction

Washington State has a wide variety of ecoregions that result in greatly different types of natural salmon habitat conditions. Ecoregions are areas of similar climate, physiography, oceanography, hydrology, vegetation, and fauna potential. There are several different classification schemes to describe ecoregions. The one chosen for this report is a slightly modified Lasmanis (1991) version based primarily upon geology. The geology with associated landforms defines the soils, vegetation, hydrology, and climate of a region, and these together determine faunal composition and typical human land use impacts. The U.S. Forest Service ecoregions classifications (Bailey 1994) result in similar divisions, and their information is incorporated in this report. Omernik and Gallant (1986) have also defined ecoregions, but their Level 3 divisions resulted in the merging of distinctly different types of watersheds such as the Willapa and Hoh, and their Level 4 divisions were too detailed for the purpose of this report.

Although ecoregion classifications are artificial designations, they are useful to enhance the understanding of habitat processes and to compare areas to one another. Although considerable differences can be found between ecoregions, they blend seamlessly into one another, and this results in similarities between regions, especially where one region joins another. In this report, the state is divided into eight regions with a ninth sub-region of Palouse in the Columbia Basin (Figure 8). The regions include the Olympic Mountains, Willapa Hills, Puget Lowland, Portland Basin, Cascade Mountains, Okanogan Highlands, Blue Mountains, and the Columbia Basin.

Along with the discussion of geology, vegetation, and hydrology for each region, it is important to consider the impact that humans have had on salmon habitat. Three broad classifications of human impacts will be reviewed in this chapter. These include human population density, land ownership, and land use categories. In a subsequent chapter, these categories will be related to the salmon habitat ratings designated in the limiting factors reports.

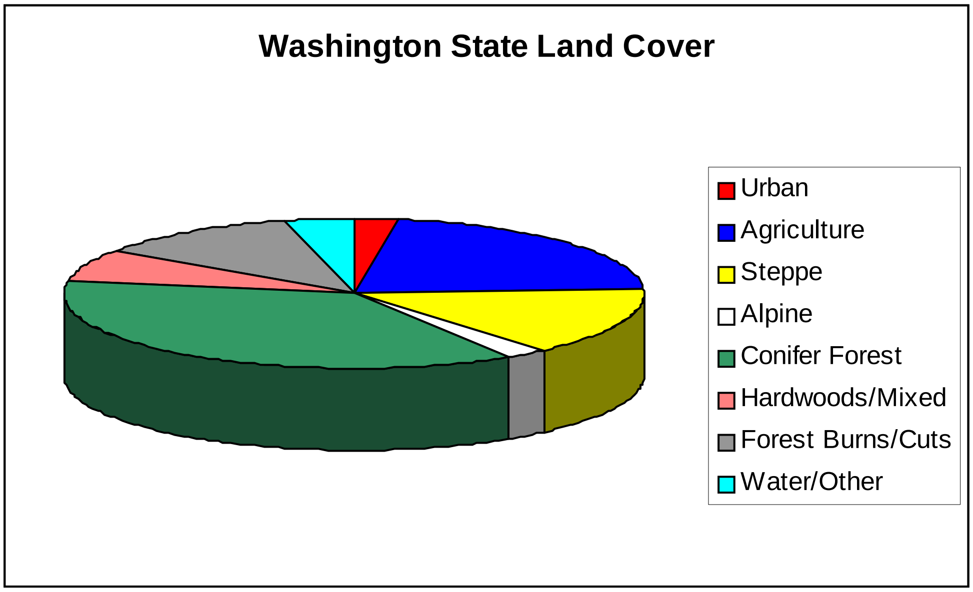
Figure 8. **Ecoregions within Washington State. Base map from U.S.G.S. (2003) and classification based upon the work of Lasmanis (1991).**

Statewide Statistics

Washington State is the 20th largest state in the nation with over 60% of its land in private ownership (La Tourrette and Luscombe 2002). Nearly 30% of its land is in federal ownership (Carpenter and Provorse 1998) with National Forest consisting of 22% and National Parks comprising only 4% (National Wilderness Institute 1995). Most of these federal land ownerships are located at higher elevations. State ownership is relatively small with Washington State Department of Natural Resources (DNR) owning about 7% of the land, most in uplands (La Tourrette and Luscombe 2002).

Even though a significant amount of land is federally owned, Washington is a relatively populous state. It ranks 15th in the nation for human population. Persons per square mile is 88.6 compared to a national average of 79.6 as estimated in the year 2000 (U.S. Census Bureau 2000). Most of the population in Washington State lives in the Puget Lowlands Region, and even though the state ranks 15th in population, urban land covers only 2.5% of the acreage in the state (Figure 9). The most common land cover is coniferous forest, comprising nearly 37% of the state, followed by agriculture at 21% (Cassidy et al. 1997).

Figure 9. Land cover by percentage of area in Washington State (data from Cassidy et al. 1997).



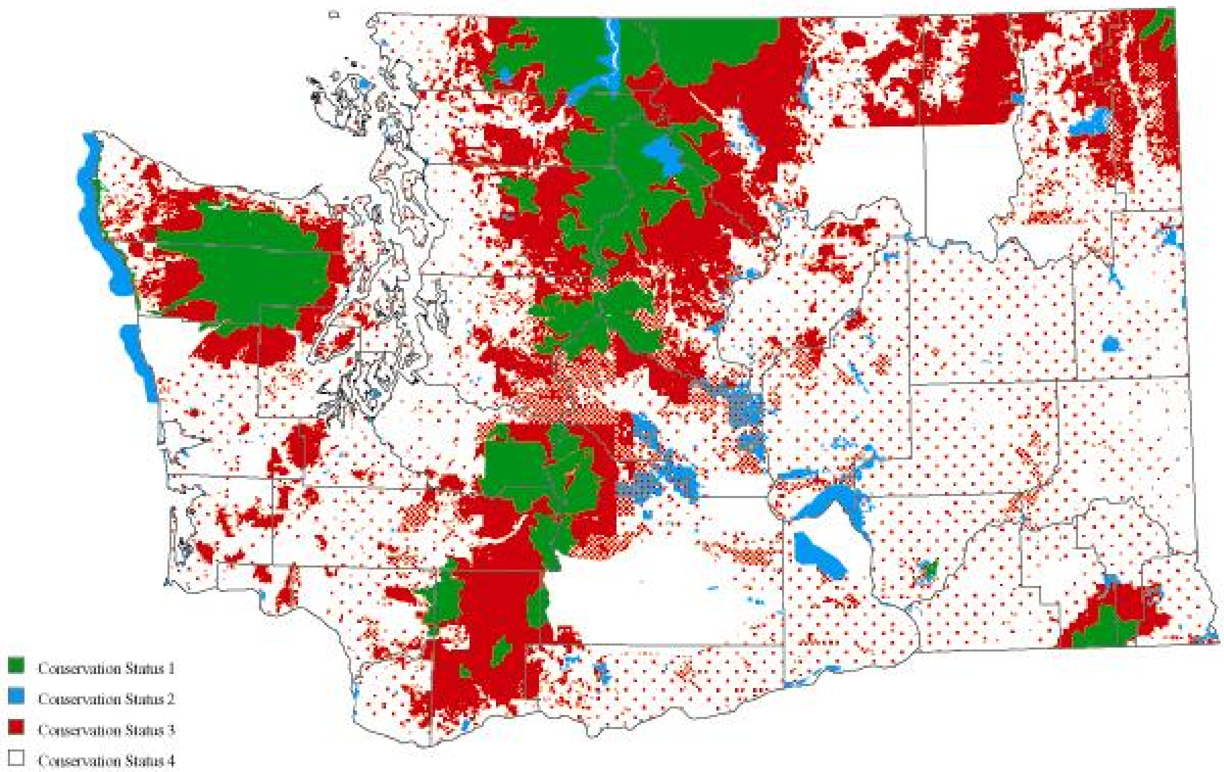
Cassidy et al. (1997) have previously analyzed the extent of land within Washington State protected by conservation areas, which was mapped (Figure 10) according to the following criteria:

- Status 1 represents permanent protection for a natural state, such as National Parks and Wilderness Areas.
- Status 2 represents lands that are primarily protected, but may have limited activities that lead to degradations, such as State Parks, Nature Conservancy lands, and Hanford.
- Status 3 includes lands that are protected from conversion, but subject to either localized intensive activities or broader less intense activities. Examples include Washington Department of Natural Resource Trust Lands, U.S. Forest Service multiple use lands, and municipal watersheds.
- Status 4 confers no protection, such as private lands.

About 12% of the land in Washington State is in either Status 1 or 2 categories, but these protected lands are primarily located in the mid to high elevations that preclude development (Cassidy et al. 1997). For example, only about 1% of the Puget Lowlands-Douglas fir zone is in Status 1 or 2 lands. Steppe habitat covers a relatively broad area (15%) of the state, but only about 6% of this land is in Status 1 or 2 protection (Figure 10).

Each of the ecoregions in Washington State is discussed below along with more detailed information regarding human population levels, land use, and land ownership. Specific habitat impacts are discussed later in the report in the appropriate habitat limiting factor category.

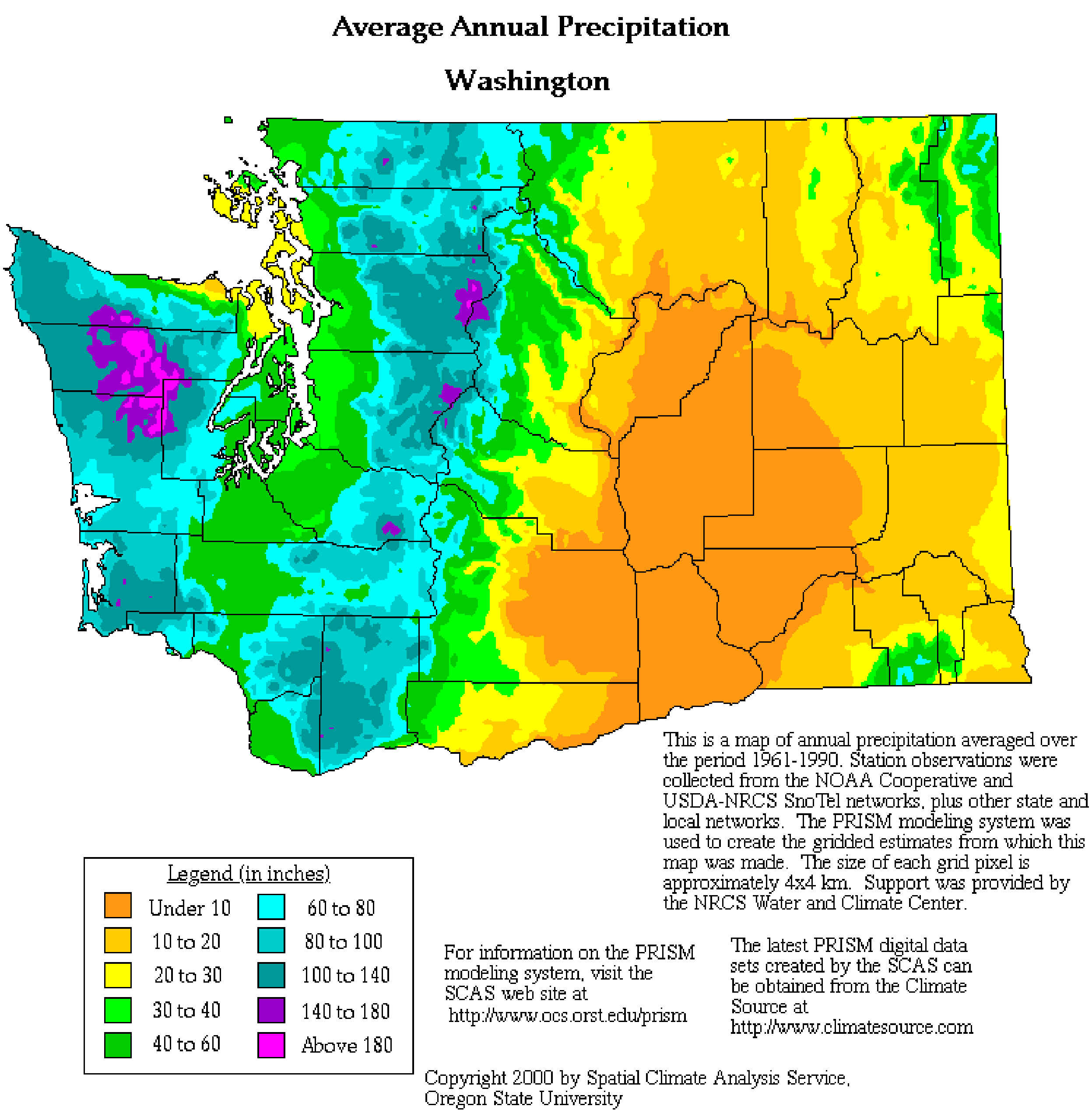
Figure 10. Conservation Status of lands in Washington State (map from Cassidy et al. 1997). The greatest protection is found in Status 1 and decreasing levels of protection in subsequent status levels with Status 4 having little to no protection for habitat conservation.



The Olympic Mountains Region

The Olympic Mountains region is characterized by deeply incised mountains with active erosion (Bailey 1994). Elevation extends to 8,000 feet with alpine meadows and barren areas at the highest elevations and cedar, hemlock, and Douglas fir along the slopes. The lower and middle elevations lie within a fog belt forested by spruce, cedar, and hemlock (Bailey 1994) comprising a temperate rainforest. Fog drip is an important source of moisture during the dry summer months. The average annual precipitation ranges from 60-240" per year, depending on location (Bailey 1994) (Figure 11). It is the wettest area within the 48 conterminous states (Carpenter and Provorse 1998). Most of the precipitation falls as rain from November through April with snow at high elevations. However in the rain shadow of the Olympic Mountains, precipitation is very low, averaging between 10 to 20" per year (Figure 11) (Oregon State University 2000). The average annual air temperature varies by location from 32-53^{o} F. Along the coast, intense winter storms of a 25 to 100 year frequency result in windthrow and landslide damage. Windthrow (blow down of a riparian buffer) is worsened by logging practices that do not leave adequate riparian buffers in areas exposed to high winds.

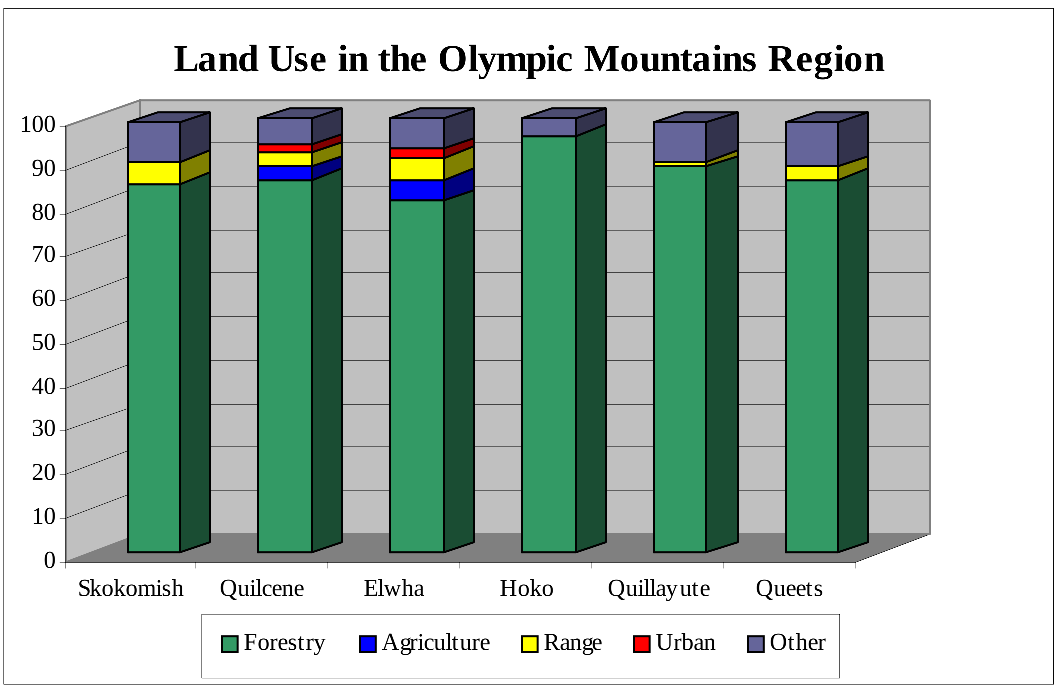
Figure 11. Average annual precipitation within the State of Washington (Oregon State University 2000, used with permission).



The precipitous Olympic Mountain Range coupled with abundant precipitation results in steep gradient, deeply incised streams with extensive dendritic drainages (Bailey 1994). The gradients drop before entering the generally limited estuaries within this region. The Strait of Juan de Fuca shoreline is comprised of mostly high bluffs, although the Dungeness River has the longest (5.5 miles) natural sandspit in the nation. The streams along the eastern side of the Olympic Mountains have much of their drainages within the Olympic Mountain Region, but their lower reaches are technically part of the Puget Sound Trough. These streams drain into the more extensive estuaries of Hood Canal.

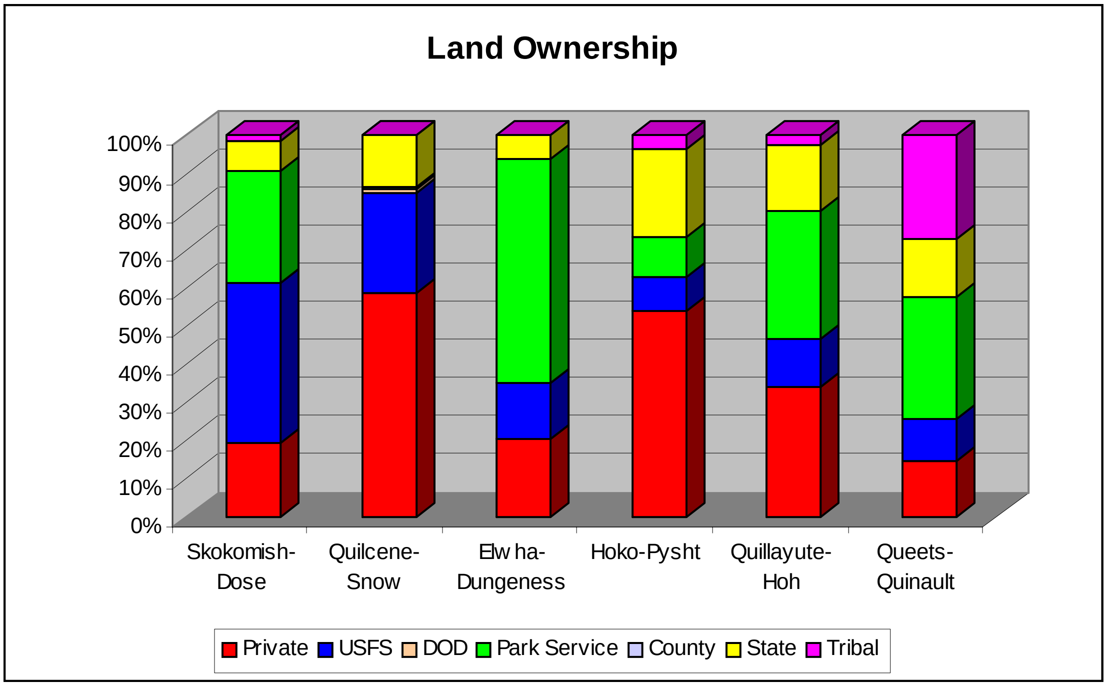
In this region, humans date back to at least 8,000 years ago, and were mostly hunters and gatherers until about 5,000 years ago when Native American villages were formed (Bailey 1994). However, land use impacts were insignificant until Euro-American development occurred in the mid-1800s. Most of the landscape changes began in the 1940s with industrial logging, road building, and limited valley farming (Bailey 1994). Currently, the primary land use in the Olympic Mountain region is forestry, which covers a range of 81 to 96% of the area within WRIAs 16-21 (Skokomish, Quilcene, Dungeness, Hoko, Quillayute, and Quinault basins) (Figure 12) (Hashim 2002). Important, but less common are fishing, hunting, and the gathering of specialty forestry products. This area supports small communities and recreation/tourism. This region has the largest wilderness area in the 48 contiguous states.

Figure 12. Land use in the Olympic Mountains Region (data from Hashim 2002).



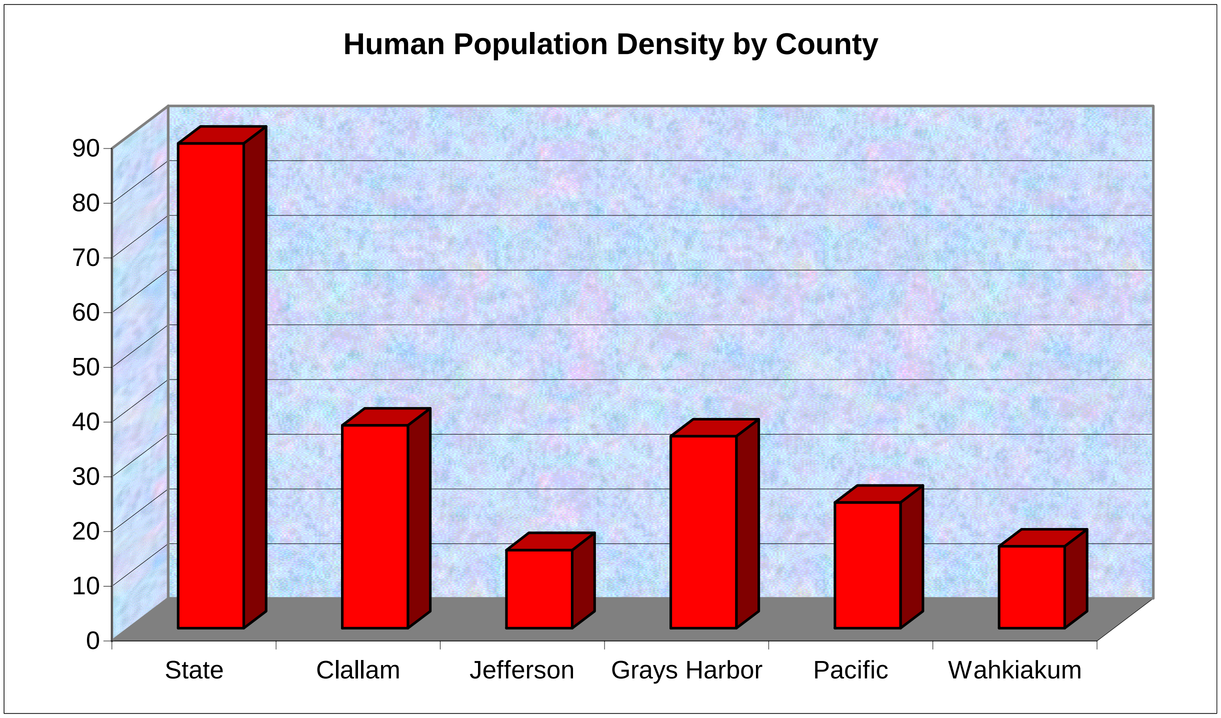
Land ownership varies with location. National Park Service lands provide the most protective habitat measures, and comprise about 59% of the Elwha-Dungeness WRIA (Figure 13) (Lunetta et al. 1997). Significant amounts of the Queets-Quinault, Quillayute-Hoh, and Skokomish-Dosewallips WRIAs are also in Park ownership. Private land ownership is greatest in the Quilcene-Snow and Hoko-Pysht WRIAs. Compared to other regions in the state, the Olympic Mountain Region has a generally higher overall percentage of land within National Parks than most other regions.

Figure 13. Land ownership by percentage of land area within the Olympic Mountains Region (data from Lunetta et al. 1997).



Human population density is low in this region. While the overall persons per square mile in Washington State is 88.6, Clallam County has a density of 37 and Jefferson has a density of 14 persons per square mile (Figure 14).

Figure 14. Human population density for the Olympic Mountain and Willapa Hills Regions compared to the state average (data from U.S. Census Bureau 2000).



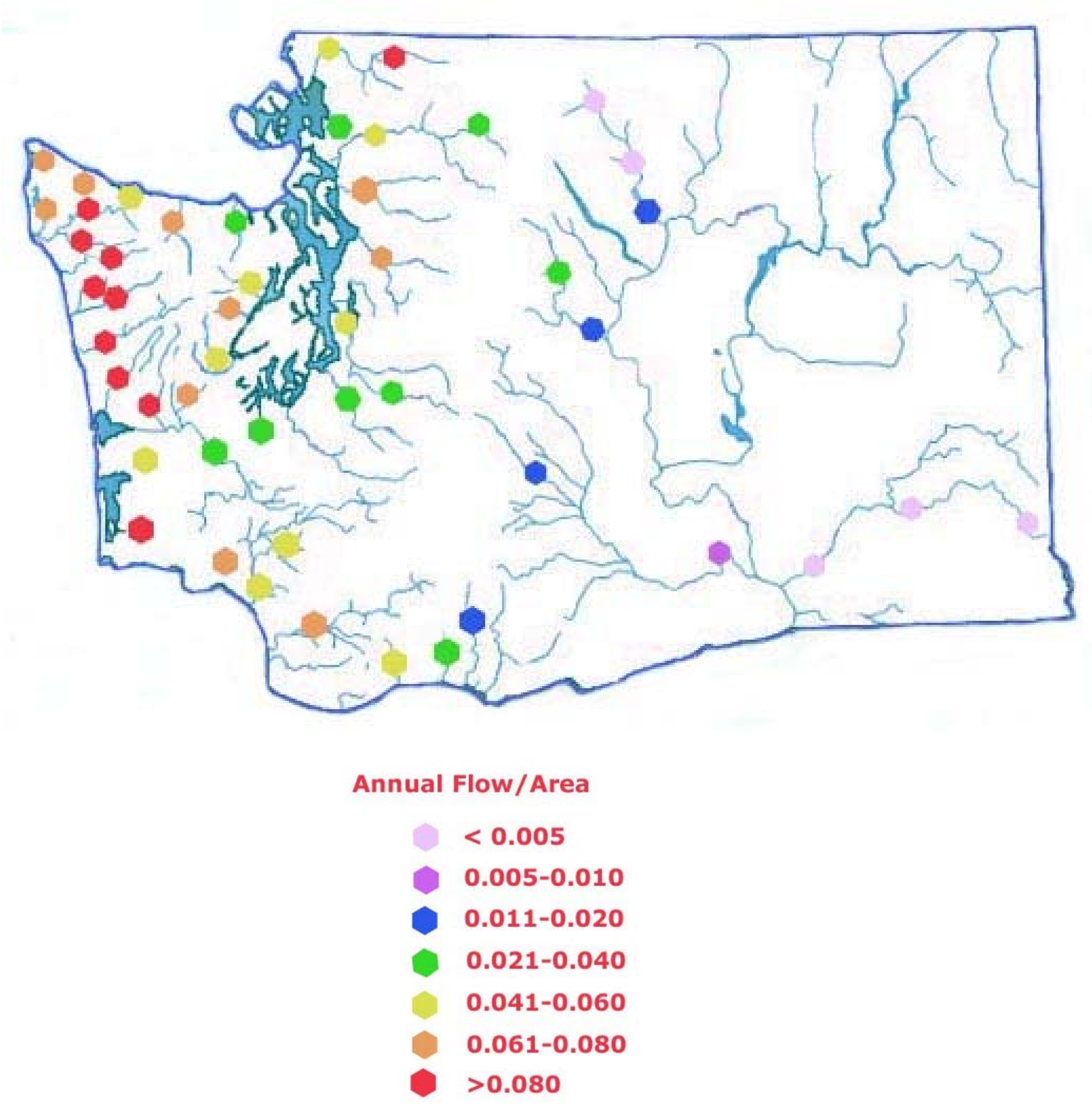
Many large river systems with dense stream networks exist in this region. The Watershed Resource Inventory Areas (WRIAs) in this region include most of 16 (southwest Hood Canal), the western part of 17 (Quilcene-Snow), 18 (Elwha-Dungeness), 19 (western Strait of Juan de Fuca), 20 (north Coast), 21 (Queets-Quinault), and the northern most part of 22 (lower Chehalis).

The largest is the Quillayute Basin, which covers roughly 468,000 acres. Other large drainages include the Queets (293,000 acres), Quinault (280,000 acres), and Elwha (206,000 acres) rivers along with moderate sized drainages such as the Skokomish (158,000), Dungeness (139,000), Hoh (135,000 acres), Hoko (45,000), and the smaller watersheds of the Duckabush, Dosewallips, Hamma Hamma, and Quilcene rivers. Numerous small independent streams are also located in this region. Nearly all of the streams in this area have their peak flow in December in most years (Weitkamp et al. 1995). The Dungeness and Hoh rivers have wide variations between low and high flows with the annual minimum monthly flow comprising less than 2% of the annual maximum monthly flow.

Within this region, average annual flow varies depending on location. Nearly all of the streams on the west side of the Olympia Mountains have the highest average flow in the state, an estimated >0.08 m^2 per second per km^2 (Figure 15) (Weitkamp et al. 1995 and Meyers et al. 1998). In contrast, the streams draining into the Strait of Juan de Fuca and Hood Canal have generally lower average flows ranging from 0.041 to 0.08, and the

Dungeness Basin has much lower flows of 0.021-0.04 (m^2 per second per km^2) (Weitkamp et al. 1995 and Meyers et al. 1998).

Figure 15. Annual stream flow per area by watershed (m^2 per second per km^2). Data from Weitkamp et al. 1995 and Meyers et al. 1998.

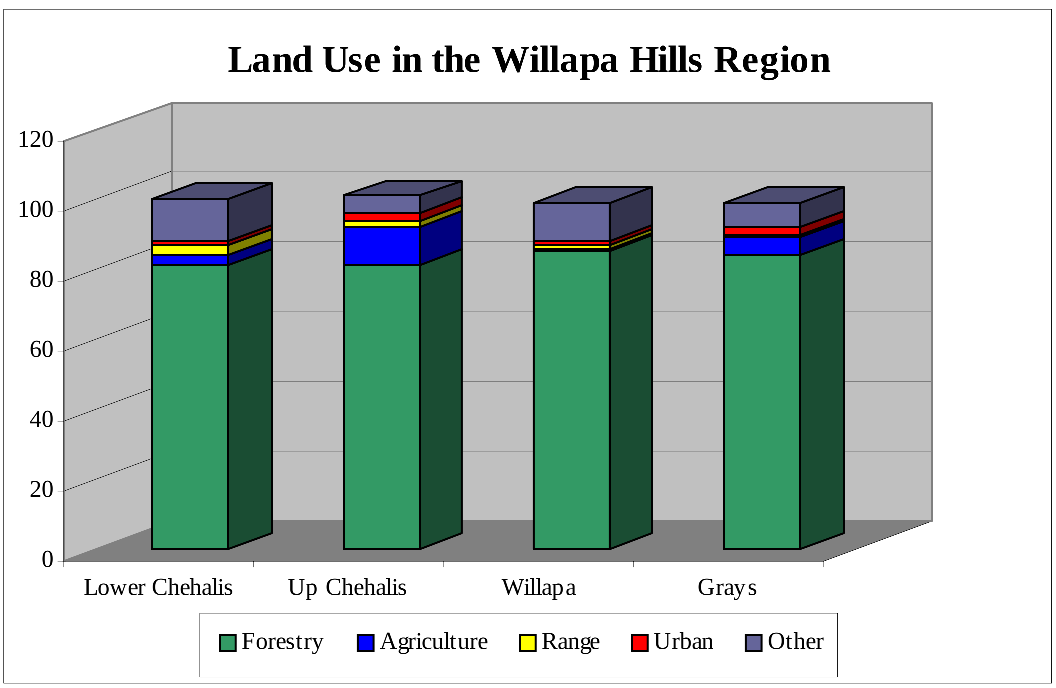


The Willapa Hills Region

The Willapa Hills region is part of the Coast Range that extends into Oregon (Lasmanis 1991). Glacial meltwater flow formed the Chehalis River valley, but most of this region was not glaciated, resulting in rounded hills. In addition to broad valleys, the area is characterized by barrier beaches bounding the large estuaries of Grays Harbor and Willapa.

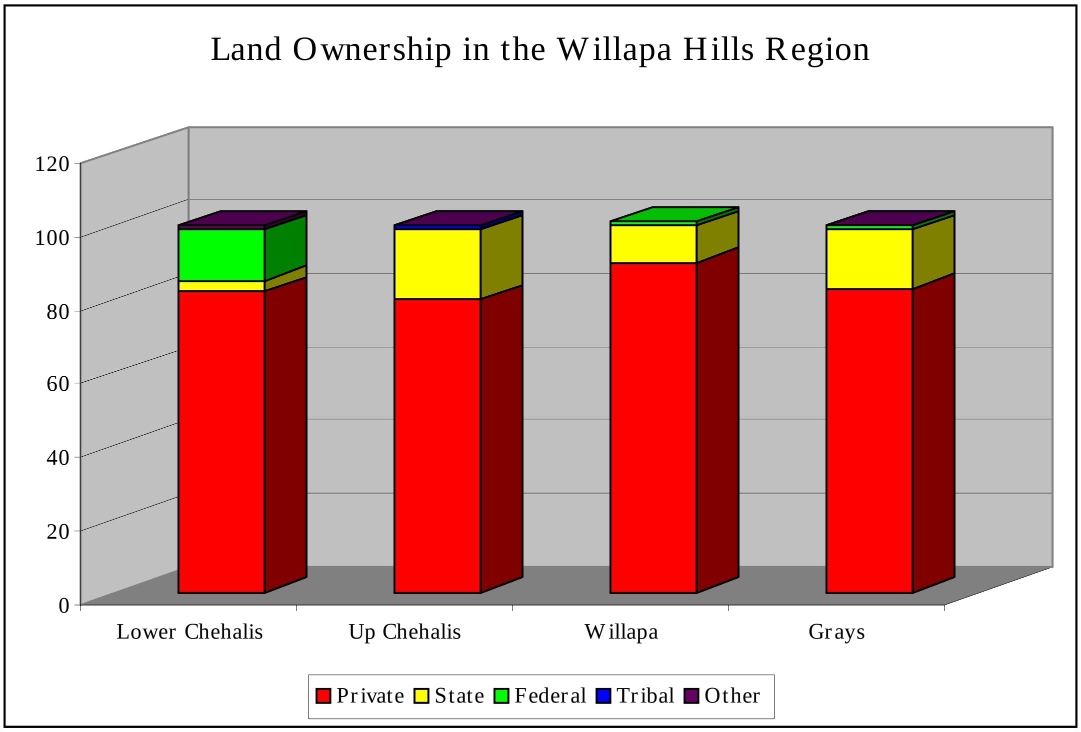
Air temperatures are very moderate ranging from 30-50^{o} in the winter and 47-78^{o} in the summer (Hashim 2002). The average annual rainfall ranges from 60 to 140" with 80" near the coastal areas, and 60" in the upper Chehalis Basin (Figure 11) (Oregon State University 2000; Hashim 2002). Greater amounts of precipitation are found in the upper reaches of tributaries that arise in the Olympic Mountains, and these headwaters are actually in the Olympic Mountains Region. Historically, much of the coastal sections of this region consisted of a temperate rain forest (Wolf et al. 1995), but this has been replaced by commercial forestry, which accounts for 85% of the Willapa, 84% of the Grays/Elochoman, and 81% of the Chehalis Basin's land use (Figure 16) (Hashim 2002). Agriculture can be found in the lowlands, comprising 11% of the upper Chehalis drainage and 1 to 5% in the remaining drainages (Figure 16). A few small cities and several towns exist in this region.

Figure 16. Land use in the Willapa Hills Region by WRIA (data from Hashim 2002).



Land ownership is overwhelmingly private with National Forest lands in the upper reaches of the Lower Chehalis Basin, which are mostly in the Olympic Mountains Region (Figure 17) (Lunetta et al. 1997; Hashim 2002). The Willapa Hills Region consists of three counties. All have a relatively low human population density of 35 persons per square mile in Grays Harbor, 23 in Pacific, and 15 in Wahkiakum Counties (Figure 14) (U.S. Census Bureau 2000).

Figure 17. Land ownership by acres in the Willapa Hills Region (data from Hashim 2002).



The WRIAs in this region include most of 22 and 23 (lower and upper Chehalis), and all of 24 (Willapa), and 25 (Wahkiakum). The Chehalis Basin dominates this region, covering 1,674,000 acres with a dense network of streams (Lunetta et al. 1997). Many large tributary systems drain into the Chehalis including the Newaukum, Skookumchuck, Satsop, and Wynoochee rivers. The Humptulips River drains into the Grays Harbor estuary. The Willapa Basin drainages are located in the southeast corner of the state. These include the North (204,000 acres), Willapa (170,000 acres), Naselle (125,000 acres), and the smaller watersheds of the Nemah, Palix, and Bear rivers. In the southern portion of the Willapa Hills region, the Grays and Elochoman rivers drain into the lower Columbia River.

The average annual flows are generally moderate in the upper Chehalis and high elsewhere in the region (Figure 15) (Weitkamp et al. 1995 and Meyers et al. 1998). Peak flows occur in December or January and high flows (flow is equal to or exceeds 50% of peak monthly flow) last 5-6 months (Weitkamp et al. 1995). However, minimum monthly flow can be quite low for streams in the upper Chehalis and North/Willapa Rivers ranging from 2-5% of maximum average monthly flow.

Puget Lowlands Region

The Puget Lowlands Region is a wide, low elevation trough, or depression, bounded by the Cascade Range to the east and the Willapa Hills and Olympic Mountains to the west (Lasmanis 1991). Volcanic eruptions from the Cascade Range have contributed much of the sediments in this region followed by numerous glaciation periods. The most recent was the Fraser Glaciation, which peaked about 14,000 years ago and extended to Littlerock. As the glacier retreated, glacial drift was deposited and the landscape was sculpted to form the stream drainages that exist today.

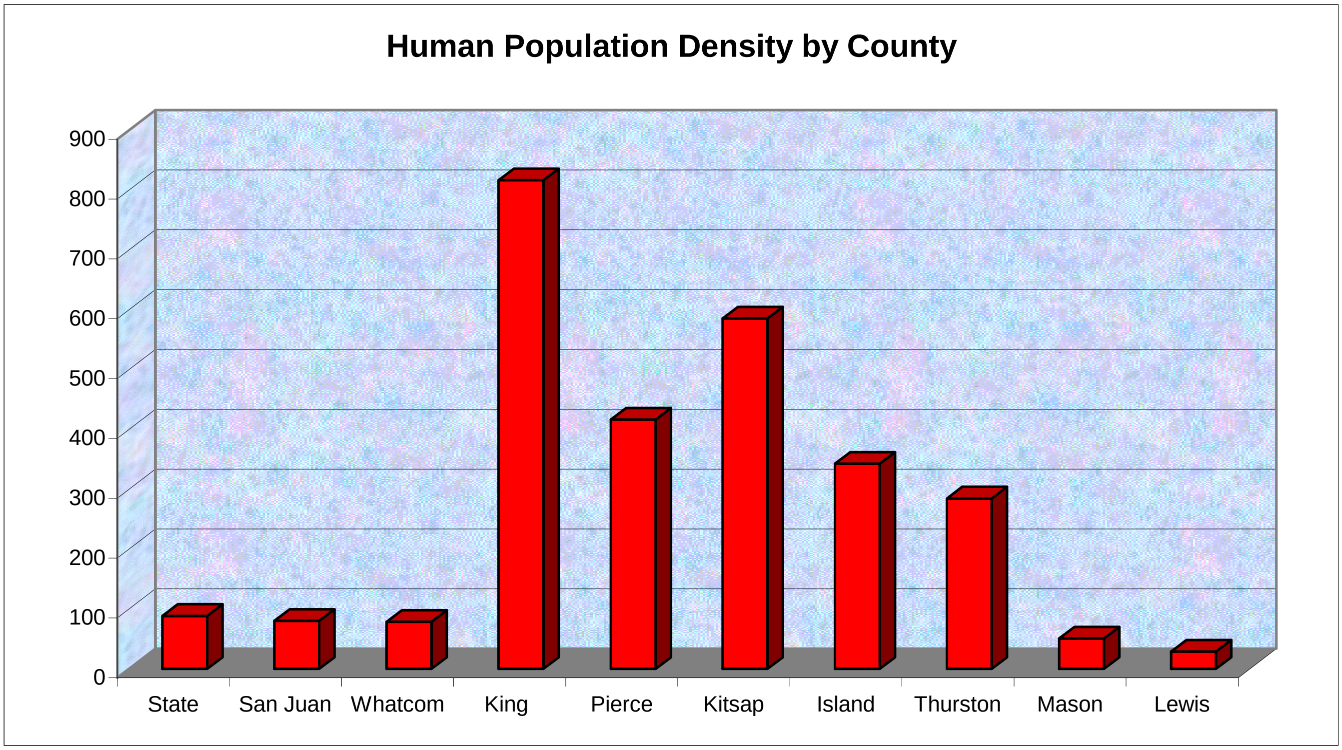
The lower portions of all of the drainages entering Puget Sound run through the Puget Lowland, but the following discussion will only include data on basins that are primarily located within the Puget Lowlands Region, because the data do not allow for finer separation. Within the Puget Lowlands Region are the western portion of WRIA 1 (Nooksack), 2 (San Juan), 6 (Island), 15 (Kitsap), 12 (Chambers), 13 (Deschutes), 14 (Mason), the eastern section of 17 (Quilcene-Snow), and most of 8 (Lake Washington), 9 (Green), 10 (Puyallup), and 11 (Nisqually) (Figure 8). Small, but populated areas within the Snohomish (WRIA 7), Stillaguamish (WRIA 5), Skagit (WRIAs 3 and 4), and Cowlitz (WRIA 26) are located in the Puget Lowlands, but are discussed in the Cascade Mountain Region.

Air temperatures in this region are moderate, ranging from 31-46^{o} in the winter. Summer temperatures vary with cooler temperatures north of King County (51-64^{o}) and a range of 47-78^{o} in the other areas. Average annual precipitation levels are highly variable throughout this large region with the lowest levels (18”) in Island County, 20-30” in San Juan and eastern WRIA 17, 30-40” along the Puget Sound rim of Pierce, King, Snohomish, Skagit, and south Whatcom Counties, and 40-60” in much of the remaining region (Figure 11) (Oregon State University 2000; Hashim 2002).

The average annual flows adjusted for watershed size are moderate in this region with a range of 0.021 to 0.04 m^2 per second per km^2 (Figure 15) (Weitkamp et al. 1995 and Meyers et al. 1998). In most of these streams, the first peak flow occurs in December or January, and a second peak relating to glacial melt occurs in the Nooksack, Cedar, Green, and Nisqually Rivers (Weitkamp et al. 1995). In the basins with headwaters in the Cascade Mountain range, the minimum flows remain relatively high at 10% or more of annual maximum monthly flow due to contributions of snow pack and glacial melt (Weitkamp et al. 1995).

Dense levels of human population are found throughout most of the Puget Lowlands, with about ¾ of the State’s population within this region (DNR 2003). Dense population levels are found in King, Kitsap, Pierce, Island, and Thurston Counties (Figure 18) (U.S. Census Bureau 2000). These levels are well above the average state density. San Juan and Whatcom Counties have densities close to the state average, while Mason and Lewis Counties have relatively low densities. In addition, the urban areas within Skagit and Snohomish Counties are located within the Puget Lowlands Region, even though the majority of the land within these counties is located within the Cascade Region (Figure 19).

Figure 18. Human population densities in the Puget Lowland Region compared to the state average (data from the U.S. Census Bureau 2000).



Land use is dominated by urbanization in the sections of King, Pierce, Thurston, and Snohomish Counties that are located near Puget Sound with forestry comprising much of the remaining land use (Figures 19 and 20). Urban land use accounts for 44% of the Chambers WRIA, 36% of the Lake Washington WRIA, 20% of the Green/Duwamish WRIA, 14% of the Deschutes WRIA, and 12% of the Kitsap WRIA (Figure 20) (Hashim 2002). However, some of these counties also are part of the Cascade Mountain Region, where forests dominate the landscape. To the north, the Puget Lowlands within the Skagit, Island, Nooksack, and San Juan WRIAs have a significant agricultural land use consisting of 22, 15, 15, and 13% respectively (Hashim 2002). To the south is a mix of agriculture and forestry (Figure 19). Historically, most of the land was covered with conifer forests. Currently, the Douglas fir zone of the Puget Lowlands consists of only 15% conifer land cover with 25% urban and 19% agricultural lands (Cassidy et al. 1997).

Figure 19. Land use and vegetation cover in Washington State (USGS 2003).

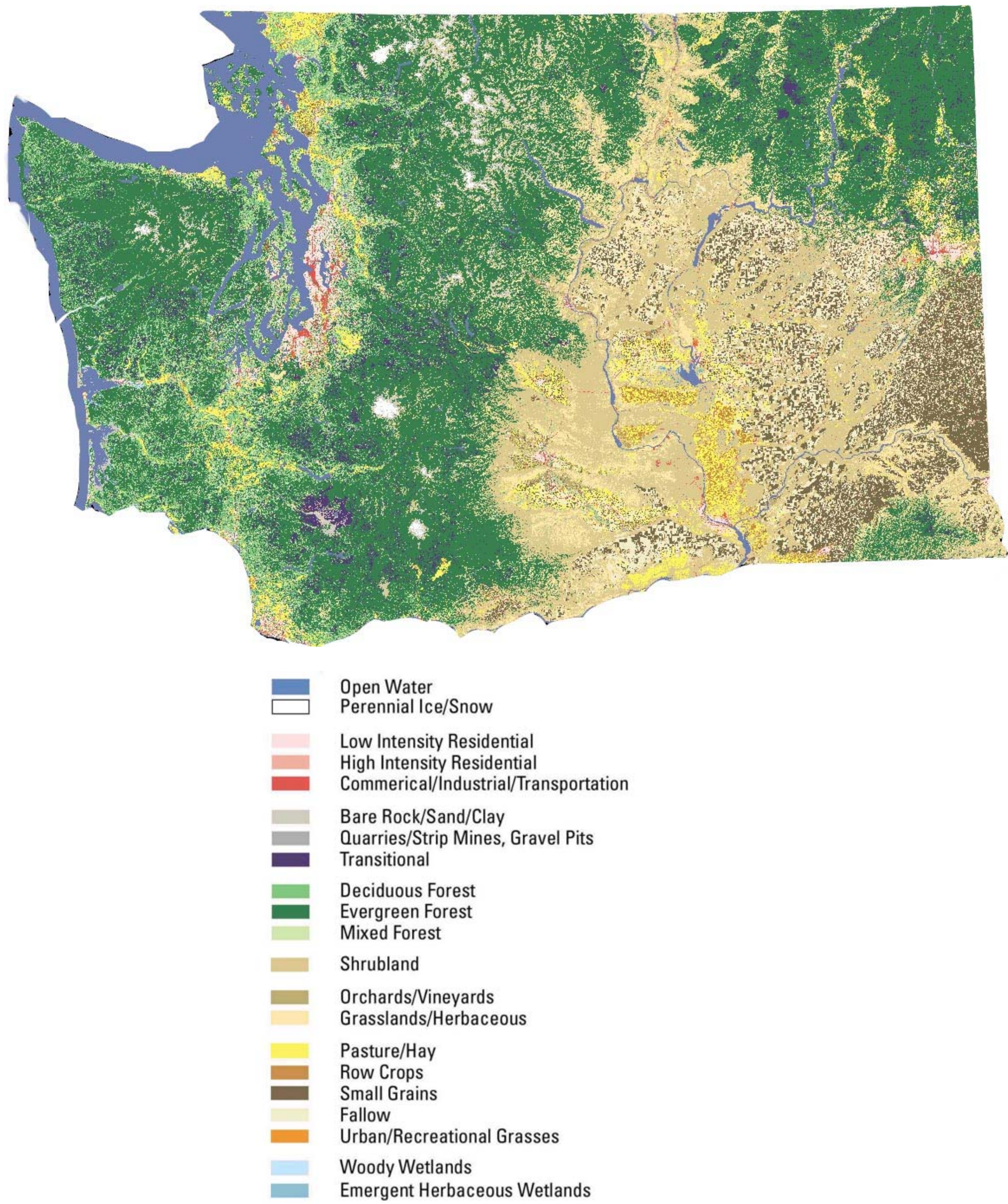
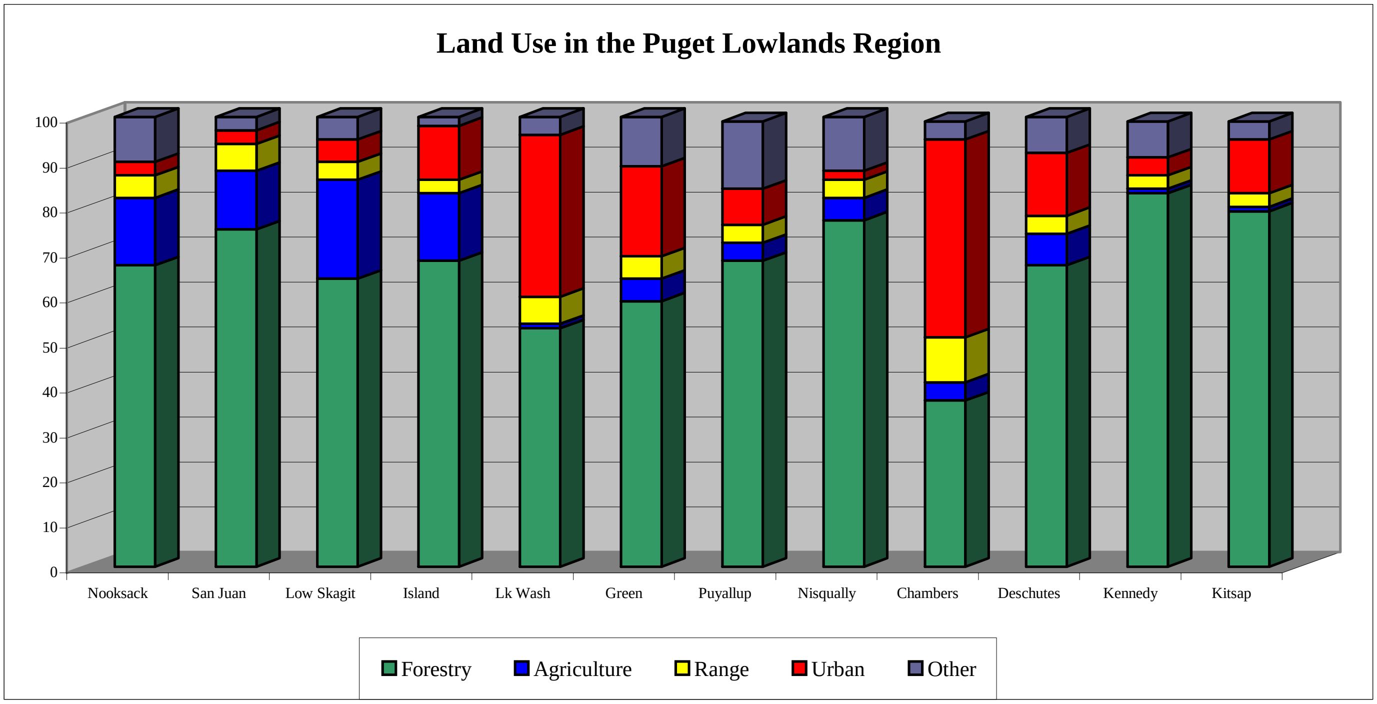
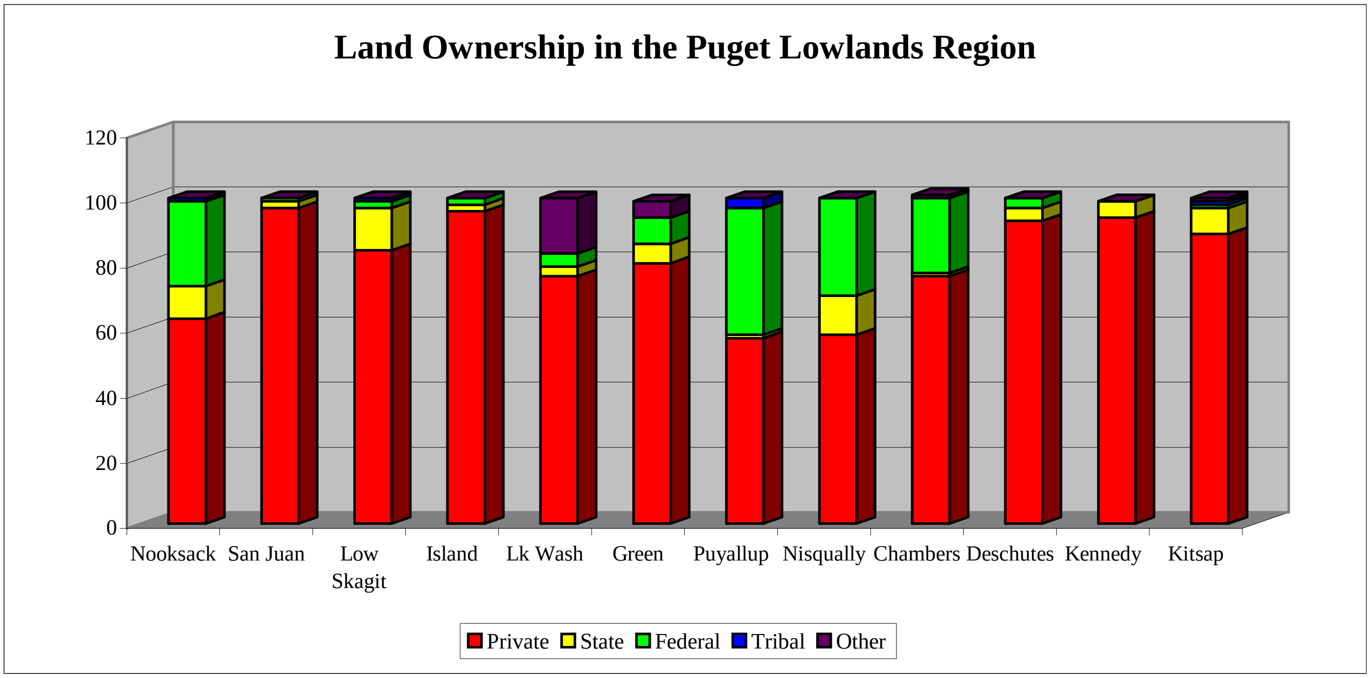


Figure 20. Land use in the Puget Lowland Region (data from Hashim 2002).



Land ownership in the Puget Lowlands Region is mostly private with percentages above 75% in all but three WRIAs (Figure 21). These three WRIAs include the Nooksack, Puyallup, and Nisqually, which have federal land ownership in the upper reaches, much of which is located in the Cascade Region.

Figure 21. Land ownership in the Puget Lowland Region by WRIA (data from Hashim 2002).



Just south of the Puget Lowlands is the Portland Basin. It is an area of low relief marking the northern end of the Willamette Lowland (Lasmanis 1991), and many of its characteristics are similar to those in the Puget Lowlands. Small portions of the Cowlitz-Coweeman (WRIA 26) and Lewis (WRIA 27) drainages, and nearly all of the Salmon and Washougal rivers (WRIA 28) are located in this region, and human population density is high at nearly 500 persons per square mile (Figure 21) (U.S. Census Bureau 2000). Within WRIA 28, the land use consists of forestry (62%) with 14% in urban lands and 15% in agriculture. Private ownership accounts for 77% of the area and state ownership comprises 18% (Hashim 2002). However, in general, much of this ecoregion is now either developed (2%) or converted into agriculture (45%) (Cassidy et al. 1997). In both the Portland Basin and Puget Lowlands, the historic conifer land cover has been greatly altered by development, logging, and agriculture so that currently, forests of mixed or deciduous trees combined, cover more land than conifer forests (Cassidy et al. 1997).

Cascade Mountains Region

The Cascade Range consists of active, high elevation volcanoes rising as tall as 14,000 feet above sea level. The height of these rugged mountains form a barrier to much of the incoming Pacific weather systems, resulting in vastly different climatic conditions between the west and east sides. The northern portion of the range is a granite mass with the second greatest concentration of alpine glaciers in the United States (Lasmanis 1991). The southern end (from Mount Rainier southward) is a series of volcanic cones.

At mid and lower elevations of this mountainous region, coniferous forests abound and much of this area is within National Forest boundaries. Along the western slopes of the Cascade Mountains, the most common native vegetation series is silver fir-Douglas fir and fir-hemlock forests (Bailey 1994). At high elevations are alpine meadows and barren areas. The northernmost region is forested with western spruce and fir with western red cedar near the rivers.

Many large river basins in Washington State receive water from the Cascade Mountains, and several basins have a majority of land within the Cascade Region. The upper Skagit (WRIA 4), Wind-White Salmon (WRIA 29), and Methow (WRIA 48) basins are nearly entirely located within this region. Also, most of Chelan (WRIA 47), Entiat (WRIA 46), Wenatchee (WRIA 45), Upper Yakima (WRIA 39), Naches (WRIA 38), Stillaguamish (WRIA 5), Snohomish (WRIA 7), Cowlitz (26), and Lewis (27) basins are located here, along with a considerable portion of eastern WRIA 1 (Nooksack) and WRIA 3 (Lower Skagit).

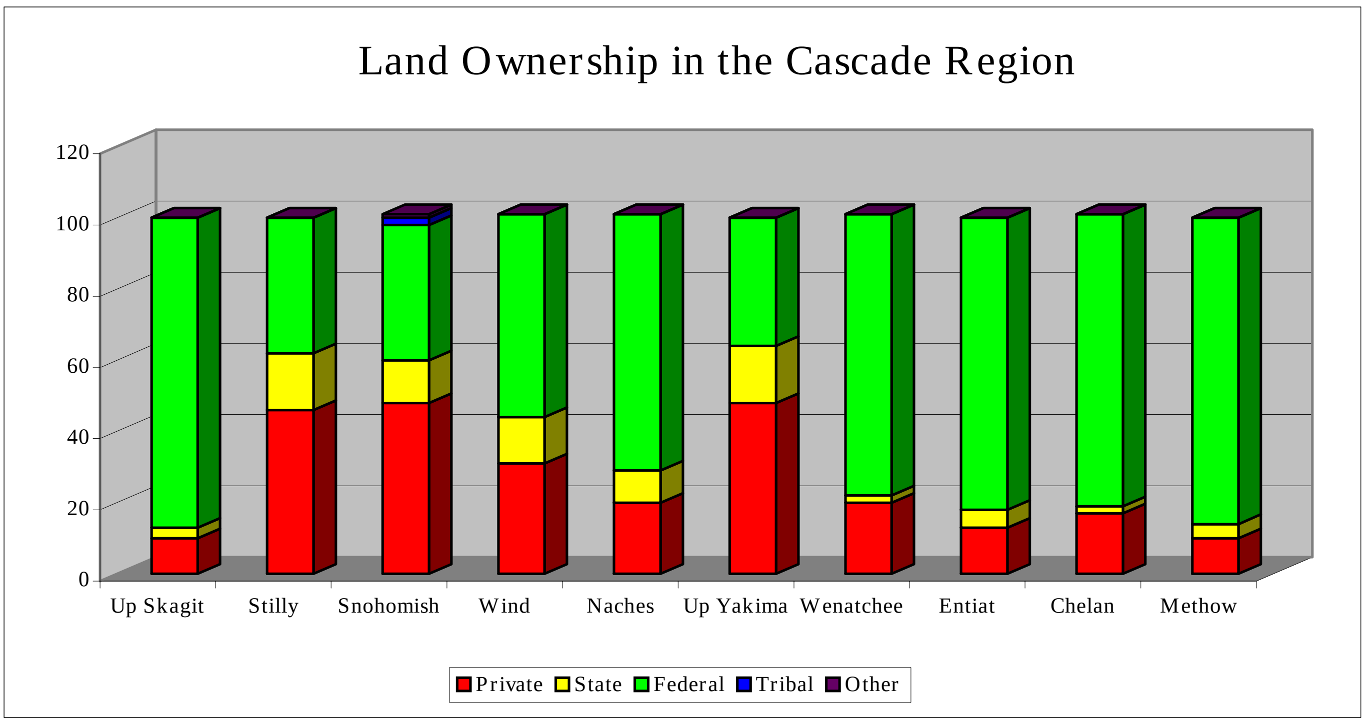
In addition, the headwaters to many other large rivers are located in this region, but these drainages are discussed in the region where the majority of their basin is located. Along the western slope, these include the headwaters to Cedar (WRIA 8), Green (WRIA 9), Puyallup-White (WRIA 10), and Nisqually (WRIA 11) rivers. These basins are discussed in the Puget Lowlands section. Along the eastern slopes the headwaters to the Klickitat (WRIA 30) Basin are located in the Cascade Mountain Region, while the middle and lower reaches are located in the Columbia Basin.

Average annual precipitation varies between 50 to 150”, falling as either rain or snow from October through June (Figure 11) (Bailey 1994; Oregon State University 2000). The Cascade Mountains have among the heaviest snowfall in the nation with some areas receiving over 200” annually (Carpenter and Provorse 1998). Snow packs can be as thick as tens of feet, leading to rain-on-snow flood events in the low to mid elevation areas, which increase erosion processes (Bailey 1994). Large order, dense stream networks characterize the area with 1.5 to 2 miles of perennial streams per square mile, not including the numerous lakes and intermittent streams. In most of the west slope streams, the first peak flow occurs in December or January, and a second peak relating to glacial melt occurs in the Nooksack, Skagit, Stillaguamish, and Snohomish Rivers (Weitkamp et al. 1995).

In the eastern Cascades, the vegetation is similar to the western Cascades in the higher elevations, but the lower elevations of the eastern Cascades consists of Ponderosa and lodgepole pine (Bailey 1994). Average annual precipitation is lower than along the western slopes, ranging from 10 to 120" with most falling as snow in the fall, winter, and spring months (Figure 11). The streams draining the eastern slopes have a snowmelt dominated flow regime. In the Methow, flow peaks during spring and early summer, although some rain-on-snow produced peaks occur in November and December (Andonaegui 2000). About 60 percent of the annual runoff volume (at Pateros) is in May and June. In general, the east slope streams have steep slopes resulting in high energy, flashy streams that show a wide variation between low and high flows.

Much of the land within the eastern Cascades region is in federal ownership with the majority within National Forest boundaries (Figure 22). Drainages with 70% or more federal lands include the Methow, Upper Skagit, Naches, Wenatchee, Entiat, and Chelan basins (Figure 22) (Bailey 1994; Hashim 2002). National Park lands are also a part of the uppermost reaches of many of these drainages. Many of the rivers are municipal water supply watersheds (Bailey 1994), and private land ownership is prominent in the Stillaguamish, Snohomish, and upper Yakima basins.

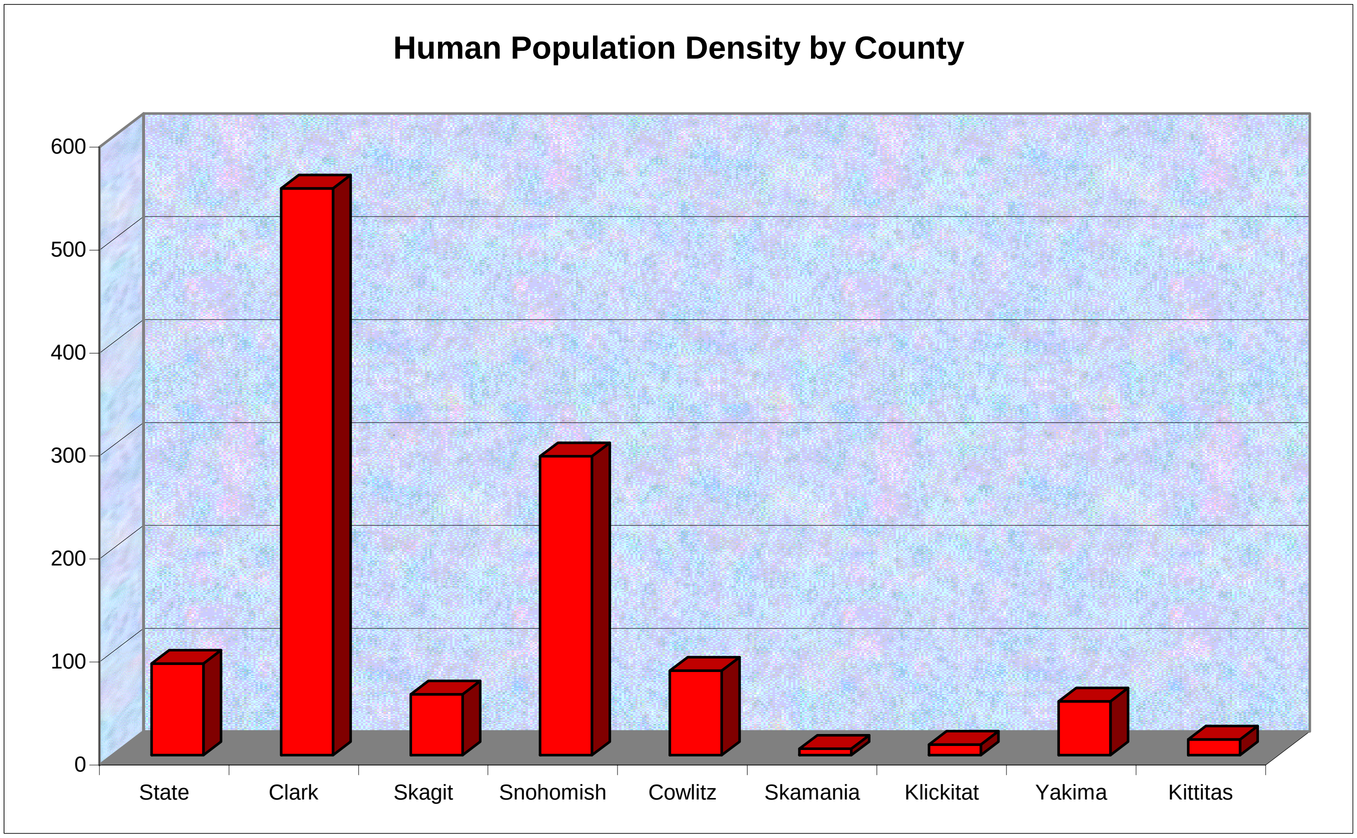
Figure 22. Land ownership by WRIA in the Cascade Mountains Region (data from Hashim 2002).



Small communities lie within the river valleys along with grazing and crop production (Figure 19), and human population densities are low. Skamania and Okanogan counties have human population densities of less than 10 persons per square mile and Chelan and Kittatas Counties have 23 and 15 persons per square mile, respectively (Figure 23) (U.S.

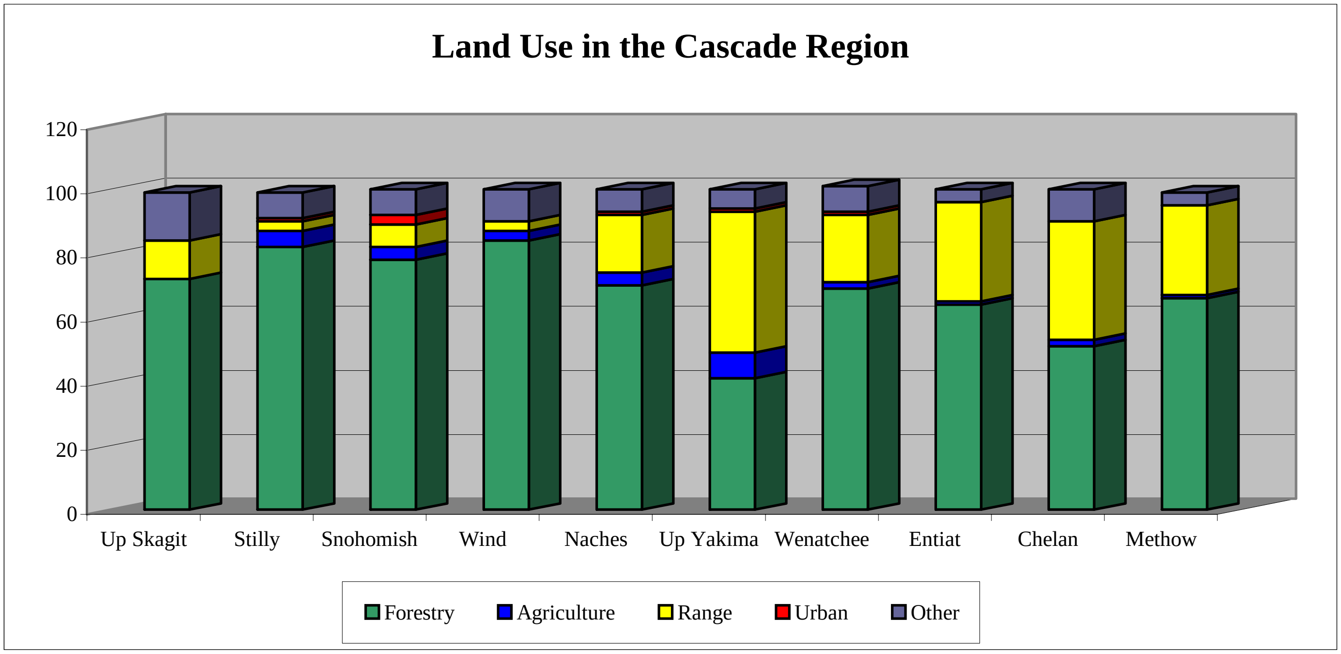
Census Bureau 2000). Many other counties have land within the Cascades region, but also have land in other regions where human populations are concentrated.

Figure 23. Human population densities in Clark County (Portland Basin Region) and the counties that comprise much of the Cascade Mountain Region (data from U.S. Census Bureau 2000).



Throughout the Cascade region, human occupation dates back at least 8,000 years with settlements forming about 5,000 years ago. Deer were an important resource, and intentional burning occurred to enhance their habitat (Bailey 1994). However, large-scale human caused changes to the landscape did not occur until the Euro-American settlers arrived in the mid 1800s. From the 1880s to the 1930s, timber harvest, dams, grazing, and mining altered the landscape (Bailey 1994). Today, forestry is the predominant land use comprising 60% or more of the Upper Skagit, Stillaguamish, Snohomish, Methow, Enitat, Naches, and Wind/White Salmon basins (Figure 24) (Hashim 2002). Range is another important land use, especially in the Naches, Upper Yakima, Entiat, Chelan, and Methow basins.

Figure 24. Land use in the Cascade Mountain basins (data from Hashim 2002).



Okanogan Highlands

The Okanogan Highlands region is a mix of rounded mountains and narrow valleys with elevations extending to nearly 8,000 feet (Lasmanis 1991), and in the east, the mountains are part of the Rocky Mountain Range (Figure 8). The native vegetation is strongly influenced by an east-west precipitation gradient that results in Ponderosa Pine in the higher elevations and sagebrush in the lower areas (Bailey 1994). East of the Columbia River, Douglas fir grows in the lower hills with Grand fir in the higher elevations.

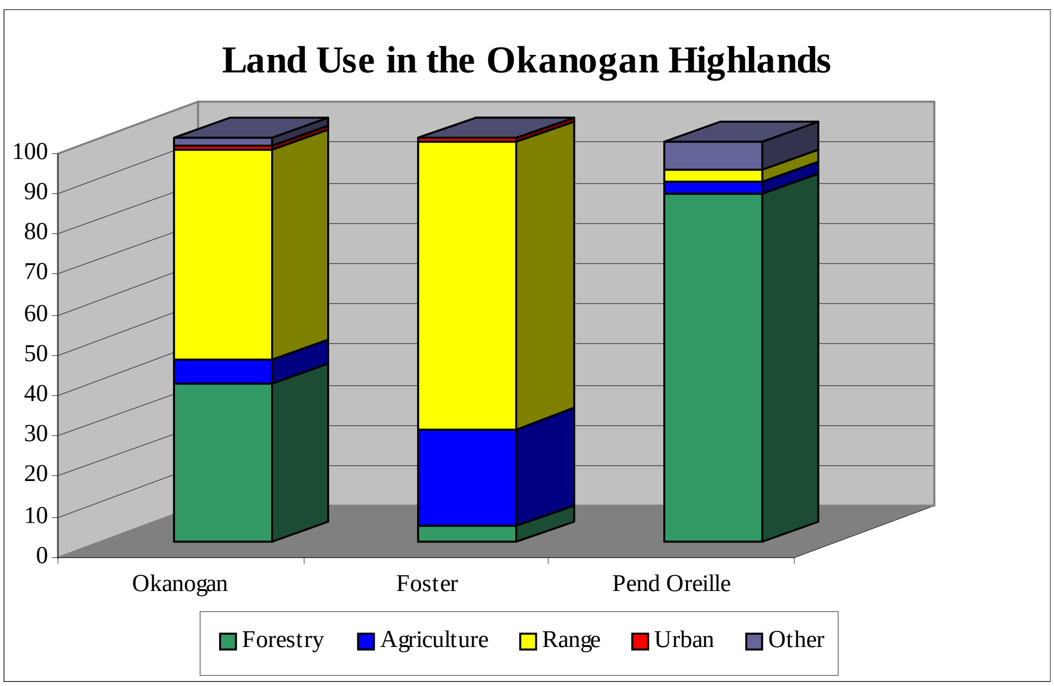
The average annual precipitation ranges from 30 to 80" with most falling as snow (Figure 11) (Bailey 1994; Oregon State University 2000). Rivers flow through narrow valleys, and many glacial lakes and wet meadows exist in northeastern Washington (Bailey 1994). Rain-on-snow events are common in the region.

Only two WRIAs in this region, the Okanogan (WRIA 49) and Foster Creek (WRIA 5), produce salmon or steelhead. One other WRIA (62, Pend Oreille) has known bull trout use, but the remaining WRIAs (50-61) have no known salmonid use at this time, although it is possible that limited numbers of bull trout may be present in some areas. The WRIAs that do not have known salmonid use outside of the Columbia River mainstem will not be included for further analysis in this report. These encompass drainages in two regions, the Okanogan Highlands and the Columbia Basin, and specifically include the Esquatzel Coulee, Upper Crab, Grand Coulee, Hangman, Colville, Middle Spokane, Little Spokane, and Nespelem basins. In addition, further analysis will not include the Lower Spokane, Lower Lake Roosevelt, Middle Lake Roosevelt, Upper Lake Roosevelt, Lower Crab, San Poil, and Kettle because of the absence of information regarding the presence of salmonids.

The lack of salmonid production is due to profound changes in habitat from the Grand Coulee and Chief Joseph Dams. The Grand Coulee project is among the largest concrete structures in the world forming Franklin D. Roosevelt Lake, which extends to the Canadian Border. It is the nation's largest and world's third largest hydroelectric producer, and provides irrigation to the Columbia Basin Project. It was constructed in 1941, and is located at RM 596.6 on the Columbia River, completely blocking passage to all anadromous salmonids. However, in 1955, Chief Joseph Dam was constructed 52 miles downstream of Grand Coulee, and posed a new complete block to salmonid migration (reviewed in McKay and Renk 2002). The conversion of a free flowing river to a lake resulted in proliferation of fish species such as carp and squawfish. Introduced walleye has become a popular sport fish in the lake.

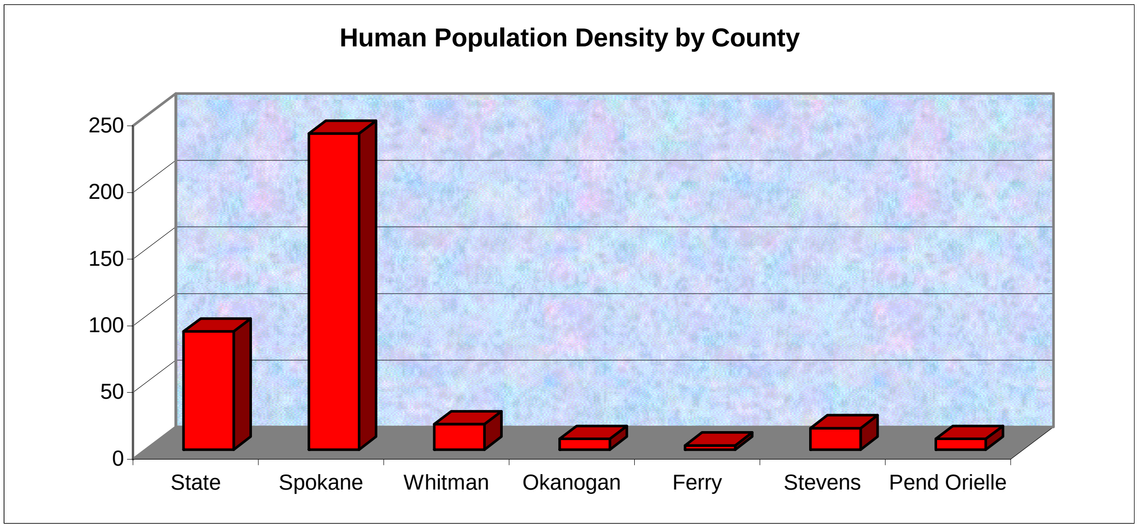
Throughout the eastern side of the state, humans occupied the area for at least 12,000 years, but large-scale landscape changes did not begin until the Euro-American influence in the mid-1800s (Bailey 1994). Significant land use alterations came as a result of mining, logging, grazing, agriculture, and dam construction. Grazing accounts for 71% of the Foster Creek Basin and 52% of the Okanogan drainage (Figure 25) (Hashim 2002). Forestry is the major land use in Pend Oreille, comprising 86% of the land.

Figure 25. Land use in the Okanogan Highlands Region (data from Hashim 2002).



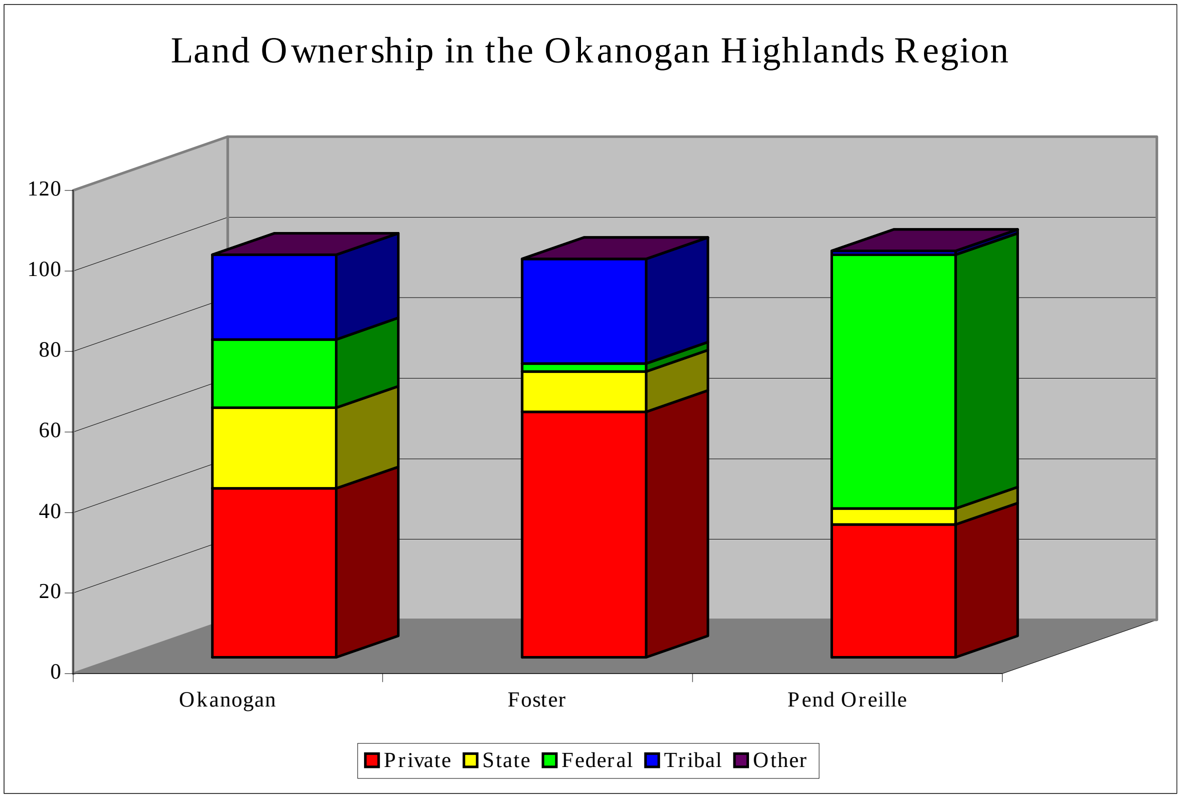
Most of the area is currently rural with very low human population densities. This region includes Okanogan, Ferry, Stevens, Pend Oreille, and the northern part of Spokane Counties. All but Spokane County have population densities well below the state average, ranging from 3 to 16 persons per square mile (Figure 26). Spokane County has a high population density (237 persons per square mile) (U.S. Census Bureau 2000), well above the state and national average, and is by far the most densely populated area in the state east of the Cascade Mountains.

Figure 26. Human population densities in the counties that comprise the Okanogan Highlands Region (data from Hashim 2002).



Private land ownership accounts for 61% of the Foster Basin, 42% of the Okanogan Basin, and 33% of the Pend Oreille Basin (Figure 27). Federal lands account for 63% of the Pend Oreille Basin with tribal lands consisting of 26 and 21% in the Foster and Okanogan Basins respectively.

Figure 27. Land ownership in the WRIAs of the Okanogan Highlands Region (data from Hashim 2002).



The Columbia Basin

The Columbia Basin is a large plateau dissected by incised rivers (Lasmanis 1991) with elevations ranging from 500 to 4,000 feet above sea level (Figure 8) (DNR 2003). This region extends into southwest Idaho and northern Oregon, and is considered to have the greatest accumulation of lava in the world (USGS 1991). Between 13,000 to 15,000 years ago, an ice sheet advanced into Idaho, damming the Clark Fork River and forming Lake Missoula. This ice dam broke several times resulting in very large-scale floods into the Columbia Basin. These floods modified the land into a mix of coulees (steep-sided ravines), buttes, mesas, ripples, and valleys, collectively referred to as the Channeled Scablands.

Much of this region is classified as an intermountain semi-desert climate with about 7-8" of precipitation per year, most as winter snowfall (Figure 11) (Bailey 1994; Oregon State University 2000). The Rocky Mountains provide a barrier from the arctic cold and the Cascades provide a barrier from Pacific storms. The mountain snow pack in the Cascade Mountain Region provides much of the water for irrigation and streamflow to the streams draining the Cascade Mountains into the Columbia Basin (Haring 2001).

The Columbia Basin is a large ecoregion encompassing much of the Kickitat (WRIA 30), Rock-Glade (WRIA 31), Alkali-Squilchuck (WRIA 40), Moses Coulee (WRIA 44), the lower Snake (WRIA 33), and the lower Yakima (WRIA 37). The lower most reaches of the Walla Walla River lie within the Columbia Basin as well. WRIAs 36 (Esquatzel), 41 (lower Crab), 42 (upper Crab), and 43 (Grand Coulee) are located within this region, but no longer produce salmon or steelhead and will not be further discussed. The lower reaches of the Naches, upper Yakima, Wenatchee, Entiat, and Chelan basins are also found in the Columbia Basin, but these drainages are discussed in the Cascade Region where most of their land is located.

The Columbia and Snake Rivers are the most predominant features in the region. The Columbia River is the largest river in volume in the western United States (Lang 2003). It drains 259,000 square miles of land with tributaries that extend into seven states (Oregon, Washington, Idaho, Montana, Nevada, Wyoming, and Utah) and Canada. The Columbia River is over 1,200 miles from its headwaters in the Canadian Rockies of British Columbia, dropping nearly 975' along its course, before emptying roughly 2 million gallons of water per second into the Pacific Ocean (Lang 2003). It is one of the world's greatest sources of hydroelectric power with 11 dams that provide not only power, but irrigation, flood control, and navigation capabilities (Lang 2003). About 15% of the Columbia River is located in Canada, and its largest tributary is the Snake River, which is about 1100 miles long. Other large Washington tributary systems in this area include the Wenatchee and Yakima drainages. Wetlands and marshes were historically common, but have been drained for agricultural uses (Bailey 1994).

The natural landscape consists mostly of sagebrush-steppe with lesser amounts of fescue-wheatgrass and wheatgrass-bluegrass vegetation. Shorter grasses comprise the interior of the Columbia Basin with longer grasses in the Palouse prairie. Near the streams, native riparian vegetation can include cottonwood, willow, alder, and elderberry.

Much of the native vegetation has been converted to agriculture. For those drainages that are located nearly completely within the Columbia Basin, the primary land use is currently dry and irrigated agriculture and grazing (Figure 28) (Bailey 1994; Hashim 2002). Irrigated agriculture provides the economic base for much of the area, with Yakima County ranking fifth in the country for total agricultural production (Haring 2001). Other significant land uses include logging, especially in the Klickitat Basin whose upper reaches lie within the Cascade Region, and dams (Bailey 1994).

Land ownership is mostly private throughout the Columbia Basin comprising 90% or more in the Rock/Glade, Walla Walla, and lower Snake Basins and just under 90% in the Moses Coulee WRIA (Figure 29) (Hashim 2002). Significant federal lands (46%) exist in the Alkali WRIA due to the Hanford Project, and large percentages of tribal lands are found in the Klickitat (40%) and lower Yakima (48%) WRIAs (Hashim 2002).

Figure 28. Land use in the Columbia Basin (data from Hashim 2002).

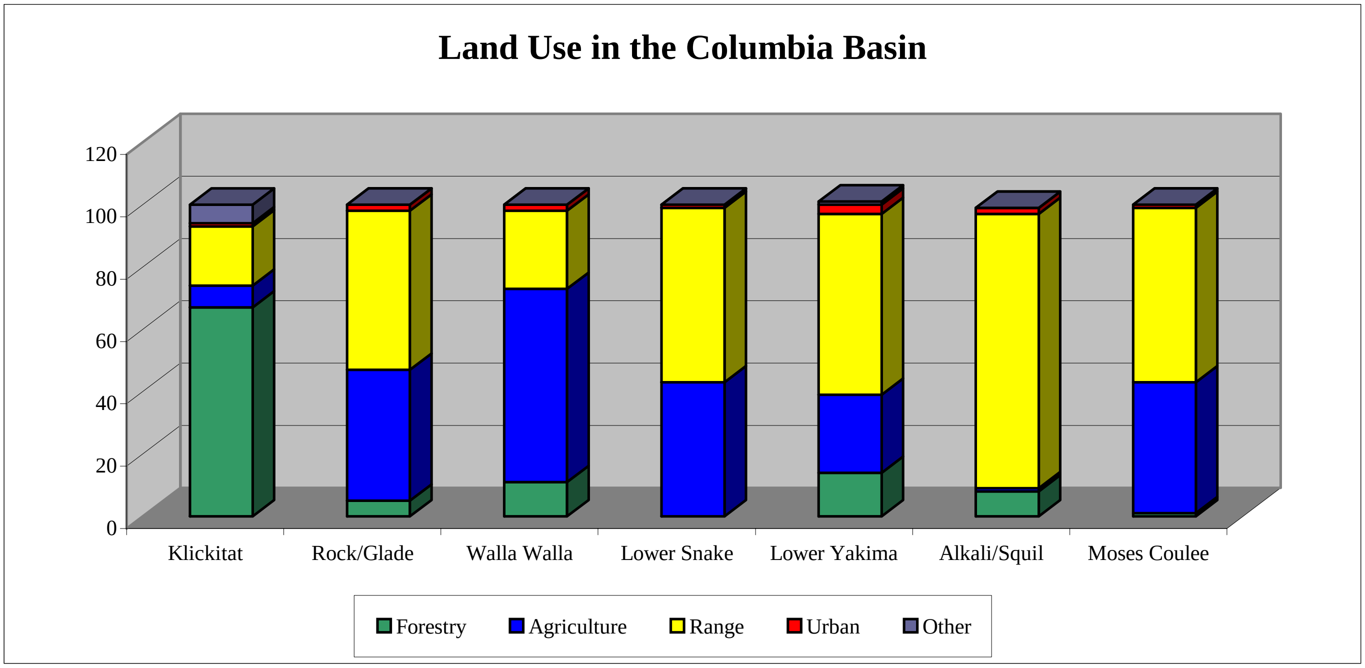
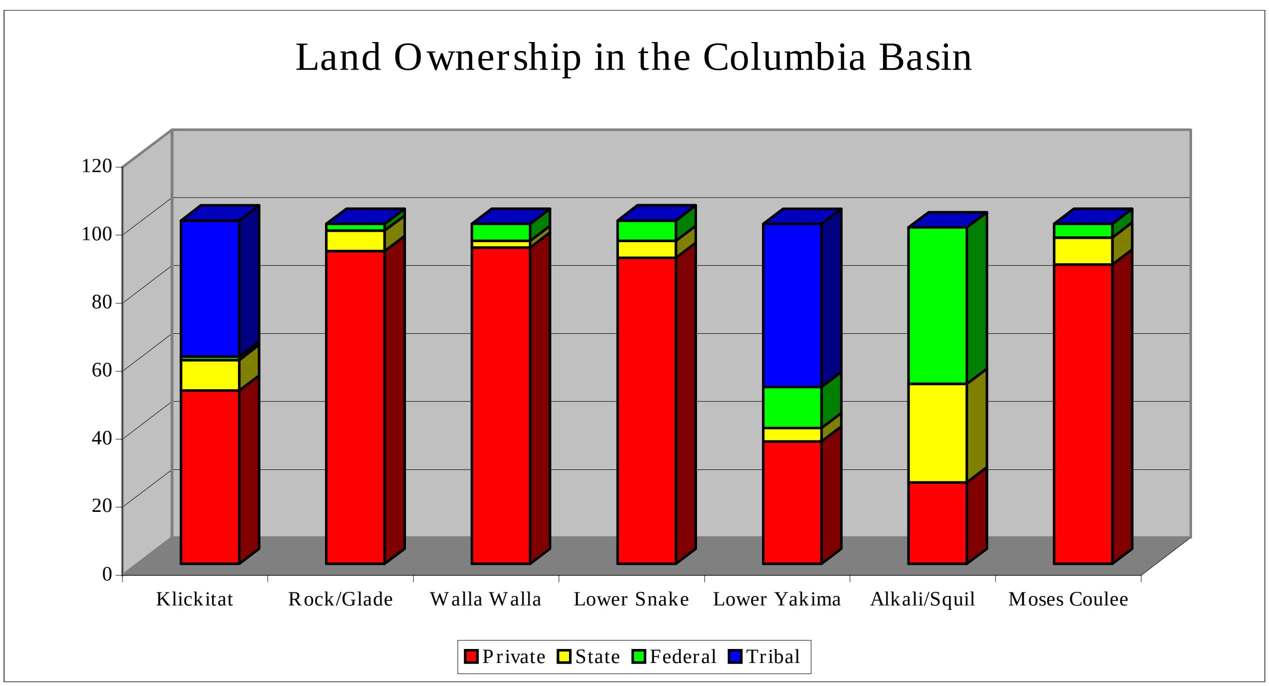
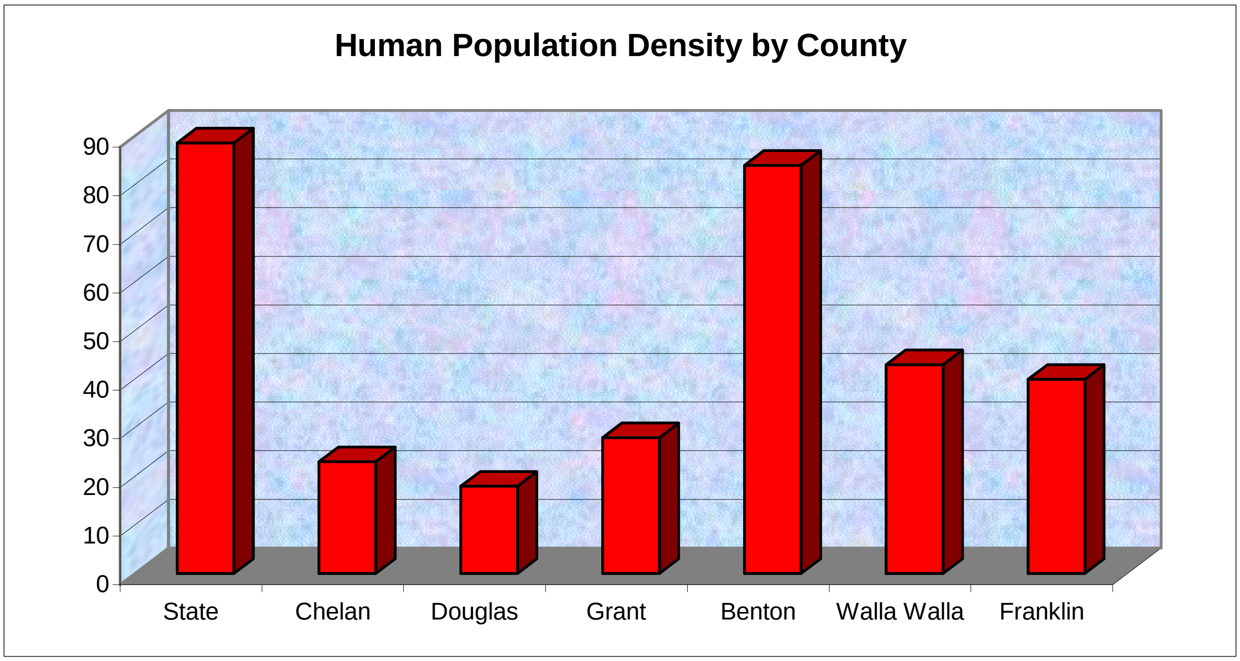


Figure 29. Land ownership in the Columbia Basin (data from Hashim 2002).



Human population densities are relatively low throughout much of the Columbia Basin with a few exceptions. Moderate densities exist in Benton, Yakima, Walla Walla, and Franklin Counties with 84, 52, 43, and 40 persons per square mile respectively (Figures 23, 30, and 31) (U.S. Census Bureau 2000). However, the remaining counties have low densities ranging from 4 to 28 persons per square mile (U.S. Census Bureau 2000). All of the population densities except for Benton County are well below those seen in the Puget Lowlands Region.

Figure 30. Human population densities in the counties comprising much of the Columbia Basin. Yakima County data are in Figure 21 (data from the U.S. Census Bureau 2000).



Comprising sub-sections of the Columbia Basin are the Palouse Prairie and Yakima Fold Belt regions. The Yakima Fold Belt was formed by folded basalt flows, resulting in the numerous ridges and valleys found in the Yakima and Ellensburg areas. Flat, perched floodplains or terraces can be found along the Yakima River where the land slowly uplifted while the river downcut (Lind and Vachon 2000). The upper layer of soils contains fertile loess, or windblown glacial dust. The WRIAs within the Yakima Fold Belt have been discussed in the Columbia Basin Region because of similarities in climate, land use, and land ownership.

The Palouse Prairie consists of dissected plains and hills with elevations ranging from 1,200 to 6,000 feet above sea level (Bailey 1994). The soil consists of loess, and is one of the most fertile areas of the country. Native vegetation is dominated by grasses, as this region is considered to be a grasslands and meadow steppe. In the west, the climate is arid with blue-bunch wheatgrass and Idaho fescues. In the east are woodlands and forests of Ponderosa Pine and Douglas fir on the hills and low mountains. The average annual precipitation is greater than the remaining areas of the Columbia Basin, ranging from 10 to 30” with most falling as snow (Figure 11) (Bailey 1994; Oregon State University 2000). There is a low to medium density of drainages in the area characterized by deeply incised streams and rapid runoff.

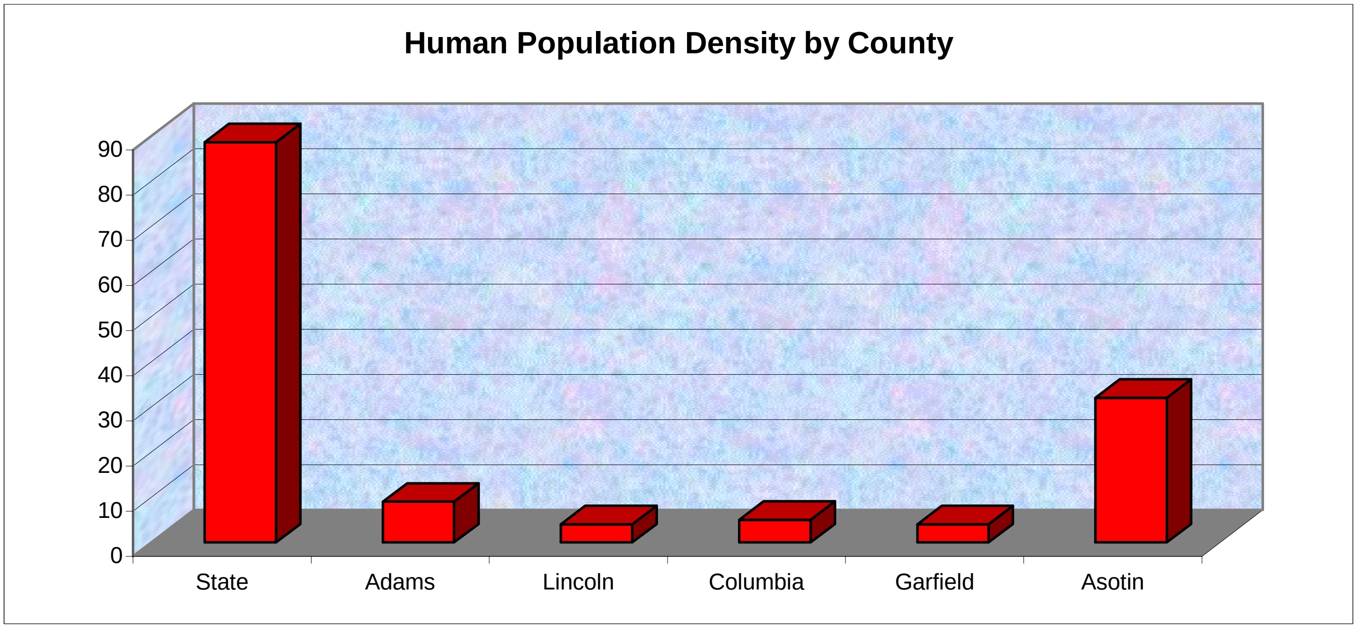
Most of Whitman County lies within the Palouse Prairie region and includes all of WRIA 34 (Palouse) and part of WRIA 35 (middle Snake). The Middle Snake WRIA is discussed in the Blue Mountains Region where most of its land is located. Human population density in Whitman County is low at 19 persons per square mile (Figure 26) (U.S. Census Bureau 2000). Agriculture (especially dry farming) and livestock production account for about 97% of the land use in the area (Figure 32), and land ownership is about 95% private and 4% state-owned (Figure 33) (Hashim 2002).

Blue Mountains Region

The Blue Mountains Region has elevations as high as 6,000 feet above sea level with highly variable precipitation levels ranging from 9-18” yearly in the valleys to 17-100” in the mountains (Figure 11) (Bailey 1994; Oregon State University 2000). Major land use alterations include logging, railroad, grazing, and fire suppression.

This region includes Asotin, parts of Garfield and Columbia, and a small part of Walla Walla Counties (Figure 8). Of the three counties that comprise most of the region (Asotin, Garfield, and Columbia), Asotin has the greatest human population density at 32 persons per square mile (Figure 31) (U.S. Census Bureau 2000). This is a relatively low level compared to the rest of the state. The other two counties have among the lowest densities in the state with 3 to 5 persons per square mile.

Figure 31. Human population densities in the Blue Mountains Region (Asotin, Garfield, and Columbia Counties) and part of the Columbia Basin Region (Lincoln and Adams Counties) compared to the state average (data from the U.S. Census Bureau 2000).



The major drainages in this region include the upper Walla Walla River (part of WRIA 32) and much of the middle Snake River (WRIA 35). The Snake River has the lowest average annual streamflow in the state at 0.005 m^2 per second per km^2 (Figure 15) (Weitkamp et al. 1995; Meyers et al. 1998).

Land use is predominantly agriculture and grazing with lesser amounts of forestry (Figure 32). Land ownership is 93% private in the Walla Walla drainage and 76% private and 19% federal in the Middle Snake drainage (Figure 33) (Hashim 2002).

Figure 32. Land use in the Blue Mountains and Palouse Regions (data from Hashim 2002).

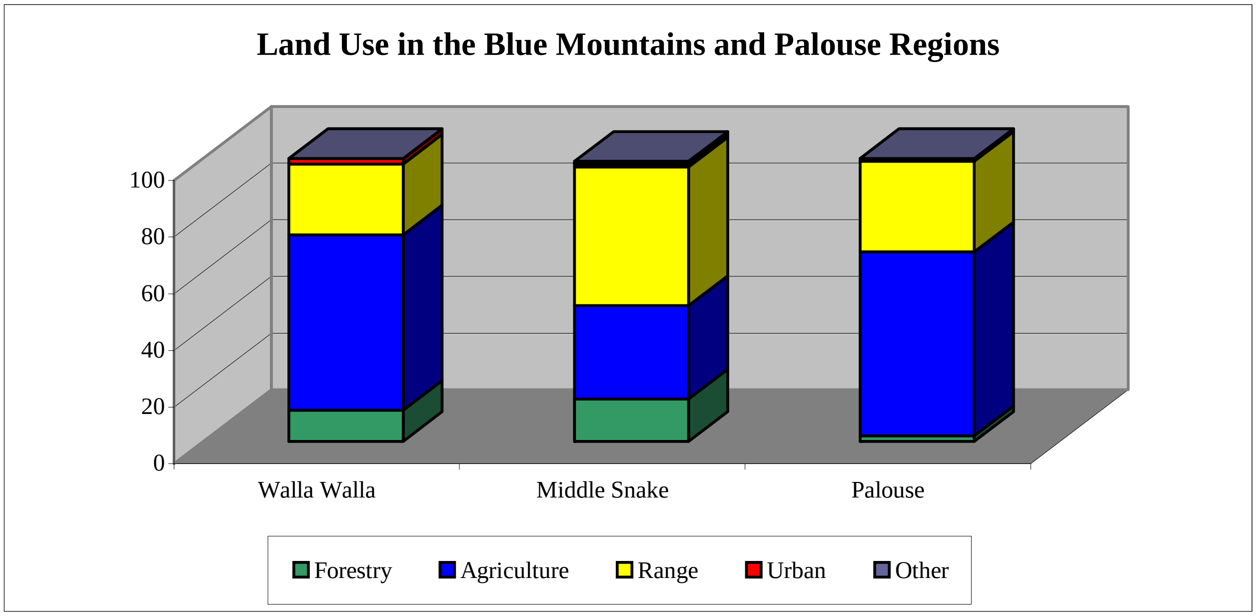
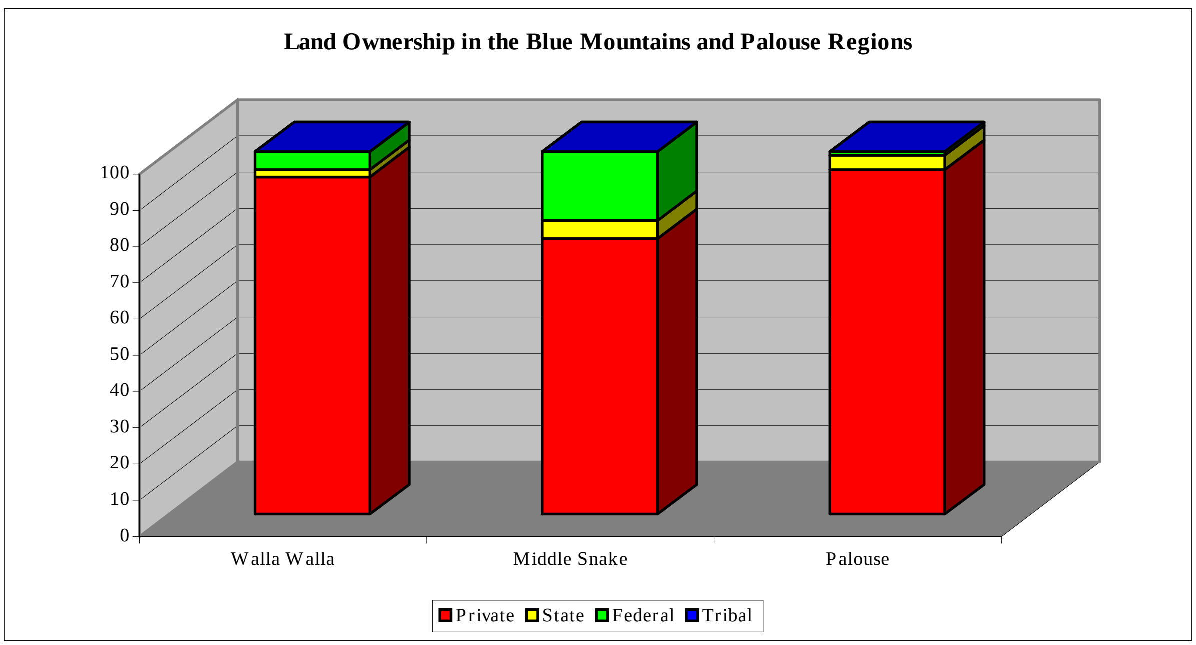


Figure 33. Land ownership in the Palouse and Blue Mountains Regions (data from Hashim 2002).



STATEWIDE HABITAT LIMITING FACTORS INTRODUCTION

Introduction to Habitat Impacts

The quantity and quality of aquatic habitat present in any stream, river, lake or estuary is a reflection of the existing physical habitat characteristics (e.g. depth, structure, gradient) as well as the water quality (e.g. temperature and suspended sediment load). There are a number of processes that create and maintain these features of aquatic habitat. In general, the key processes regulating the condition of aquatic habitats are the delivery and routing of water, sediment, and wood (Montgomery 2004). These processes operate over the terrestrial and aquatic landscape. In addition, ecological processes operate at various spatial and temporal scales and have components that are lateral (e.g., floodplain and riparian), longitudinal (e.g., landslides in upstream areas) and vertical (hyporheic processes).

The effect of each process on habitat characteristics is a function of variations in local geomorphology, climate, spatial and temporal scales of disturbance, and terrestrial and aquatic vegetation. For example, wood is a more critical component of stream habitat than in lakes, where it is primarily an element of littoral habitats. In stream systems, the routing of water is primarily via the stream channel and subsurface routes whereas in lakes, water is routed by circulation patterns resulting from inflow, outflow, and climatic conditions.

Human activities degrade and eliminate aquatic habitats by altering the key natural processes described above. This can occur by disrupting the lateral, longitudinal, and vertical connections of system components as well as altering spatial and temporal variability of the components. In addition, humans have further altered habitats by creating new processes by the introduction of exotic species. The following sections identify and describe the major alterations of aquatic habitat that have occurred, the relative condition between basins, and potential relationships to land use, human population density, and land ownership.

Individual Limiting Factors Analysis Background and Methodology

This report is based upon the set of individual limiting factors analysis reports (LFAs) that were completed for all salmon-producing Watershed Resource Inventory Areas (WRIAs) in Washington State in addition to one bull trout only WRIA (a total of 45 WRIAs). With the exception of one WRIA (Okanogan), each LFA followed the same outline and protocol, which is described below. The Okanogan LFA was developed independently without input from the Washington Conservation Commission, and for that reason differs in scope and detail. Habitat ratings were not supplied in the Okanogan LFA, but were developed in this report based upon the information within their LFA. These were sent to the Okanogan Lead Entity Coordinator for local review, but no reply was received. Because of this, uncertainty exists as to the accuracy of the Okanogan results.

In the remaining LFA reports, the following freshwater salmon habitat topics were assessed when the reports were originally developed: access (culverts, dams), floodplain, sedimentation, large woody debris (LWD), pools, riparian, water quality, and flows. In the original LFAs, technical Advisory Groups (TAGs) reviewed all available data, and compared those data to standards (Table 8) to derive a rating of good, fair, poor, or data gap. In some instances, professional knowledge and judgment were used to develop a rating, and those are documented with their sources in each LFA report. The earliest set of reports did not develop ratings for habitat conditions, and to make them consistent with the other LFAs, ratings were developed in this process based upon the habitat standards used in all other LFAs. These ratings were sent to each of the applicable Lead Entities for local review. After all LFAs had a consistently developed set of ratings, the data were integrated in this statewide summary. Specific details on the methods used to summarize data are in the following section.

As part of the original LFA process, all available data were reviewed and discussed by TAGs who are comprised of local, state, and federal participants. These often include staff from counties, lead entities, cities, tribes, the Northwest Indian Fisheries Commission, the Washington Department of Fish and Wildlife, the Department of Ecology, the Department of Natural Resources, U.S. Forest Service, U.S. Fish and Wildlife Service, National Park Service, WSU-Cooperative Extension, the USDA National Resource Conservation Service, Public Utility Districts and other power companies, irrigation districts, interested citizens and private timber companies. Other agencies and groups participated in select areas, depending on the issues, such as Army Corps of Engineers, salmon enhancement groups, the Puget Sound Action Team, watershed councils, Pacific Biodiversity Institute, Interagency Committee for Outdoor Recreation, Friends of San Juan, U.S. Army (Fort Lewis), U.S. Air Force (McChord), Trout Unlimited, health departments, University of Puget Sound, Clover Park Technical College, Washington State University, Oregon Water Resources Department, Golder Associates, and others.

WRIA-Scale Data Summarization Methodology

The statewide data summary includes all of the original habitat condition ratings by stream or stream reach (see separate spreadsheet file), then combines ratings within each category to give a single rating for each category for each WRIA. There were nine categories used in this statewide summary. They are: access, floodplain, riparian, sedimentation, large woody debris, pools, water quality, high flows/hydromaturity, and low flows.

Ratings were combined using the following process. Because there were numerous data gaps in each category and in each WRIA, a minimum of 30% of the streams within a WRIA was required to have a rating that was not a data gap. If less than 30% of the streams within a WRIA had a rating, then the WRIA was listed in this report as having a WRIA-wide data gap for that habitat category. For each habitat category within a WRIA, the poor, fair, and good ratings were tallied. The most common rating was the rating assigned for that habitat condition in that WRIA. However, if another rating type was within 20% in frequency to the most common rating, then both ratings were presented with the most frequent rating listed first. In some cases, an approximately equal (within 20% of frequency) number of all three ratings were found within a habitat category, and in those cases, the rating that represented that category was a "fair" rating because this was the middle rating.

There was concern that this method would over-represent smaller streams because all streams were treated equally although the large mainstem rivers typically were broken up into reaches and each reach was treated separately. Still, even with reach breakouts, the size of a mainstem reach would often greatly exceed the quantity of habitat within many smaller streams. To address this problem, a separate but comparable analysis was done on only Type 1 streams within each WRIA. Type 1 streams are the largest streams and include mainstem rivers and larger tributaries. They are more numerous in the lower portions of basins, where much of the anadromous salmon habitat exists. Surprisingly, very few differences were found between the ratings based upon all streams in a WRIA and only Type 1 streams. Where such difference existed, they are discussed in the following results section.

Once ratings were developed for each habitat category in each WRIA, they were related to land ownership and land use. The land ownership and land use data are from Hashim 2002 because this report provided both ownership and land use data for each WRIA throughout the state and based such data on WRIA boundaries. Many other sources of land ownership or land use data often don't include the entire state or use different boundaries (such as county) to describe their data. Correlations were run for each of the land ownership and land use relationships, but due to the overwhelming number of poor ratings that were scattered throughout all percentages of land use and land ownership categories, the results did not produce p-values of .05 or less (statistically significant). Another reason for the lack of statistical significance is likely due to the inability to directly attribute habitat conditions to specific blocks of land ownership and land use. Future work should include finer resolution and direct comparison. For these reasons, the results are discussed mostly in terms of observations about the distribution of data.

One of the main purposes of this report is to summarize the LFA data on a broad scale to show the extent and locations of degradations in various habitat categories across the state. One necessary result is that detail and variability with each WRIA is no longer displayed. Readers should keep this in mind when reviewing the following analyses. Much variability exists within a WRIA and even within a stream, and readers are encouraged to review specific stream information in each LFA if they need finer resolution or a greater sense of the degree of variability. If a category is rated poor in a particular WRIA, it indicates that more streams in that WRIA rated poor versus any other rating, but does not preclude that good and fair ratings exist within the WRIA for that category.

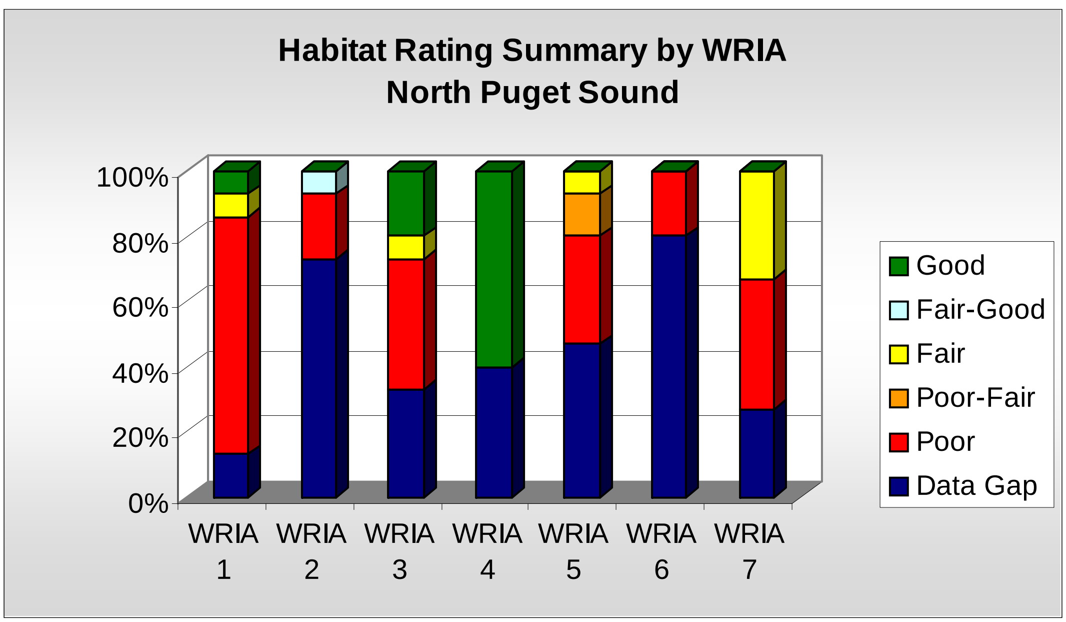
In addition, most ratings have not been updated since the LFA report was done in a given area. New data has been collected, but time and budget constraints prevented updates at this time. This work should be considered a snapshot in time that is based upon the dates when each LFA report was completed.

STATEWIDE HABITAT LIMITING FACTORS RESULTS

Table 4 lists the WRIA-based ratings for each habitat category. Most of the ratings are either data gaps (43%) or poor ratings (38% of total). Only 13% of the total ratings were good and 7% fair. Data gaps were especially common in the water quality, sedimentation, and flow categories. While water quality has programmatic support to measure select stations over time, it is not funded sufficiently to adequately assess the full range of salmon producing streams across the state. Flow data are also supported by programmatic funds through the U.S. Geological Survey, but analyses are needed to correlate flow data with salmon habitat and salmon production and to monitor trends over time and climatic changes. Sedimentation includes sediment quantity, sediment quality, road density, and bank/bedload stability, and few data were available for all of these sediment-related categories. Results within each category are discussed in the next chapter.

When habitat conditions are compared across WRIAs in north Puget Sound, there is large variation (e.g. Figure 34), likely due to land ownership or land use differences, which are discussed in the next chapter. The upper Skagit (WRIA 4) has excellent habitat conditions, while nearby Nooksack has generally poor conditions. The two island WRIAs (2 and 6) have mostly unknown freshwater habitat conditions, and poor-fair conditions predominate in the Snohomish Basin (WRIA 7).

Figure 34. Summary of habitat conditions in WRIAs 1-7 (WRIAs 1=Nooksack, 2=San Juan, 3-4=Skagit, 5=Stillaguamish, 6=Island, and 7=Snohomish).

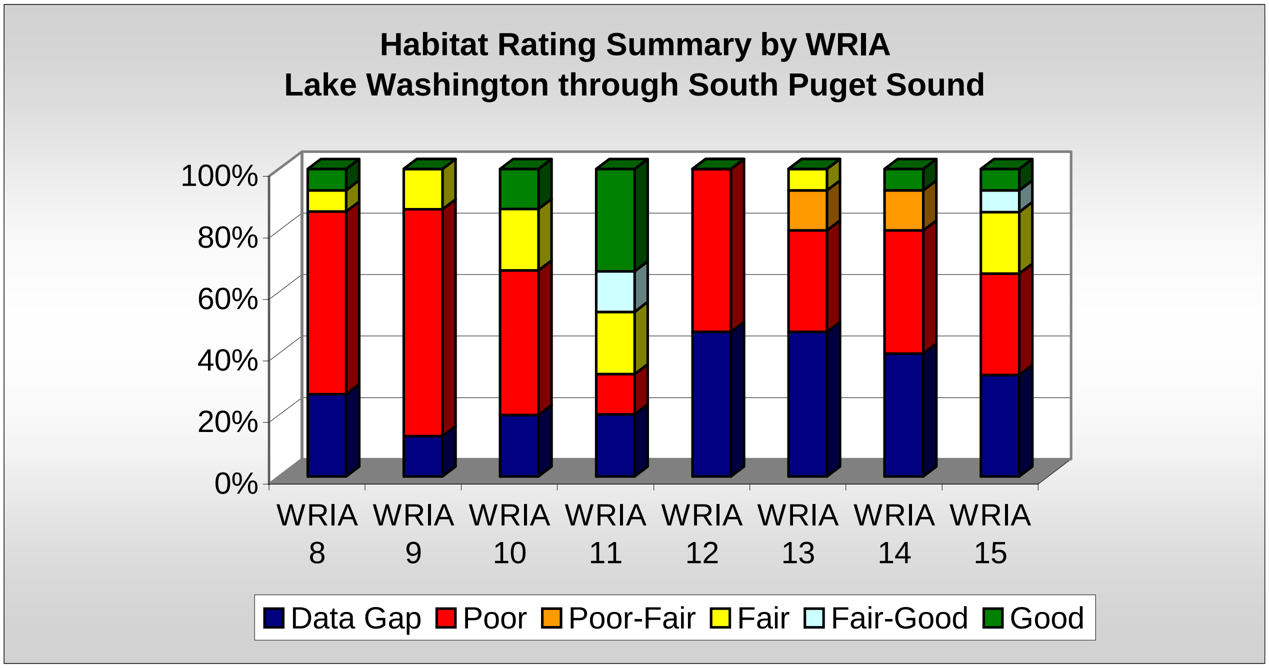


More wild salmonid stocks (39%) in these WRIAs are healthy than not healthy (24%), although a large percentage (38%) is of unknown status (see Anadromous Salmonid Stocks and their Status in Washington State chapter). Within this area, Snohomish has the greatest percentage (60%) of healthy wild stocks, followed by Stillaguamish (45%), Skagit/Samish (33%), and Nooksack (22%). It may seem incongruent that fewer healthy wild salmonid stocks are found in the Skagit when freshwater habitat conditions are better than elsewhere. However, several plausible explanations exist for this apparent discrepancy. One explanation is that factors other than freshwater conditions alone account for the low percentage of healthy stocks. This is supported by data that shows estuarine habitat to be limiting for at least six stocks of chinook in the Skagit Basin (Beamer 2003; Beamer et al. 2000, 2002a, 2002b). Other factors that play a role in salmonid production are ocean conditions and fisheries. Another consideration is that the best habitat conditions in the Skagit are in the upper basin. All anadromous salmonids migrate to and from saltwater, and must use habitat in the lower basin where conditions are generally poorer and are impacted by those conditions.

From Lake Washington through South Puget Sound, habitat conditions are generally poor or unknown with the exception of Nisqually (WRIA 11) and Kitsap (WRIA 15). Nisqually has mostly good habitat ratings, and Kitsap has a mix of fair-good and poor ratings (Figure 35). Overwhelmingly percentages of poor habitat ratings were found in the Lake Washington and Green River WRIAs (WRIAs 8 and 9), and no fair or good ratings existed on a WRIA scale for the Chambers/Clover Basin.

Even though habitat conditions were predominantly poor in this area, 40% of the wild salmonid stocks in this area are healthy. Depressed or critical stocks account for 35% with the remaining stocks being unknown status. Kennedy (WRIA 14) has the greatest percentage of healthy wild stocks (56%), followed by Kitsap (55%), Chambers (50%), Nisqually and Puyallup (33%), Lake Washington (29%), Deschutes (20%) and Green (0%). When looking at depressed or critical stocks, WRIAs are ordered from better to worse as Kennedy (11% depressed or critical wild stocks), Kitsap (15%), Deschutes (20%), Nisqually (33%), Chambers (50%), Puyallup (67%), Lake Washington (71%) and Green (100%). It is noteworthy that many of the wild stocks in Kennedy, Kitsap, and Chambers are chum salmon stocks, and these fish spend very little time in freshwater, explaining why there can be a surprisingly large percentage of healthy stocks in an area with significant freshwater habitat impacts. The Green River Basin had only one salmonid stock that was classified as wild in the 2002-2003 SaSI update (WDFW 2002).

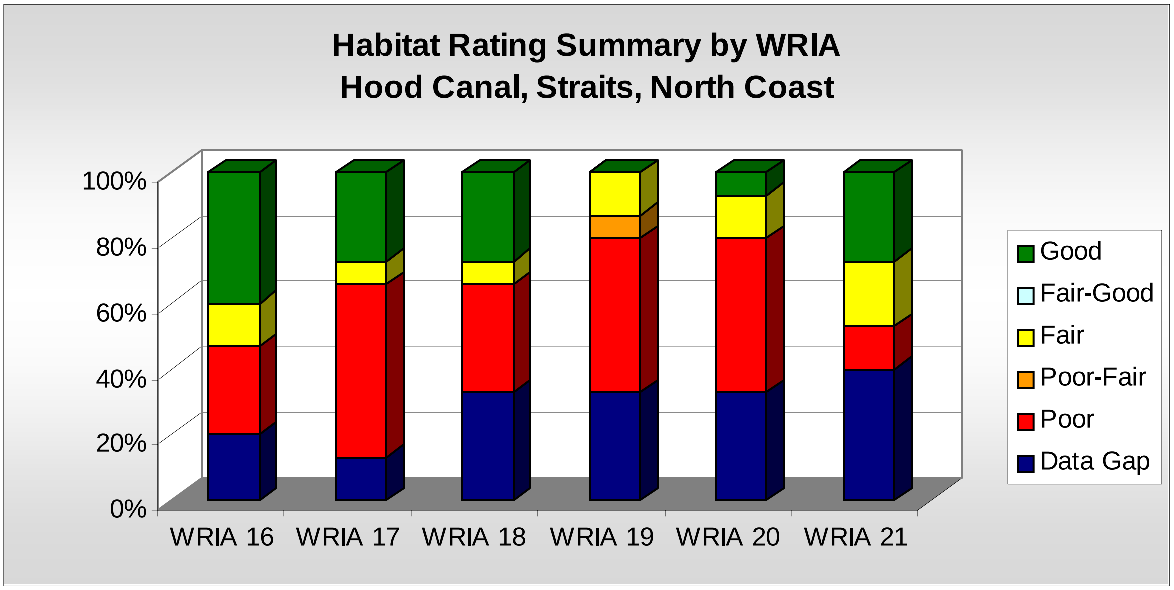
Figure 35. Summary of habitat conditions in WRIAs 8-15 (WRIAs 8=Lake Washington, 9=Green, 10=Puyallup, 11=Nisqually, 12=Chambers, 13=Deschutes, 14=Kennedy, 15=Kitsap).



Better habitat conditions are found from West Hood Canal through the North Coast areas with the exception of Hoko (WRIA 19) and the North Coast (WRIA 20) (Figure 36). However, the ratings for the North Coast are likely biased towards poor because few data were available in the upper basins on National Park Service land. These areas are likely excellent, but were listed as data gaps. Another important consideration is that much of the good rated area in the Elwha WRIA is currently inaccessible to salmon because of the dams in the Elwha River.

As a group, 38% of the wild salmonid stocks in this area are healthy, 31% are unknown, and 31% are not healthy. Hoko is the WRIA with the greatest percentage of poor habitat conditions, and has the greatest percentage of healthy stocks (56%) with only 6% depressed or critical stocks. The percentage of healthy stocks is quite high in several other WRIAs in this area such as West Hood Canal and the North Coast (55%) and Queets/Quinault (35% with a high percentage of unknown stock status). In contrast, only 20% of the wild stocks in Quilcene are healthy, and none are healthy in the Elwha/Dungeness WRIA. The percentage of depressed or critical stocks is very low in the North Coast (0%) and Queets/Quinault (15%), but higher in West Hood Canal (35%), Quilcene (40%), and Elwha/Dungeness (55%).

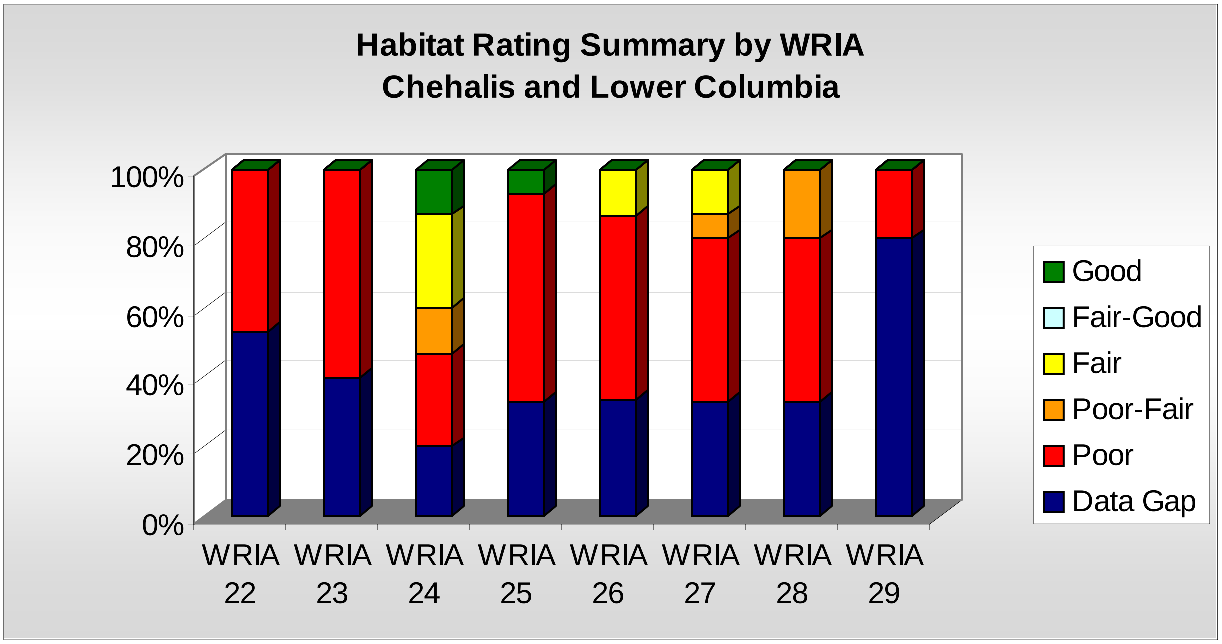
Figure 36. Summary of habitat conditions from WRIA 16-21 (WRIAs 16=West Hood Canal, 17=Quilcene, 18=Dungeness/Elwha, 19=Hoko, 20=North Coast, and 21=Queets/Quinault).



Habitat conditions are worse in the south coast through lower Columbia WRIAs (Figure 37). Predominantly poor habitat conditions exist throughout these WRIAs with the exception of the Willapa (WRIA 24), which has approximately equal fair to good habitat ratings as poor and poor-fair ratings. The Wind/White Salmon WRIA (29) has mostly unknown habitat conditions.

While 51% of wild stocks in the south coast WRIAs (Chehalis and Willapa) are healthy, only 7% are healthy in the lower Columbia WRIAs. Fifty-five percent of the lower Columbia wild salmonid stocks are depressed or critical, compared to 26% in the south coast. By WRIA, 69% of the wild stocks are healthy in the Willapa, followed by 39% in the Chehalis, 25% in Lewis, and none in the Grays, Cowlitz, Washougal, and Wind/White Salmon Basins. Depressed or critical stocks comprised 86% of the wild stocks in Grays, 83% in the Cowlitz, 39% in Chehalis, 38% in Lewis, 25% in Washougal and Wind/White Salmon, and only 8% of the Willapa.

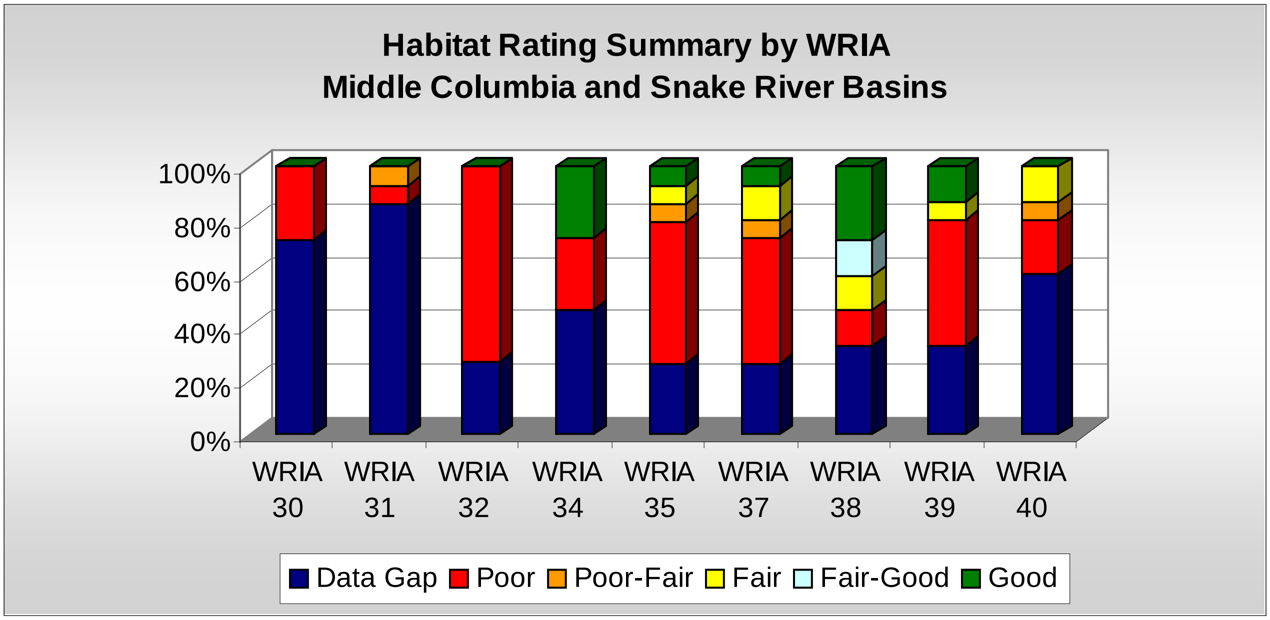
Figure 37. Summary of habitat conditions in WRIAs 22-29 (WRIAs 22-23=Chehalis, 24=Willapa, 25=Grays, 26=Cowlitz, 27=Lewis, 28=Salmon/Washougal, and 29=Wind/White Salmon).



In the middle Columbia and Snake River regions, three WRIAs have mostly unknown habitat conditions. These are the Klickitat, Rock/Glade, and Alkali WRIAs (30, 31, and 40) (Figure 38). Of the remaining WRIAs, mostly poor conditions are found in the Walla Walla, Middle Snake, Lower Yakima, and Upper Yakima WRIAs (WRIAs 32, 35, 37, 39) with mostly good conditions in the Naches WRIA (38) and a mix of good and poor conditions in Palouse (WRIA 34).

Depressed or critical salmonid stocks comprise 100% of the Snake River wild stocks and 38% of the middle Columbia wild stocks. No wild salmonid stocks are healthy in the Snake/Walla Walla Basin, and only 25% are healthy in the middle Columbia region. By WRIA, the status of wild healthy stocks is dismal with 33% in the Klickitat, 25% in the Yakima, and none in the remaining WRIAs (31-35). Many of the wild stocks are of unknown status, but all are depressed or critical in the Snake Basin and 75% are depressed or critical in the Yakima Basin.

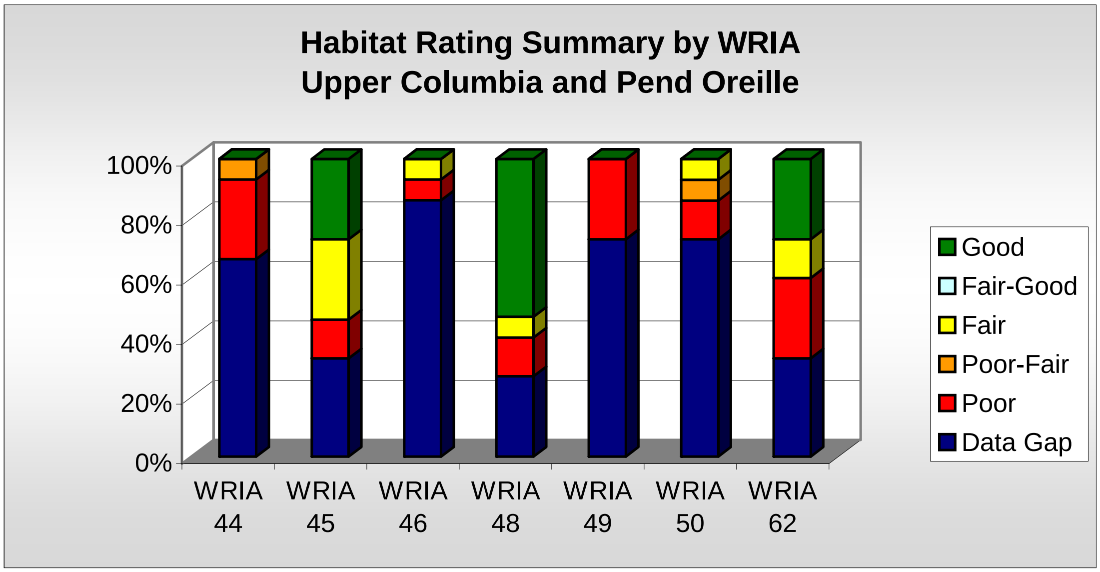
Figure 38. Summary of habitat conditions in WRIAs 30-40 (WRIAs 30=Klickitat, 31=Rock, 32=Walla Walla, 34=Palouse, 35=Middle Snake, 37=Lower Yakima, 38=Naches, and 39=Upper Yakima).



Habitat conditions in the upper Columbia and Pend Oreille are largely unknown or good (Figure 39). Unknown conditions are found in Moses Coulee, Entiat, Okanogan, and Foster WRIAs (WRIAs 44, 46, 49, and 50). Good and fair conditions make up most of the Wenatchee Basin, and good conditions in the Methow Basin. Pend Oreille consists of approximately equal amounts of poor and good/fair ratings.

Stock status does not relate to freshwater habitat conditions in this area. While habitat conditions are fair to good in the Wenatchee and Methow basins, no wild stocks in the upper Columbia are healthy and 90% are either depressed or critical. The reason for this is likely due to cumulated mortality that occurs at each dam in the mainstem Columbia.

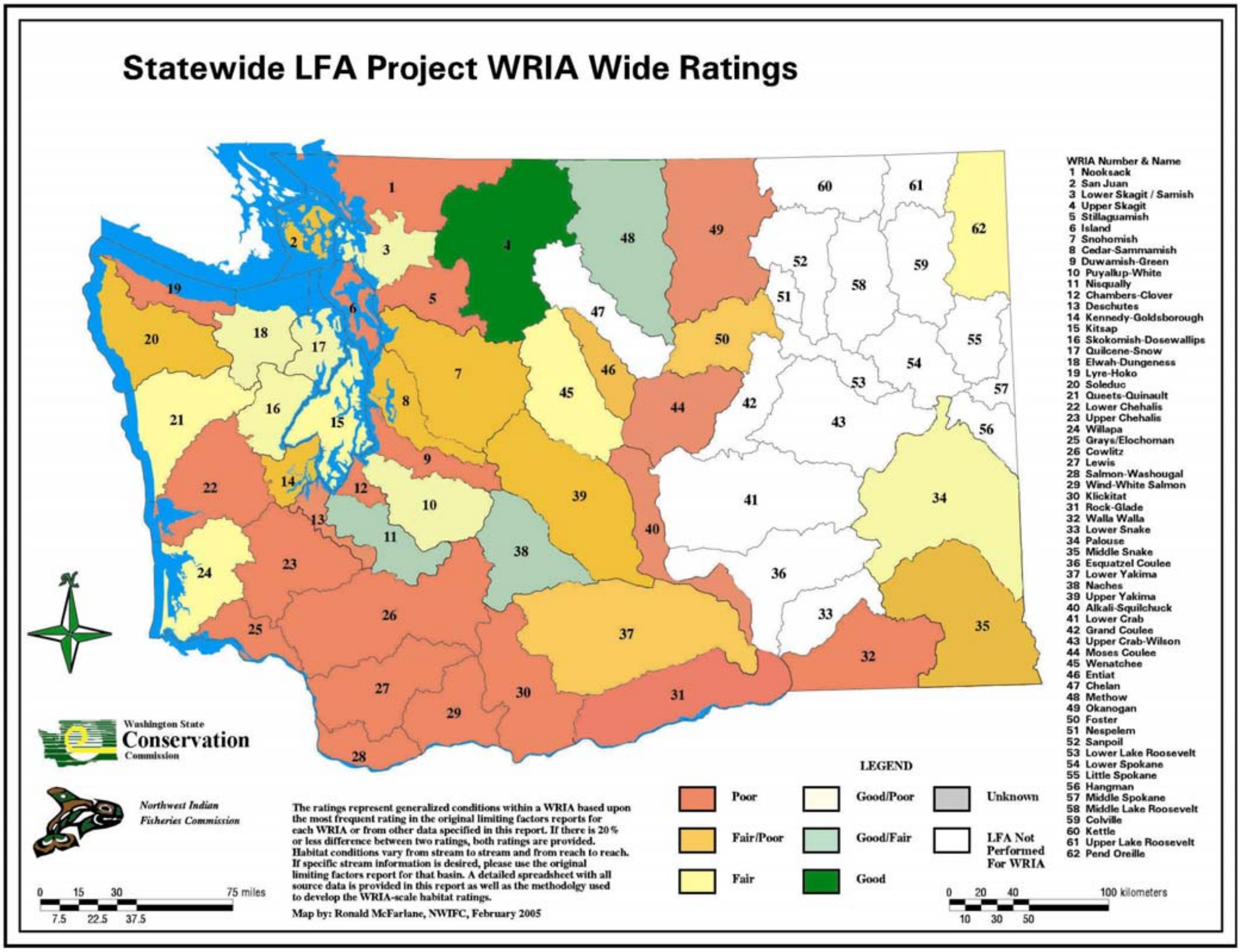
Figure 39. Summary of habitat conditions in WRIAs 44-62 (WRIAs 44=Moses Coulee, 45=Wenatchee, 46=Entiat, 48=Methow, 49=Okanogan, 50=Foster, and 62=Pend Oreille).



WRIAs Sorted by Habitat Ratings

Table 5 lists all salmon and steelhead producing WRIAs sorted by overall habitat condition in descending order. Only one WRIA (Upper Skagit) had overall good habitat ratings in all categories that were not data gaps. Methow, Naches, and Nisqually had an overall fair-good rating with 11 additional basins rating fair overall. Ten basins rated poor-fair, but most (20) basins rated poor (Figure 40). However, please note the concerns discussed above for some of the ratings, especially the probable negative bias for the north coast and the lack of access to good habitat in the Elwha River.

Figure 40. Overall WRIA-wide ratings based upon the total score of habitat conditions in Table 5.

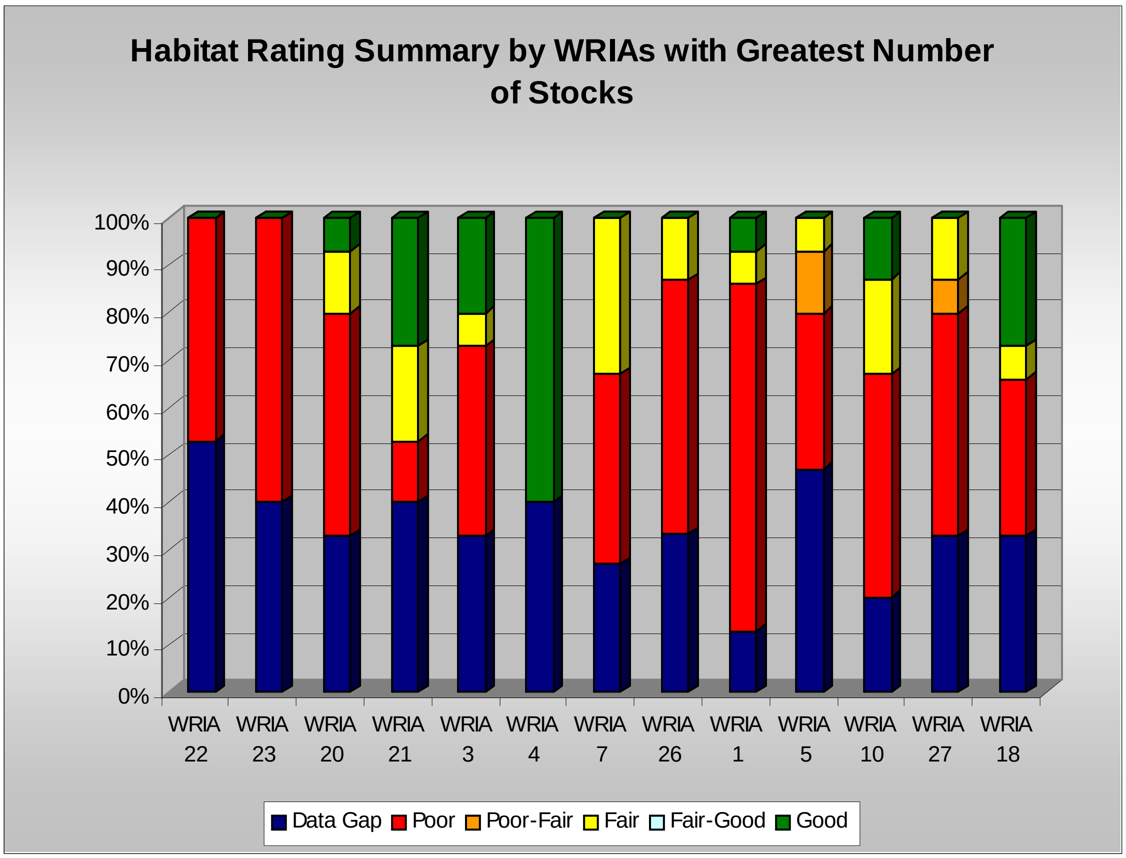


WRIAs Sorted by Salmonid Stock Results

The stock status chapter discussed the relative differences of stock quantity and chinook abundance between drainages. The drainages that produce the greatest number of total salmon and steelhead stocks are (in descending order): Chehalis, Quillayute, Skagit, Snohomish, Cowlitz, Nooksack, Queets, Stillaguamish, Puyallup, Quinault, Lewis, and Dungeness. Queets and Quinault comprise a single WRIA and because both drainages are in the group of top stock producers and the habitat data are by WRIA, the stock numbers were combined for the graph below. Figure 41 illustrates the general habitat conditions of the state's basins that contribute the greatest number of salmon and steelhead stocks.

Most of the state's best producers of salmon and steelhead stocks have generally poor habitat conditions with five having an overall poor habitat rating (Chehalis, Cowlitz, Nooksack, Stillaguamish, and Lewis). Two rated poor-fair (Snohomish and Quillayute) although the Quillayute rating is likely biased low because of a lack of habitat data from federal land (probable good habitat) in this basin. Four drainages rated fair (Queets, Quinault, Dungeness, and Puyallup) and Skagit rated fair-good. These data suggest that to maintain genetic diversity of salmon and steelhead in Washington State, it is important to improve habitat conditions in these drainages.

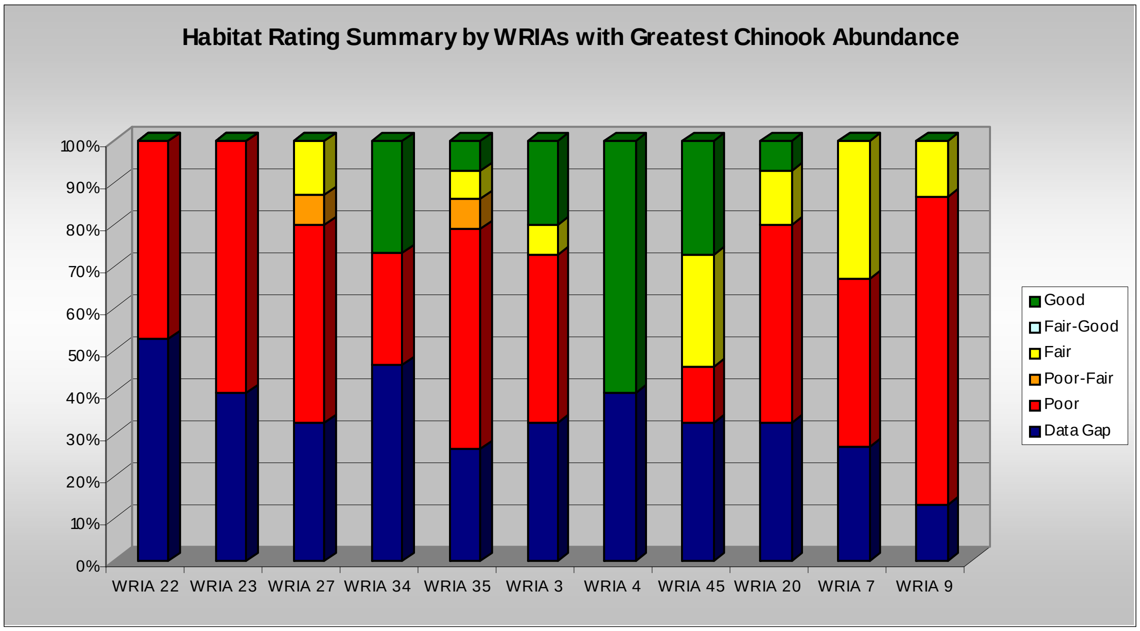
Figure 41. Habitat ratings by WRIA for the drainages with the greatest number of salmon and steelhead stocks. For a list of WRIA names with number, see the legend in Figure 40.



WRIAs were also sorted by the number of chinook salmon produced, which resulted in the following basins having the greatest abundance: Chehalis, Lewis, Snake, Skagit, Wenatchee, Quillayute, Snohomish, and Green. When these drainages are sorted out, an even higher percentage of the basins have poor habitat conditions (Chehalis, Lewis, Middle Snake, and Green) (Figure 42).

As discussed in the stock status chapter, chinook abundance was used because it better represented more of the state compared to other species and because there is generally more and higher quality data associated with the escapement estimates. Few data exist for char, cutthroat, and steelhead across the state, and pink, chum, and wild coho abundance would greatly under-represent the Columbia River salmon production. In addition, coho estimates are mostly based upon index counts and are rarely counted throughout their range in a particular stream.

Figure 42. Habitat ratings by WRIA for drainages with the greatest abundance of chinook salmon. For a list of WRIA names with number, see the legend in Figure 40.



Salmon Habitat Ratings by Recovery Region

When all ratings are combined for salmon recovery regions, much of the interesting variability is lost (Figure 43). By region, the lower Columbia has the least percentage of good ratings, while the Snake River Basin has the greatest percentage of poor ratings. More data gaps exist in the middle and upper Columbia regions than elsewhere in the state.

Figure 43. Summary of habitat conditions by salmon recovery region.

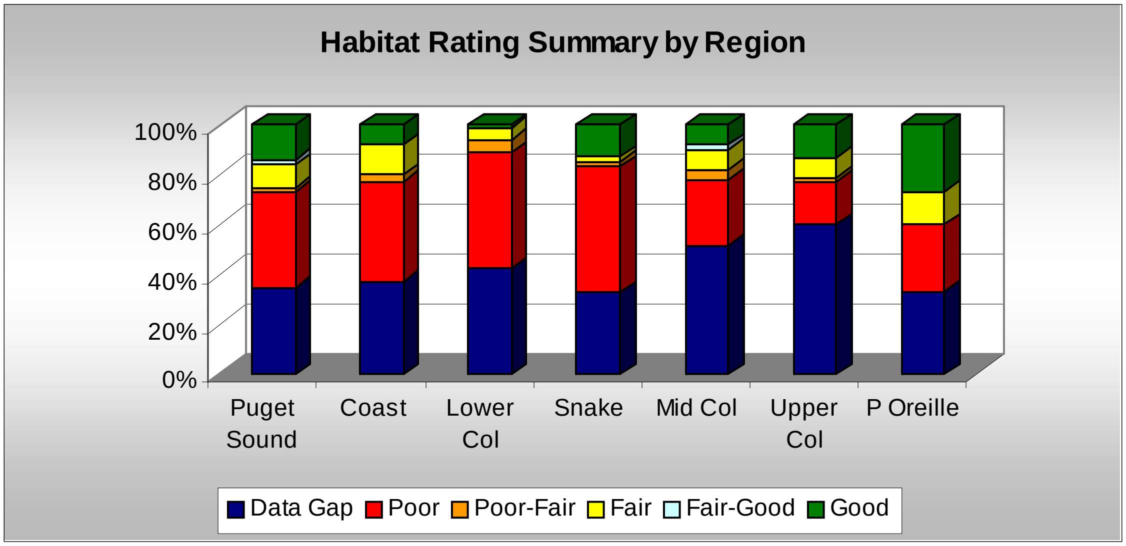


Table 4. Statewide habitat limiting factors results by WRIA.

Stream	Access	Side-Channel Floodplain	Sediment Quantity	Sediment Quality	Road Density	Bank/ Streambed/ Channel Stability	Instream LWD	Pool Habitat	Riparian	Water Quality Water Temp	Dissolved Oxygen	Other Nutrients Toxins, pH	Hydro Maturity High Flows	Impervious Surfaces	Low Flows
WRIA 1	DG	Poor	Poor	Poor	Poor	Poor	Poor	DG	Poor	Poor	Poor-Good	Poor	Poor	Good	Poor
WRIA 2	DG	NA	DG	DG	DG	DG	DG	DG	Poor	Good-Fair	DG	DG	DG	DG	Poor
WRIA 3	Good	Poor	Poor	DG	Fair	DG	DG	DG	Poor	Poor	Good	Poor	Poor	Good	DG
WRIA 4	Good	Good	Good	DG	Good	DG	DG	DG	Good	Good	Good	DG	Good	Good	DG
WRIA 5	DG	DG	Poor	DG	Fair	DG	Fair-Poor	Fair-Poor	Poor	Poor	DG	DG	Poor	DG	Poor
WRIA 6	Poor	Poor	DG	DG	DG	DG	DG	DG	Poor	DG	DG	DG	DG	DG	DG
WRIA 7	Poor	Poor	DG	Fair	Fair	DG	Poor	Poor	Poor	Good-Poor	DG	DG	Fair	Fair	Poor
WRIA 8	Poor	Poor	DG	DG	Poor	Fair	Poor	Poor	Poor	Good	DG	DG	Poor	Poor	Poor
WRIA 9	Poor-Good	Poor	Poor	Poor	Poor	Poor	Poor	DG	Poor	Poor	Poor	Poor-Good	Poor	DG	Poor
WRIA 10	Good	Good	Poor	DG	Poor	Poor	Poor	Poor	Poor	Fair	DG	DG	Poor	Poor-Good	Poor-Good
WRIA 11	Good	Good-Fair	DG	Fair	Poor	Fair-Good	Poor	Fair	Fair	Good	DG	Good	Good	DG	Good
WRIA 12	Poor	Poor	DG	DG	Poor	DG	DG	DG	Poor	DG	DG	Poor	Poor	Poor	Poor
WRIA 13	Fair	DG	DG	Fair-Poor	Poor	Poor	Poor	Poor	Fair-Poor	DG	DG	DG	Poor	DG	DG
WRIA 14	Fair-Poor	Poor	DG	Poor	Poor	Poor	Poor	Poor-Fair	Poor	DG	Good	DG	DG	DG	DG
WRIA 15	Poor	Good-Poor	DG	Fair	Poor	Fair-Good	Poor	Poor	Fair	Good	DG	DG	Poor	DG	DG
WRIA 16	Good	Poor	Good-Poor	DG	Good	Good-Poor	Poor	Poor	Good	Good	DG	DG	Good	Good	DG
WRIA 17	Good	Poor	Poor	DG	Poor	Good	Poor	Poor	Poor	Fair	Good	DG	Poor	Good	Poor
WRIA 18	Fair	Poor	DG	Poor	Good	DG	Poor	Poor	Good	Good	DG	DG	Good	DG	Poor

Stream	Access	Side-Channel Floodplain	Sediment Quantity	Sediment Quality	Road Density	Bank/ Streambed/ Channel Stability	Instream LWD	Pool Habitat	Riparian	Water Quality Water Temp	Dissolved Oxygen	Other Nutrients Toxins, pH	Hydro Maturity High Flows	Impervious Surfaces	Low Flows
WRIA 19	Fair-Poor	Poor	Poor	Poor	Fair	Poor	Poor	DG	Poor	Poor-Good	DG	DG	Poor	DG	DG
WRIA 20	DG	Poor	Poor	Poor	Fair	Poor	Poor	Good	Poor	Poor	DG	DG	Fair	DG	DG
WRIA 21	DG	Poor	DG	DG	Good	DG	Fair	Fair	Fair	Poor	Good	DG	Good	DG	Good
WRIA 22	DG	Poor	Poor	Poor	Poor	DG	DG	DG	Poor	Poor	DG	DG	Poor	DG	DG
WRIA 23	DG	Poor	Poor	Poor	Poor	DG	Poor	DG	Poor	Poor	DG	DG	Poor	DG	Poor
WRIA 24	Poor-Good	Fair-Poor	Poor	Poor-Good	Poor	DG	Poor	Fair-Poor	Fair	Poor	Good	DG	Poor-Good	DG	Good
WRIA 25	Poor	Poor	DG	Poor	Poor	Good	Poor	Poor	Poor	Poor	DG	DG	Poor	DG	DG
WRIA 26	Good-Poor	Poor	DG	Poor	Poor	Poor-Good	Poor	Poor	Poor	Poor	DG	DG	Poor	DG	DG
WRIA 27	Good-Poor	Poor	DG	Poor	Poor	Fair-Poor	Poor	Fair	Poor	Poor	DG	DG	Poor	DG	DG
WRIA 28	Poor-Good	Poor	DG	Poor	Fair	Fair	Poor	Poor	Poor	Poor	DG	DG	Poor	DG	DG
WRIA 29	DG	DG	DG	Poor	DG	DG	Poor	DG	Poor	DG	DG	DG	DG	DG	DG
WRIA 30	DG	Poor	DG	DG	DG	DG	DG	DG	Poor	Poor	DG	DG	DG	DG	Poor
WRIA 31	DG	Poor-Fair	DG	DG	DG	DG	DG	DG	DG	Poor	DG	DG	DG	DG	DG
WRIA 32	Poor	Poor	DG	Poor	DG	Poor	Poor	Poor	Poor	Poor	DG	Poor	Poor	DG	Poor
WRIA 34	Good	Poor	DG	Poor	DG	Good	Poor	Poor	Good	DG	DG	DG	DG	DG	Good
WRIA 35	Good	Poor-Fair	DG	Poor	DG	Poor	Poor	Poor	Poor	Poor	DG	Poor	Good	DG	Poor-Good
WRIA 37	Poor	Poor	DG	Poor-Good	DG	DG	Poor	Good	Poor-Fair	Poor	Poor	Poor	Fair	DG	Poor
WRIA 38	Poor-Good	Good	DG	Good-Fair	DG	DG	Good	Fair	Good	Poor	DG	Good	Fair-Good	DG	Poor
WRIA 39	Poor	Poor	DG	Poor	DG	DG	Poor	Poor	Fair	Poor	DG	Good	Good	DG	Poor
WRIA 40	Poor	Fair-Poor	DG	DG	DG	DG	Poor	DG	Fair	DG	DG	DG	Fair	DG	Poor

Stream	Access	Side-Channel Floodplain	Sediment Quantity	Sediment Quality	Road Density	Bank/ Streambed/ Channel Stability	Instream LWD	Pool Habitat	Riparian	Water Quality Water Temp	Dissolved Oxygen	Other Nutrients Toxins, pH	Hydro Maturity High Flows	Impervious Surfaces	Low Flows
WRIA 44	Poor	Poor	Poor	DG	DG	DG	DG	DG	Fair-Poor	DG	DG	DG	DG	DG	Poor
WRIA 45	Good	Good-Poor	DG	Poor-Good	DG	Good	Poor	Poor-Good	Fair	Good	DG	DG	Good	DG	Poor
WRIA 46	DG	DG	DG	Fair	DG	DG	DG	DG	DG	Poor	DG	DG	DG	DG	DG
WRIA 48	Good	Good	Poor	Good	DG	DG	Good-Poor	Good	Good	Good	DG	Good	Good	DG	Poor
WRIA 49	Poor	Poor	DG	DG	DG	DG	DG	DG	DG	DG	DG	DG	Poor	DG	Poor
WRIA 50	Poor	Poor	DG	DG	DG	DG	DG	DG	Poor-Fair	DG	DG	DG	Fair	DG	DG
WRIA 62	Good	Good	DG	Poor	Poor	Good	Good	Poor	Fair	Poor	DG	DG	Fair	DG	DG

Table 5. WRIAs sorted by overall habitat ratings in descending order. See detailed spreadsheets in a separate file for ratings details. Numerical ratings of 3=Good, 2=Fair, 1=Poor.

WRIA	Basin	Numerical Rating Access	Numerical Rating Floodplain	Numerical Rating Sediment	Numerical Rating Instream	Numerical Rating Riparian	Numerical Rating Water Quality	Numerical Rating Flow	Rating Numerical Final	Rating Final
WRIA 4	Upper Skagit	3	3	3	DG	3	3	3	3	Good
WRIA 48	Methow	3	3	2	2.5	3	3	2	2.6	Fair-Good
WRIA 38	Naches	2	3	2.5	2.5	3	2	1.8	2.4	Fair-Good
WRIA 11	Nisqually	3	2.5	2	1.5	2	3	3	2.4	Fair-Good
WRIA 45	Wenatchee	3	2	2.5	1.5	2	3	2	2.3	Fair
WRIA 16	W Hood Canal	3	1	2.3	1	3	3	3	2.3	Fair
WRIA 21	Queets/Quinault	DG	1	3	2	2	2	3	2.2	Fair
WRIA 34	Palouse	3	1	2	1	3	DG	3	2.2	Fair
WRIA 62	Pend Oreille	3	3	1.7	2	2	1	2	2.1	Fair
WRIA 18	Elwha	2	1	2	1	3	3	2	2	Fair
WRIA 10	Puyallup/White	3	3	1	1	1	2	1.7	1.8	Fair
WRIA 24	Willapa	2	1.5	1.3	1.3	2	2	2.5	1.8	Fair
WRIA 3	Lower Skagit	3	1	1.5	DG	1	1.7	2	1.7	Fair
WRIA 15	Kitsap	1	2	1.8	1	2	3	1	1.7	Fair
WRIA 17	Quilcene	3	1	1.7	1	1	2.5	1.7	1.7	Fair
WRIA 35	Middle Snake	3	1.5	1	1	1	1	2.5	1.6	Poor-Fair
WRIA 14	Kennedy	1.5	1	1	1.3	1	3	DG	1.5	Poor-Fair
WRIA 46	Entiat	DG	DG	2	DG	DG	1	DG	1.5	Poor-Fair

WRIA 2	San Juan	DG	NA	DG	DG	1	2.5	1	1.5	Poor-Fair
WRIA 37	Lower Yakima	1	1	2	2	1.5	1	1.5	1.4	Poor-Fair
WRIA 7	Snohomish	1	1	2	1	1	2	1.7	1.4	Poor-Fair
WRIA 8	Lake Washington	1	1	1.5	1	1	3	1	1.4	Poor-Fair
WRIA 20	Soleduck/Hoh	DG	1	1.3	2	1	1	2	1.4	Poor-Fair
WRIA 39	Upper Yakima	1	1	1	1	2	2	2	1.4	Poor-Fair
WRIA 50	Foster	1	1	DG	DG	1.5	DG	2	1.4	Poor-Fair
WRIA 13	Deschutes	2	DG	1	1	1.5	DG	1	1.3	Poor
WRIA 19	Hoko/Lyre	1.5	1	1.3	1	1	2	1	1.3	Poor
WRIA 31	Rock/Glade	DG	1.5	DG	DG	DG	1	DG	1.3	Poor
WRIA 40	Alkali	1	1.5	DG	1	2	1	1.5	1.3	Poor
WRIA 1	Nooksack	DG	1	1	1	1	1.3	1.7	1.2	Poor
WRIA 5	Stiilaguamish	DG	DG	1.5	1.5	1	1	1	1.2	Poor
WRIA 9	Green	2	1	1	1	1	1.3	1	1.2	Poor
WRIA 26	Cowlitz	2	1	1.3	1	1	1	1	1.2	Poor
WRIA 27	Lewis	2	1	1.2	1.5	1	1	1	1.2	Poor
WRIA 28	Washougal	2	1	1.7	1	1	1	1	1.2	Poor
WRIA 25	Grays	1	1	1.7	1	1	1	1	1.1	Poor
WRIA 44	Moses Coulee	1	1	1	DG	1.5	1	1	1.1	Poor
WRIA 6	Island	1	1	DG	DG	1	DG	DG	1	Poor
WRIA 12	Chambers	1	1	1	DG	1	1	1	1	Poor
WRIA 22	Lower Chehalis	DG	1	1	DG	1	1	1	1	Poor
WRIA 23	Upper Chehalis	DG	1	1	1	1	1	1	1	Poor

WRIA 29	Wind/White Salmon	DG	DG	1	1	1	DG	DG	1	Poor
WRIA 30	Klickitat	DG	1	DG	DG	1	1	1	1	Poor
WRIA 32	Walla Walla	1	1	1	1	1	1	1	1	Poor
WRIA 49	Okanogan	1	1	DG	DG	DG	DG	1	1	Poor

STATEWIDE SALMONID ACCESS CONDITIONS

This chapter focuses on human-caused barriers that prevent access of salmonids to spawning or rearing habitat. While natural features of the landscape such as channel gradient, waterfalls, and logjams, can limit salmon access, they are not discussed in this chapter because they are natural conditions. The most common artificial obstructions include dams and culverts, which can completely block or partially restrict salmonid migration up and down streams. Depending on the location and longevity of the barrier, the negative effect may be limited to one stage of only one generation, or in extreme cases, the barrier may cause the extinction of an entire run of fish.

Salmon access to habitat can also be affected by flows. Very low flows can act as a barrier, while high flows can allow better passage at some waterfalls. The effect of flows varies with the species of salmon as well. Flow impacts to salmon habitat are included in this chapter when flow is altered by human causes and poses a barrier to salmonids.

Because none of the individual limiting factor reports covered the mainstem Columbia River, it will not be discussed in this report. However, readers are encouraged to review other literature sources for migration impacts from the numerous dams on the Columbia River, and consider their overall impact to stocks that spawn and rear in tributary systems upstream of such dams.

Out of 45 Watershed Resource Inventory Areas (WRIAs), 38% have an overall poor rating for salmonid access conditions with 32% rating good, 24% fair, and 6% rating fair-poor (Figure 44). Good and poor rated WRIAs were evenly distributed between the east and west side of the state (Figure 45).

Figure 44. Salmonid access ratings by WRIA.

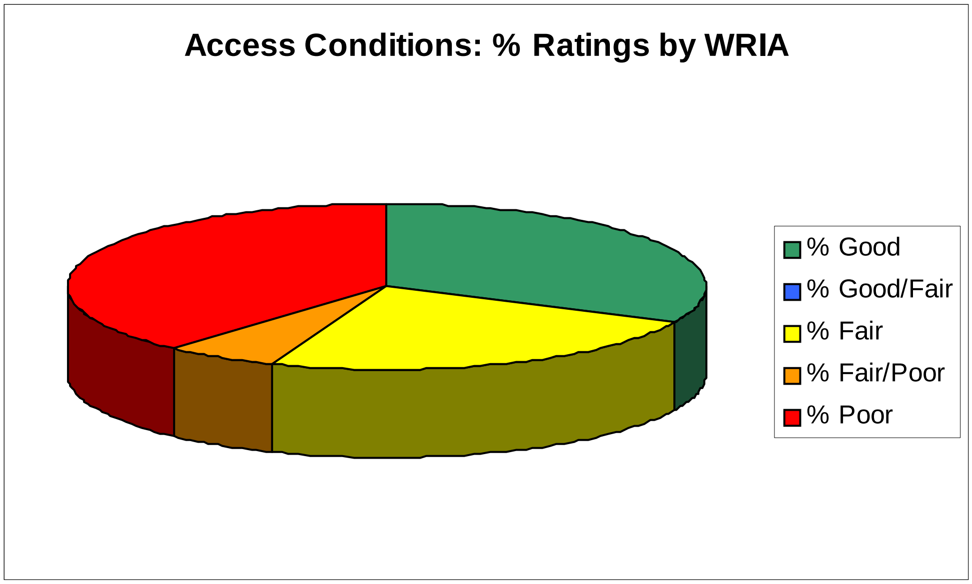
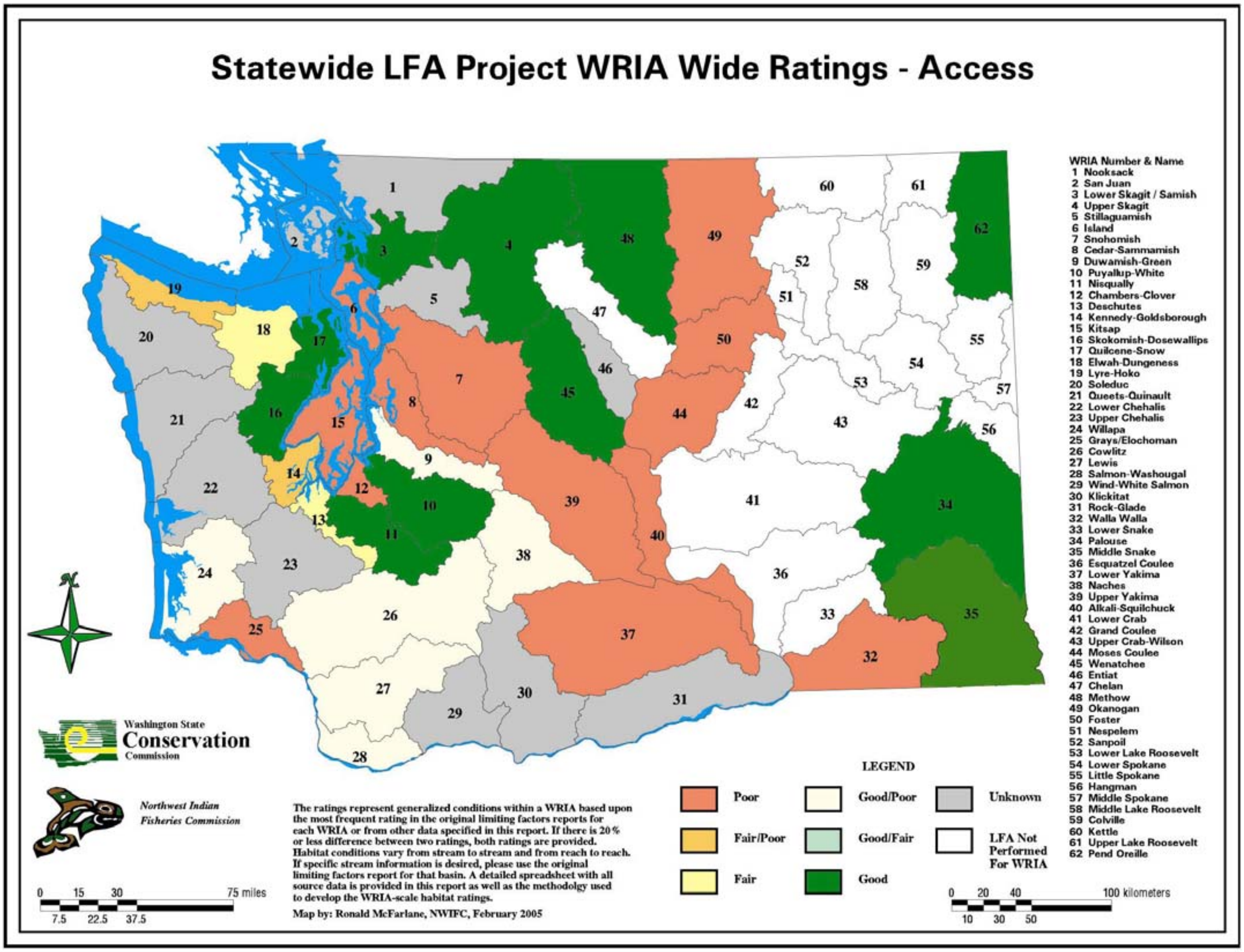


Figure 45. Map of salmonid access ratings by WRIA throughout the State.



Land Ownership

WRIAs consisting of 50% or more of federal lands had only fair or good ratings for access conditions (Figure 46). None of these WRIAs rated poor. However, fair and good ratings were also found in WRIAs with lower percentages of federal lands. While better access conditions were generally found in WRIAs with higher percentages of federal owned lands, the opposite may be the case for state-owned lands. All of the good rated WRIAs and all but one of the fair ratings were in WRIAs that had less than 15% state-ownership (Figure 47). Low percentages of state-owned land did not guarantee better access conditions though because poor ratings were scattered throughout all percentages of state-owned land. There appears to be no relationship between access conditions and private land ownership (Figure 48).

Figure 46. Salmonid access conditions based upon federal land ownership.

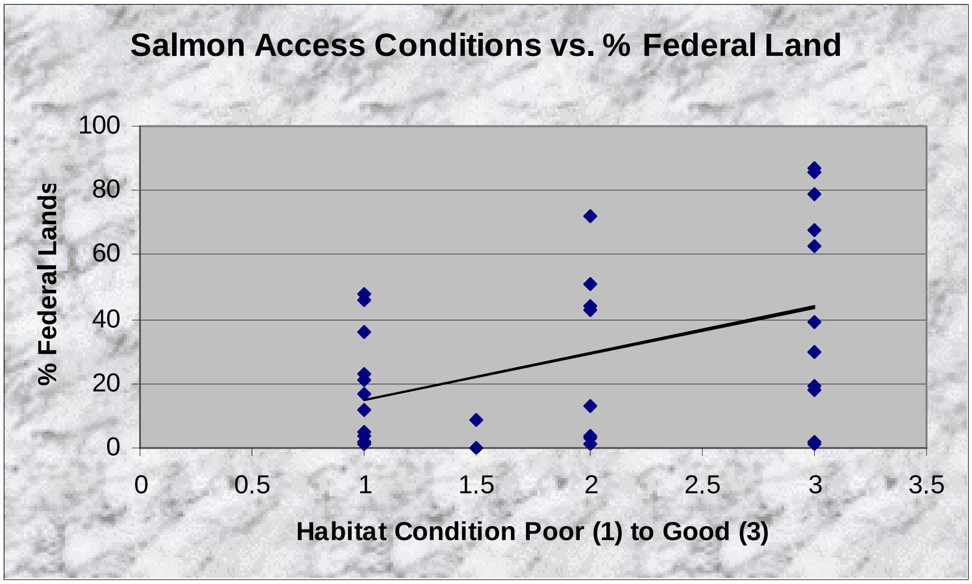


Figure 47. Salmonid access conditions based upon state land ownership.

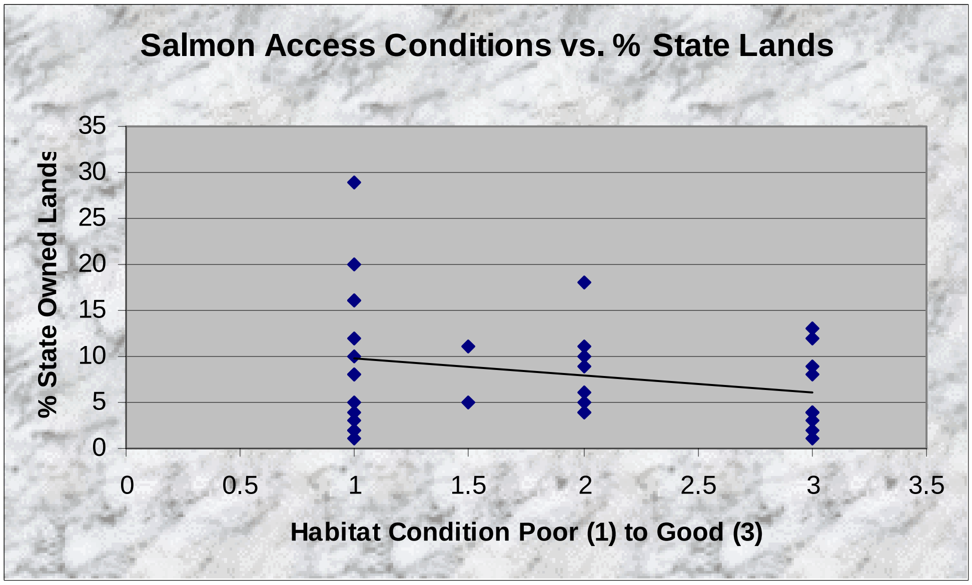
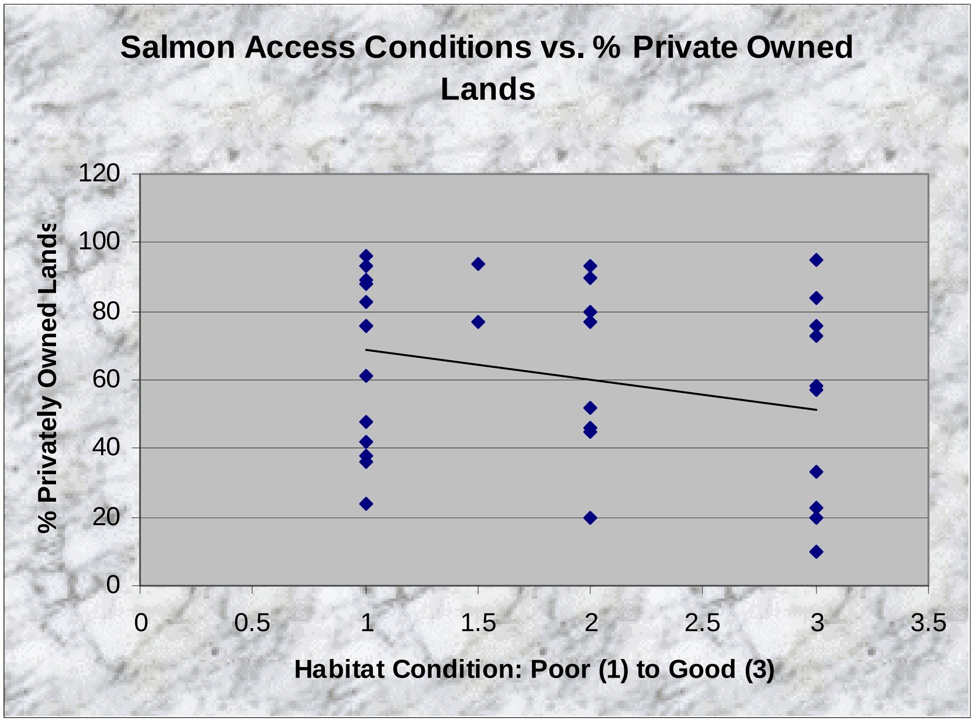


Figure 48. Salmonid access conditions based upon private land ownership.



Land Use

Land use data show some interesting patterns. With two exceptions, all fair and good rated WRIAs have 60% or greater forestry as its land use (Figure 49). The exceptions are Palouse and middle Snake, which are WRIAs primarily dominated by agriculture (Palouse has naturally very limited salmon access due to a waterfall on the mainstem). However, poor rated WRIAs were found throughout all percentages of forestland. Although many of the fair or good rated forestry dominated WRIAs also had a high percentage of federal ownership, several did not, such as Nisqually, Kitsap, Willapa, Quilcene, and Puyallup. Active local recovery efforts in Kitsap and Puyallup have improved access conditions in recent years.

All but two (Palouse and middle Snake) of the agriculturally dominated (50% or more agricultural or range land) WRIAs have poor access conditions (Figure 50). All high urban and high population density WRIAs had poor access conditions, although the sample size was low (Figures 51 and 52).

Figure 49. Salmonid access conditions based upon forestry land use.

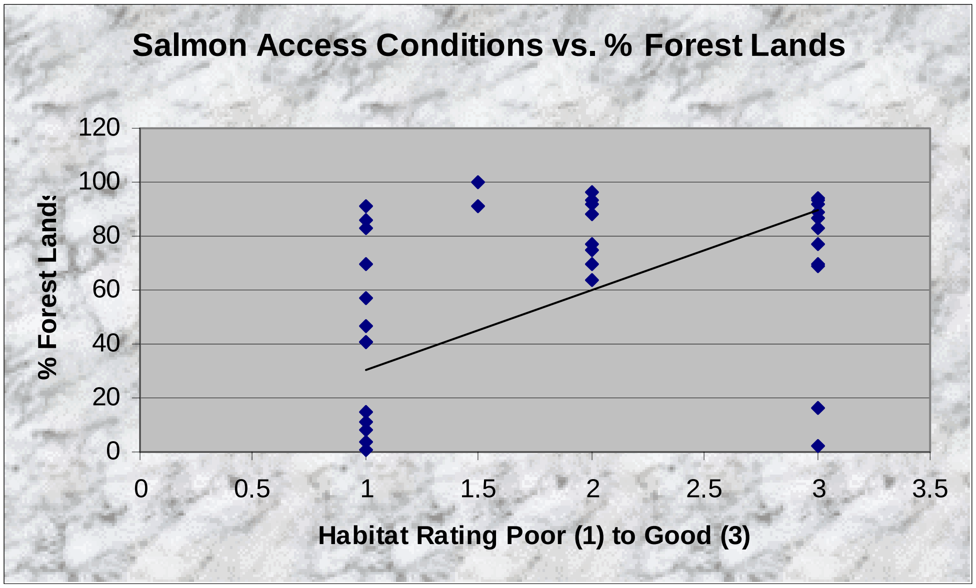


Figure 50. Salmonid access conditions based upon agricultural land use.

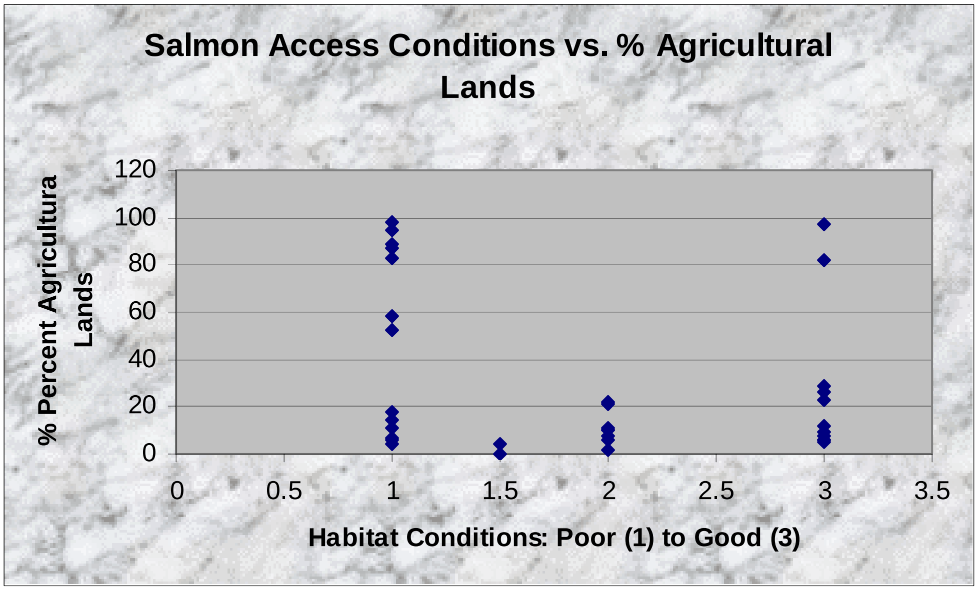


Figure 51. Salmonid access conditions based upon urban land use.

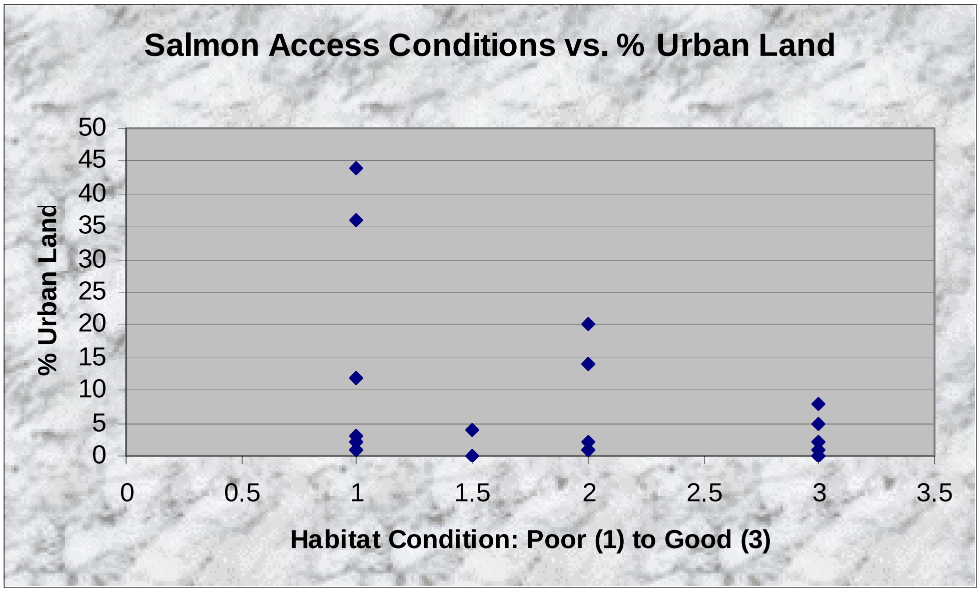
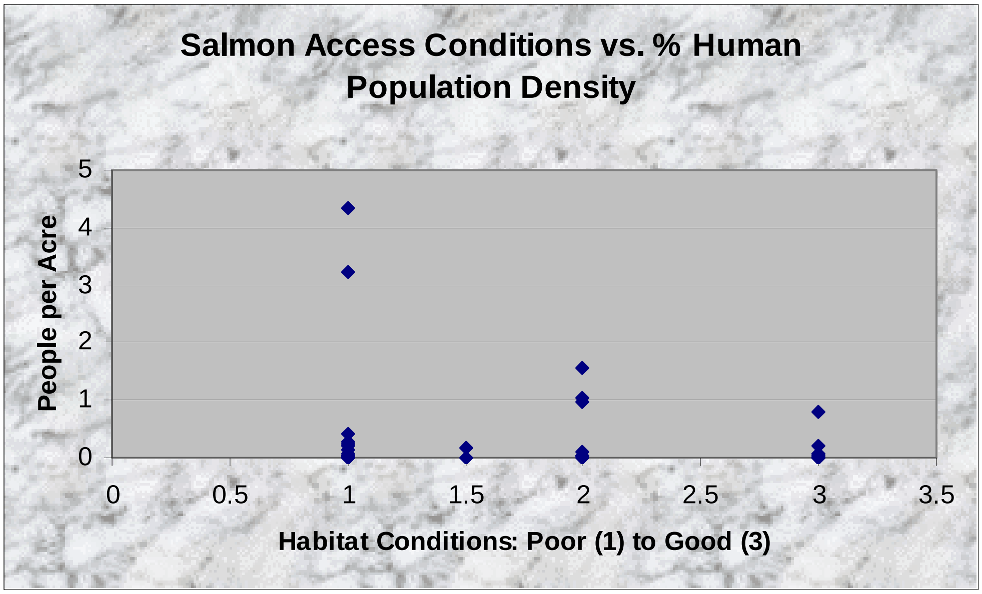


Figure 52. Salmonid access conditions based upon population density.



Data Gaps in Salmonid Access Conditions

Eleven WRIAs have insufficient data to develop a rating for salmon access conditions with four of these WRIAs located along the coast. The WRIAs that are greatly lacking access data are: Nooksack, Stillaguamish, Soleduck/Hoh, Queets, Chehalis (lower and upper), Entiat, Wind/White Salmon, Klickitat, and the Rock/Glade WRIA. Survey efforts are underway in the two Chehalis WRIAs.

Most of the other WRIAs in the state need additional data to develop a complete barrier database or need further analysis to prioritize the data that exist. These WRIAs include: Skagit (lower and upper), Island, Snohomish, Green, Puyallup, Nisqually, Deschutes, Elwha, western Straits, Willapa, Grays, Cowlitz, Lewis, Squilchuck, Washougal, Walla Walla, Snake, Palouse, Alkali, Moses Coulee, Foster, Wenatchee, Methow, and Okanogan.

STATEWIDE SALMONID FLOODPLAIN CONDITIONS

Introduction

Floodplain Function and Types of Impacts

Floodplains are relatively flat areas adjacent to larger streams and rivers that are periodically inundated during high flows. In a natural state, they allow for the lateral movement of the main channel and provide storage for floodwaters, sediment, macroinvertebrate production (food), and large woody debris (LWD). Floodplains generally contain numerous sloughs, side-channels, and other features that provide important spawning habitat, rearing habitat, and refugia during high flows (Benda et al. 2001), and may be used by rearing salmonids for long periods of time depending upon the species. Off-channel areas provide an abundance of food with fewer predators than would typically be found in the river, and provide habitat for juvenile salmonids to hide from predators and conserve energy (Sandercock 1998). The importance of floodplain habitat to salmonids cannot be overstated. In the Skagit and Stillaguamish Basins, more than half of the total salmonid habitat is contained within the floodplain and estuarine deltas, while this habitat encompasses only 10% of the total basin area (Beechie et al. 2001).

Functional floodplains also moderate high flows by substantially increasing the area available for water storage (Ziemer and Lisle 2001). Water seeps into the groundwater table during floods, recharging wetlands, off-channel areas, and shallow aquifers. Wetlands and aquifers in turn release water to the stream during the summer months through a process called hydraulic continuity (Water Facts Group 1997). This process ensures adequate flows for salmonids during the summer months, and reduces the possibility of high-energy flood events that can destroy salmonid redds (nests) during the winter months. Floods are a natural process that is important for maintaining stream function. Flood flows flush fine sediment from spawning gravel, create pools and riffles by reshaping the streambed, deposit fine sediment on the floodplain, and move large woody debris from the floodplain to the stream channel (Benda et al. 2001). However, frequent catastrophic floods are not a natural phenomenon. These events are typically caused by human-induced changes in watershed cover such as extensive logging, high road densities, or river channel changes (Ziemer and Lisle 2001).

Floodplain impacts include the direct loss of aquatic habitat from human activities (filling), disconnection of main channels from floodplains with dikes, levees, revetments, and roads, and impeding the lateral movement of flood flows with dikes, roads, levees, and revetments. Floodplain disconnection can also result from channel incision caused by changes in hydrology or sediment inputs. The loss of LWD can lead to channel incision and a loss of side channel habitat, while bank hardening hinders lateral migration that recruits LWD. The loss of large wood has contributed to the disruption of natural processes that create and sustain floodplain habitat.

Out of 41 WRIAs with overall floodplain ratings in Washington State, 71% had generally poor floodplain conditions. Fair-poor conditions accounted for 10% of the rated WRIAs, while fair conditions comprised only 5%. Good and good-fair conditions were 12 and 2% of the WRIAs, respectively (Figure 53). The poor-rated WRIAs were distributed across the salmon producing regions in the state, while the good-rated WRIAs were those with significant forestland in the uplands (Figure 55). One of the good rated WRIAs (Puyallup/White) has a highly degraded floodplain in the lower reaches, but good floodplain ratings in most other areas in the basin have masked the poor conditions downstream when developing the WRIA-wide rating. This is an example of how conditions vary across the WRIA and even within a single stream, and readers are cautioned that the results discussed in this report are on a broad scale only. Finer scale ratings can be found in the individual limiting factors reports. The remaining good rated basins for floodplain conditions are upper Skagit, Methow, Pend Oreille, and Naches. The fair-good rated basin is Nisqually, and the fair rated basins are Wenatchee and Kitsap.

Data were also compared for Type 1 only streams within a WRIA. These are the largest streams in basin, specifically defined as "all waters within their ordinary high water marks that have been inventoried as "shorelines of the state" under chapter 90.58 RCW (Shoreline Management Act)". An example of one of the smaller Type 1 streams is Boise Creek in the White River Basin. When ratings from the Type 1 streams were examined, the Puyallup/White WRIA changes from good to poor for floodplain conditions. Other WRIAs with different results for Type 1 streams are: the Green and Elwha Basins, whose ratings changed slightly from poor to fair-poor; Kennedy and Lower Yakima upgraded from poor to fair; Naches downgraded from good to poor-fair; and the Methow Basin decreased from good to fair. All of the others remained the same. Overall, these changes slightly downgraded the results with fewer good ratings and more fair or fair-poor ratings (Figure 54). Comparing overall results to just Type 1 streams indicates whether the problems are in all types of streams, mostly the larger streams, or mostly the smaller streams. Floodplain problems in the larger streams will impact all species, while impacts in only small streams will more greatly affect coho salmon and trout.

Figure 53. Floodplain ratings by WRIA across Washington State.

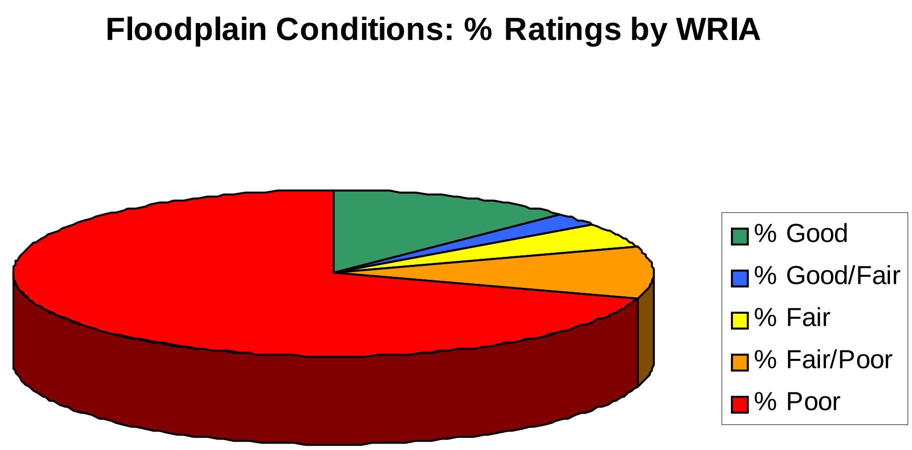


Figure 54. Floodplain conditions in Type 1 streams by WRIA.

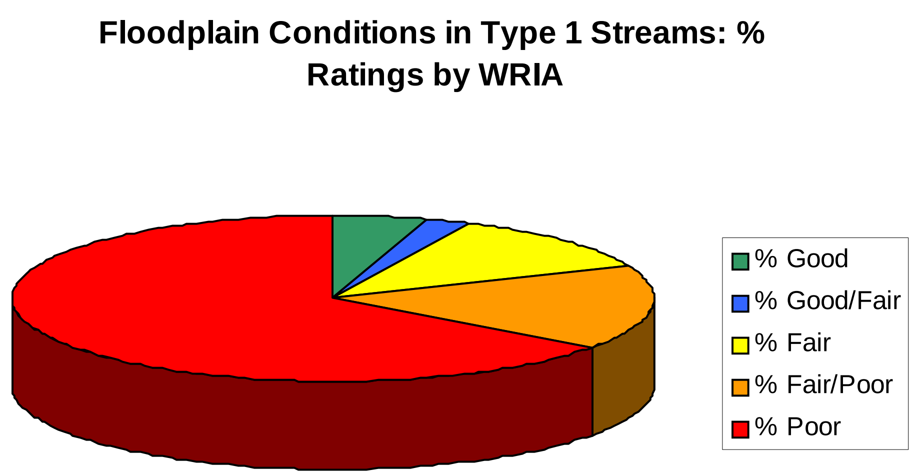
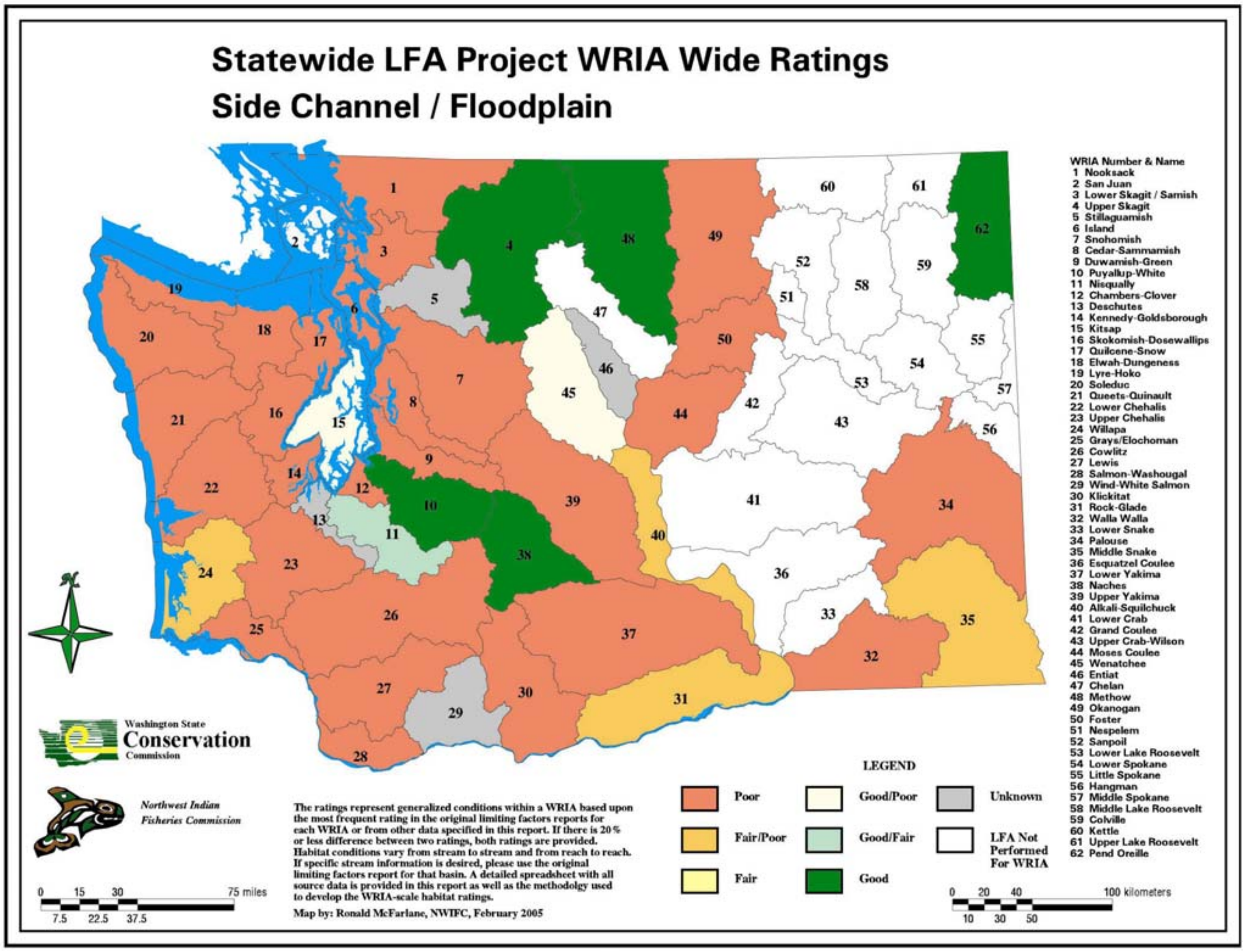


Figure 55. Map of floodplain ratings by WRIA in Washington State. Floodplain conditions were not applicable in WRIA 2.



Floodplain Conditions and Land Ownership

Generally, there are more good-rated floodplains in WRIAs with a higher percentage of federal land and more poor-rated floodplains in basins with lower federal land percentages (Figure 56). However, the results are too scattered to have a statistical trend. State-owned lands had the opposite results. All good to fair-rated WRIAs were in areas consisting of 12% or less state-owned land, and all basins with higher state land percentages had typically poor floodplains (Figure 57). However, poor-rated basins were found in areas with lower percentages of state owned lands as well. The results for private land ownership were scattered, but more good rated basins were associated with lower percentages of private land (Figure 58).

Figure 56. Floodplain conditions based upon percent federal land.

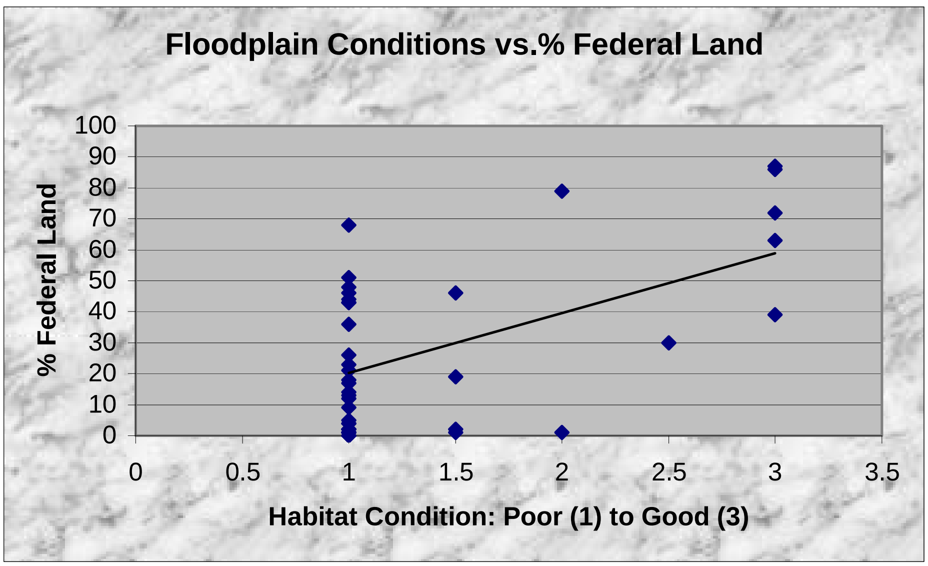


Figure 57. Floodplain conditions based upon the percent of state owned land.

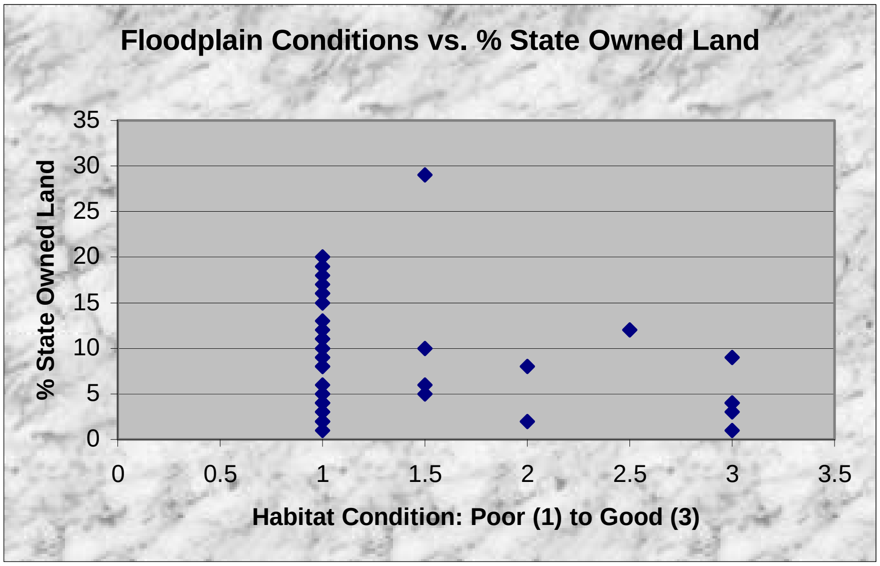
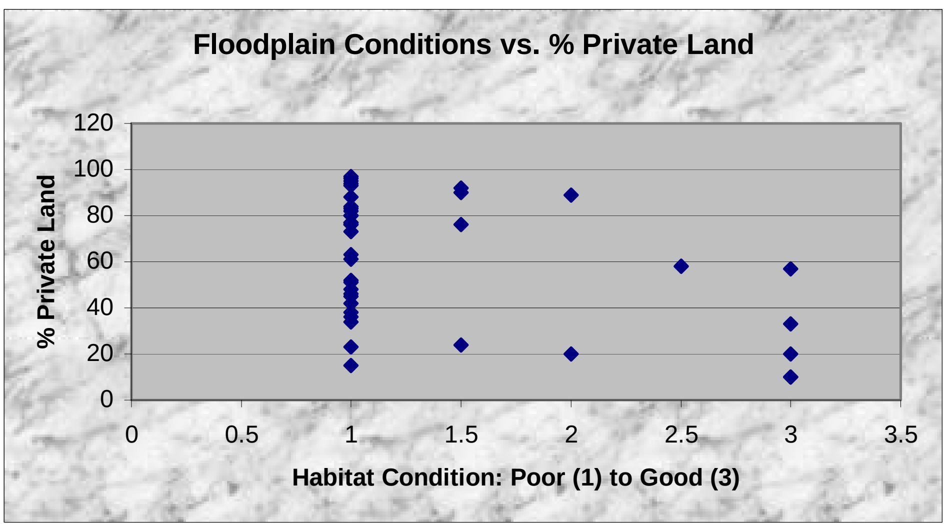


Figure 58. Floodplain conditions based upon percent of private land.



Floodplain Conditions and Land Use

All of the basins that rated fair or good for floodplain conditions consisted of 65% or more forestland (Figure 59). In contrast, agriculture-dominated WRIAs (25% or greater) were all rated either poor or poor-fair for overall floodplain conditions (Figure 60). Urban lands also had poor-rated floodplains, as basins with 15% or greater urban lands only had poor or poor-fair floodplains (Figure 61). All of the fair or good-rated WRIAs were associated with a low human population density of less than 1 person per acre (Figure 62). However, some basins with low human population densities also had poor floodplain conditions.

Figure 59. Floodplain conditions based upon percent of forestland.

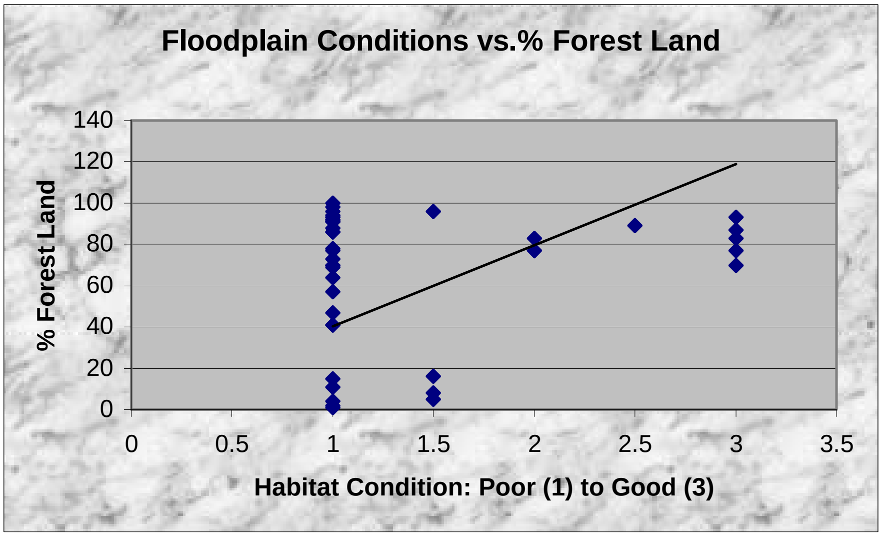


Figure 60. Floodplain conditions based upon percent agricultural land.

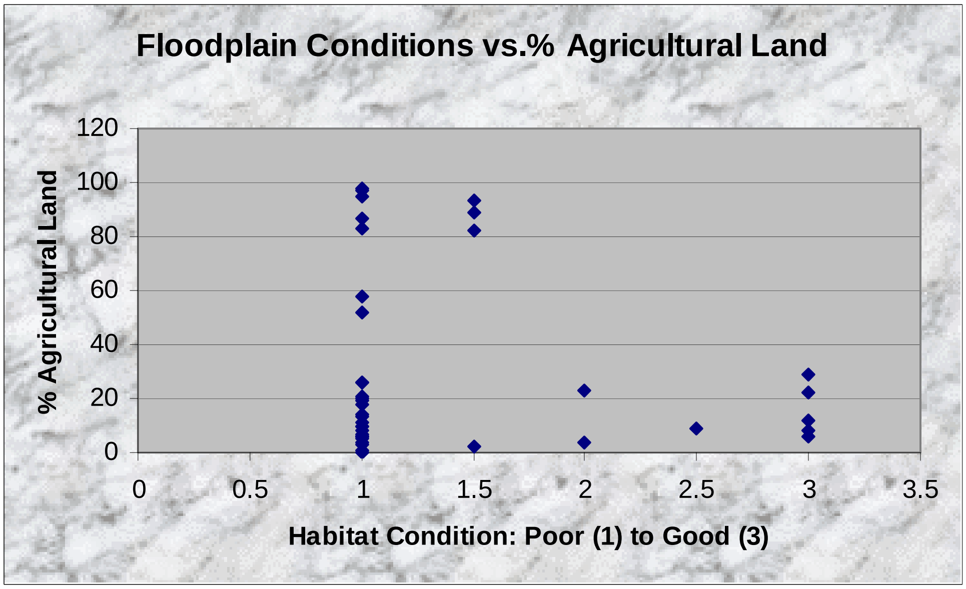


Figure 61. Floodplain conditions based upon percent urban land.

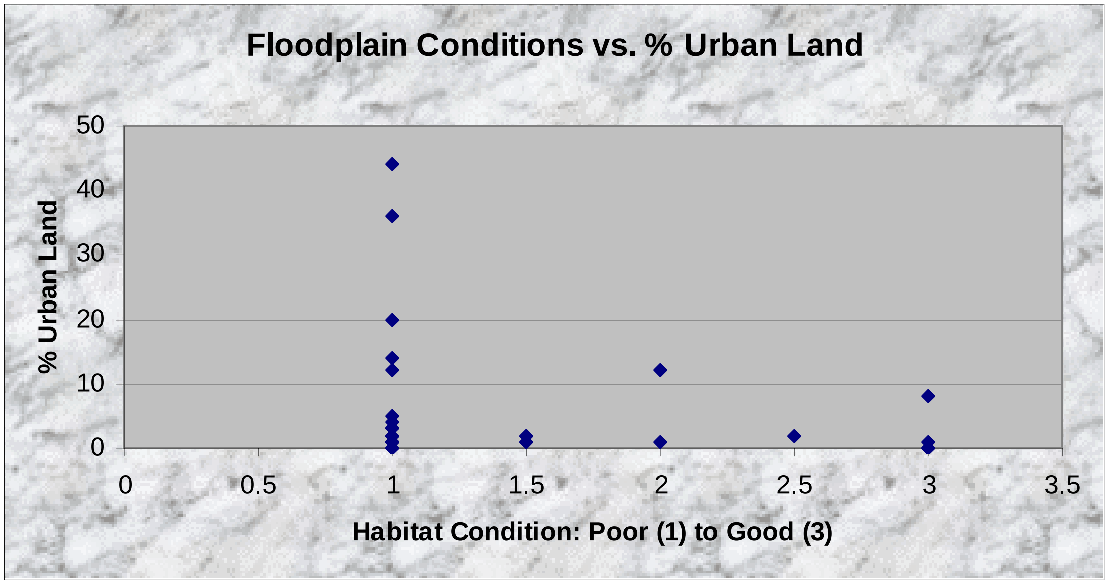
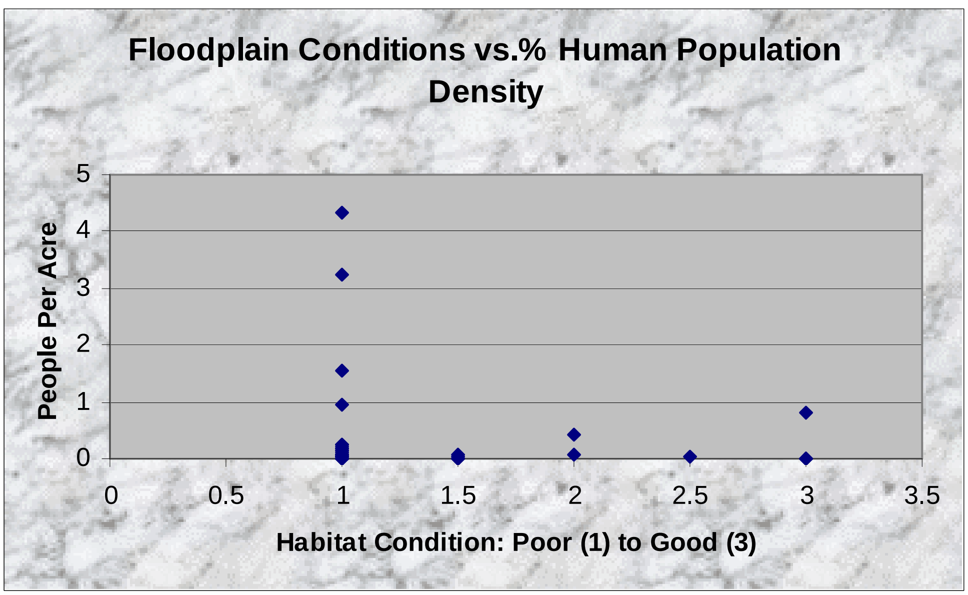


Figure 62. Floodplain conditions based upon human population density.



Data Gaps for Statewide Floodplain Conditions

Four basins were not included in the above analysis because of a complete lack of data for floodplain conditions. These are the Deschutes, Entiat, Stillaguamish, and Wind/White Salmon WRIAs. In addition, the data for all of the remaining WRIAs are incomplete and need further surveys and assessments. Some WRIAs have good floodplain assessments, such as the Skagit, where floodplain conditions have been inventoried throughout the mainstem rivers. However, most of the basins have scattered floodplain results (studies encompassing a very limited geographical area), or have floodplain conditions that are based upon professional judgment.

The types of data used in this category include: historic compared to current floodplain habitat, inventories of floodplain impacts such as bank hardening, levees, etc., wetland habitat type and loss, or inventories of other impacts such as roads in the floodplain. No WRIA had data in all of these categories, and typically, a basin would have some data in one category with little to no data in the others. Given the importance of floodplain habitat for salmonid production and maintenance of natural processes, floodplain conditions should be better assessed and monitored. An excellent example of work assessing historic floodplain habitat can be found in Collins and Sheikh 2002a and 2002b.

STATEWIDE SALMONID RIPARIAN CONDITIONS

Introduction

Riparian areas include the land adjacent to streams, rivers, and nearshore environments, and serve as the interface between the aquatic and terrestrial environments. These zones are normally covered with grasses and forbs to shrubs and large trees depending upon ecoregion. Riparian zones have several important functions in maintaining natural riverine processes. Tree and shrub roots hold streambanks together (Montgomery and Buffington 2001), stabilizing channels, decreasing erosion, and facilitating the formation of undercut banks (fish habitat) (Bjornn and Reiser 1991). Overhanging trees shade water (Naiman et al. 2001), maintaining the cool temperatures required by salmonids (Bjornn and Reiser 1991) and contributing leaf litter, which is an important component of primary production within the stream (Bisson and Bilby 2001). The decaying leaf litter is food for microinvertebrates (zooplankton) and macroinvertebrates (larval insects, aquatic snails, etc.), which then serve as food for fish (Bisson and Bilby 2001).

Mature trees in the riparian zone also provide important functions when they fall into streams to become large woody debris (LWD), and windthrow, floods, and landslides aid in adding LWD to the stream. Large woody debris stabilizes streambeds and banks, holds spawning gravels, promotes pool formation, provides resting and hiding cover for salmonids, and creates habitat for insects and other food items important to salmonids (Bilby and Bisson 2001) (discussed more fully in a subsequent chapter). Riparian vegetation also filters pollutants from soil (Knutson and Naef 1997, Welch et al. 2001) and reduces flood damage by slowing down floodwaters and dissipating energy (Naiman et al. 2001).

Riparian zones are impacted by all types of land use practices. Riparian functions are impaired by: direct removal of riparian vegetation, roads and dikes located adjacent to the stream channel, road crossings, agricultural/livestock crossings, unrestricted livestock grazing in the riparian zone, and development in the riparian corridor. Further, riparian vegetation species composition can be dramatically altered when native trees are replaced by exotic species (e.g., Japanese knotweed, reed canarygrass), and where native coniferous riparian areas are converted to deciduous tree species. Deciduous trees have generally smaller diameters than conifers and when they fall into streams to form LWD, they decompose faster than conifers and are vulnerable to being washed out by lower magnitude floods. Once impacted, riparian functions can take many decades to recover as forest cover regrows and coniferous species colonize. It may take as long as 80 to120 years to restore functional LWD to the channel.

This category addresses factors that limit the ability of native riparian vegetation to fully function, including its ability to recruit LWD. Typical data sources used in this chapter are watershed analyses and other riparian inventories. Where such data were unavailable, landsat data from Lunetta et al. (1997) was used to determine the conifer and non-forest components on a WAU and WRIA scale. In limited cases, professional knowledge was used in areas lacking data. The types of data sources used are documented in each limiting factors report as well as briefly labeled in the summary spreadsheet located in a separate file to this report.

Out of 42 basins that were rated for WRIA-wide riparian conditions, 57% were rated poor, 10% fair-poor, 19% fair, and 14% good (Figure 63). The good rated WRIAs include upper Skagit, Methow, Naches, West Hood Canal, Palouse, and Elwha Basins. Many of the poor rated basins are located in the lower Columbia and eastern Puget Sound (Figure 64). When Type 1 streams were examined separately, only two changes were noted. The riparian rating for Kitsap fell from fair to poor and the rating for the Naches WRIA decreased from good to fair.

Figure 63. Statewide riparian conditions by WRIA.

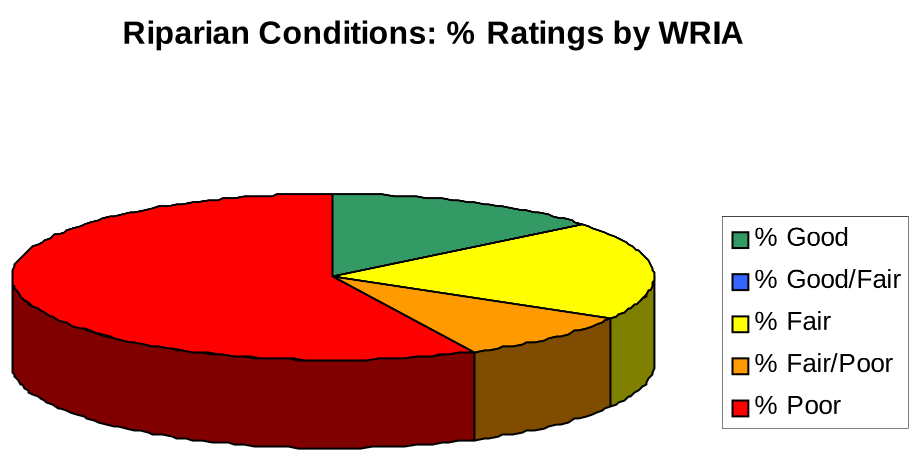
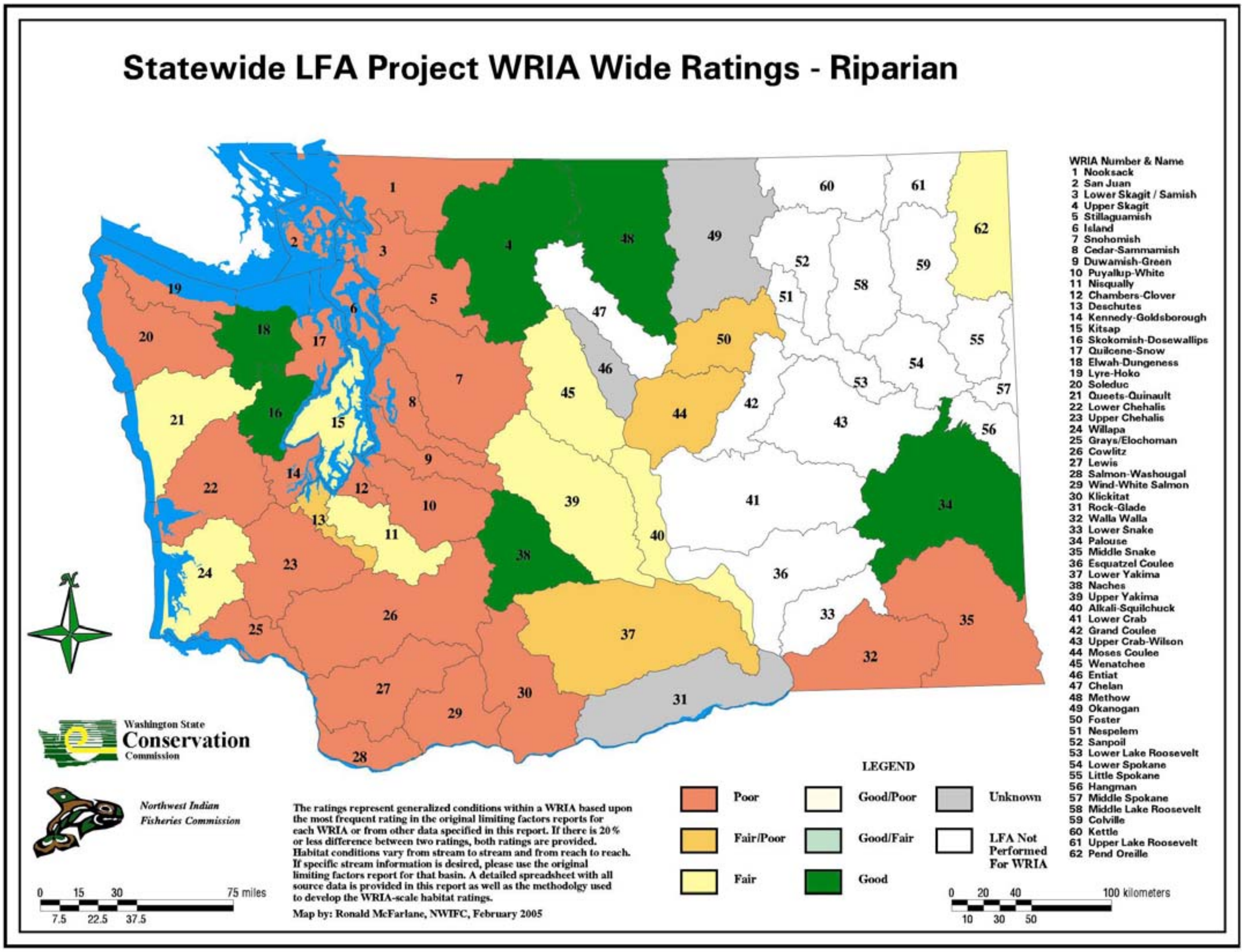


Figure 64. Map of riparian conditions by WRIA throughout Washington State.



Riparian Conditions and Land Ownership

There were generally more good-rated basins associated with higher percentages of federally-owned land with the exception of Palouse and Nisqually (Figure 65). Riparian conditions were scattered across different percentages of state and private land (Figures 66 and 67).

Figure 65. Riparian conditions based upon percent federal land.

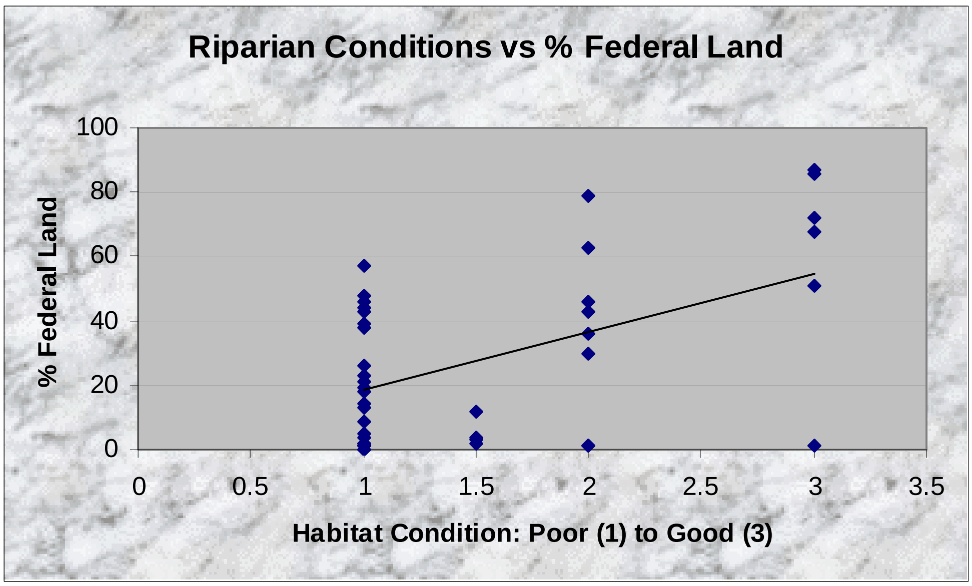


Figure 66. Riparian conditions based upon percent state owned land.

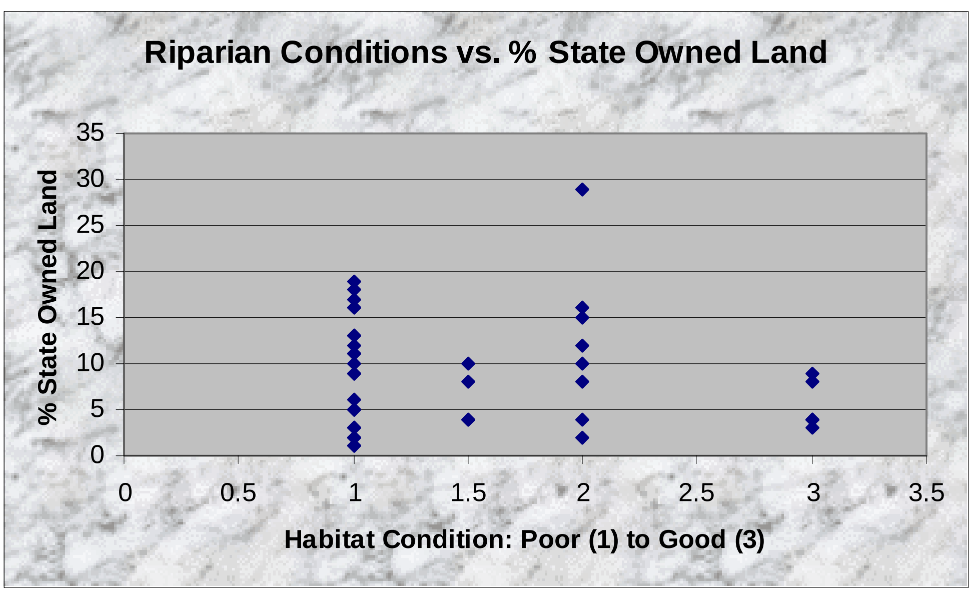
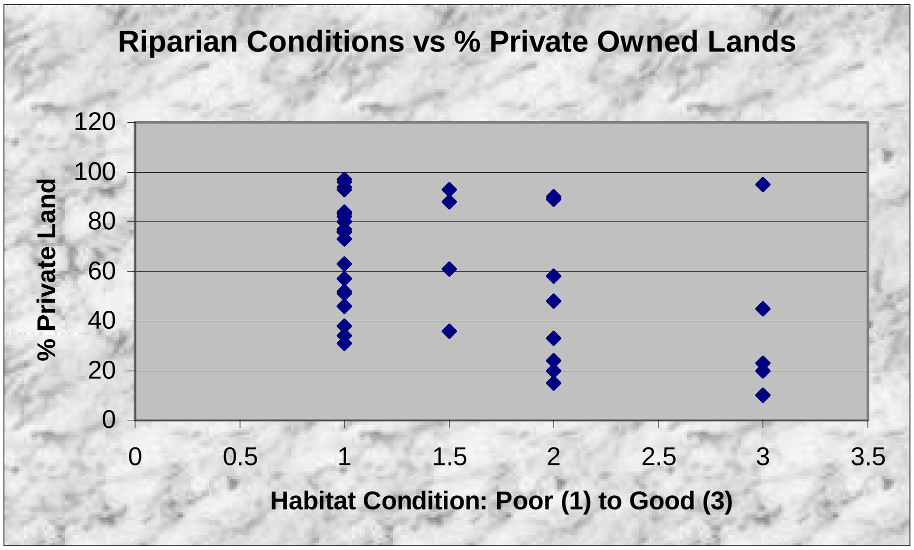


Figure 67. Riparian conditions based upon percent private land.



Riparian Conditions and Land Use

The only land use type that appeared to have a consistent relationship with riparian condition was urban use/human population density. While all rating categories were found throughout various percentages of forestland (Figure 68), no basins with 15% or more urban land had good or fair WRIA-wide riparian ratings (Figure 69). Also, basins with human population densities of 1.5 people per acre or greater were all rated poor for basin-wide riparian conditions (Figure 70). However, poor-rated riparian basins were also found throughout all percentages of urban lands and across all population density types. There appeared to be no relationship between agricultural lands and an overall riparian rating as results were scattered throughout all percentages of agricultural land (Figure 71).

Figure 68. Riparian conditions based upon percent forestland.

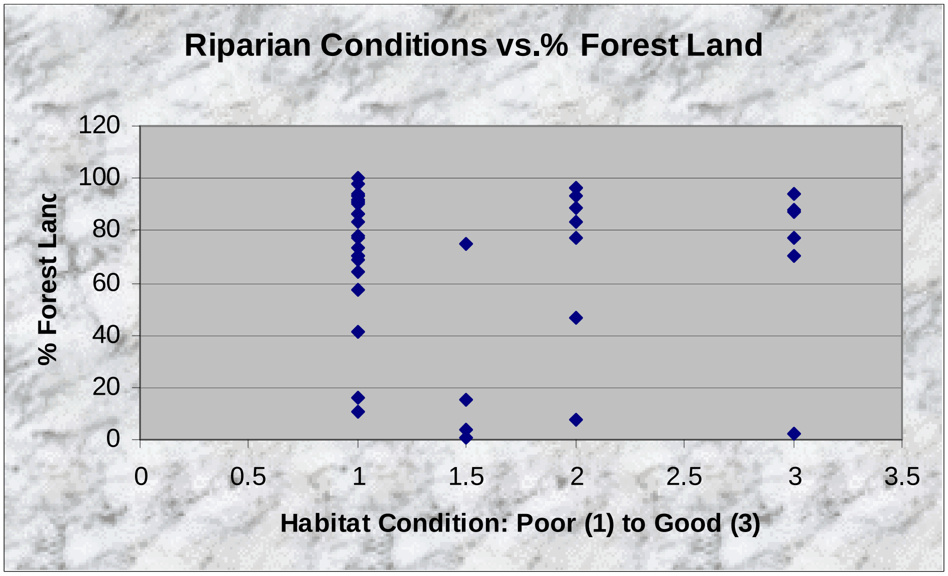


Figure 69. Riparian conditions based upon percent urban land.

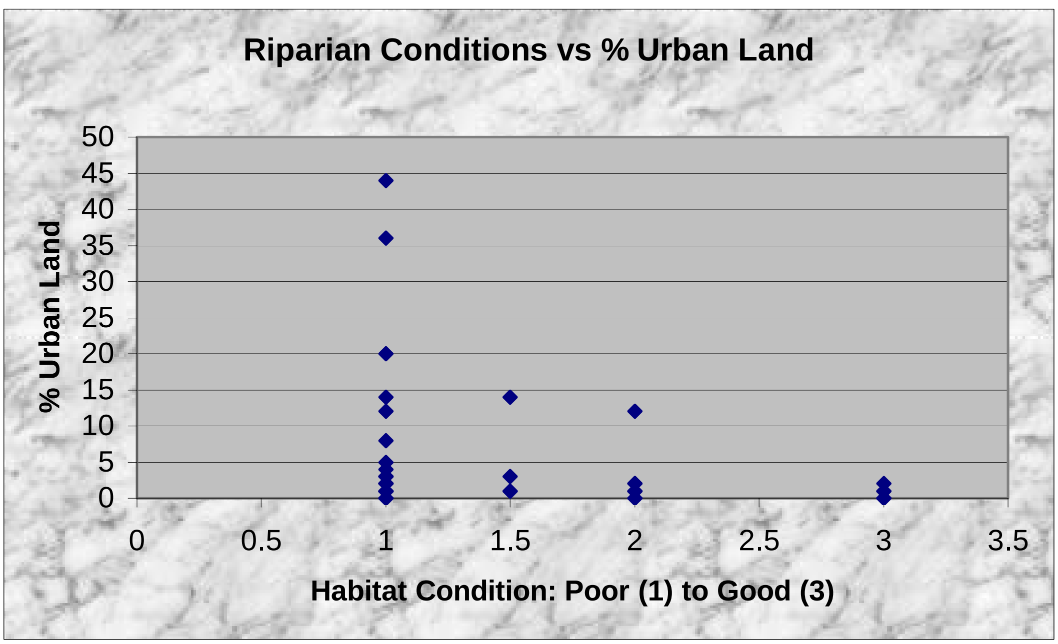


Figure 70. Riparian conditions based upon human population density.

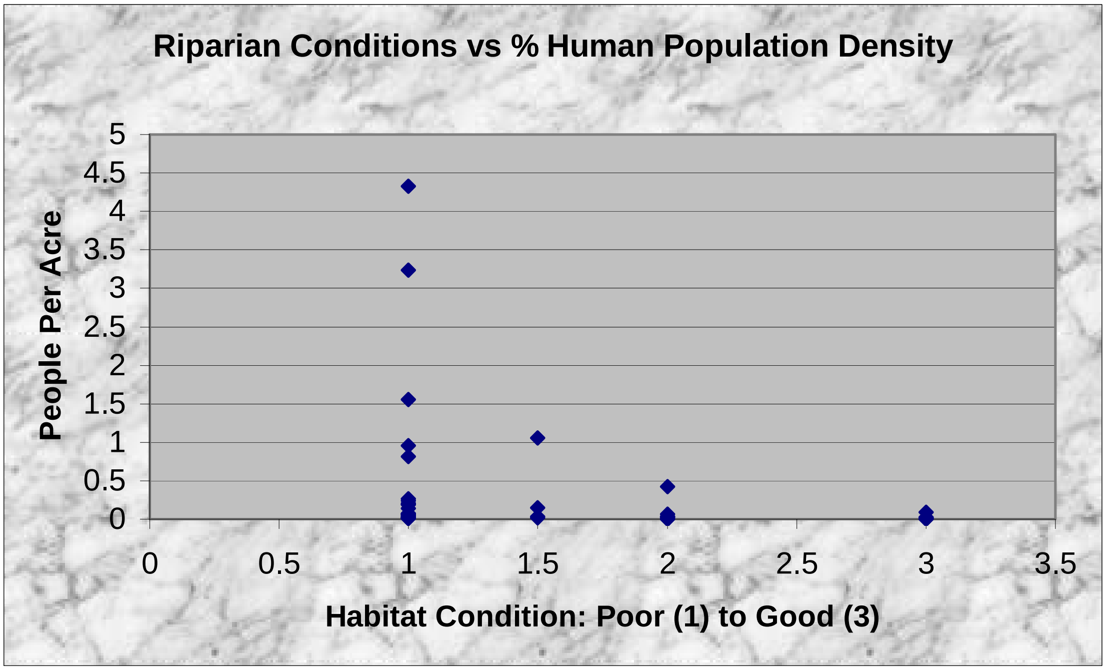
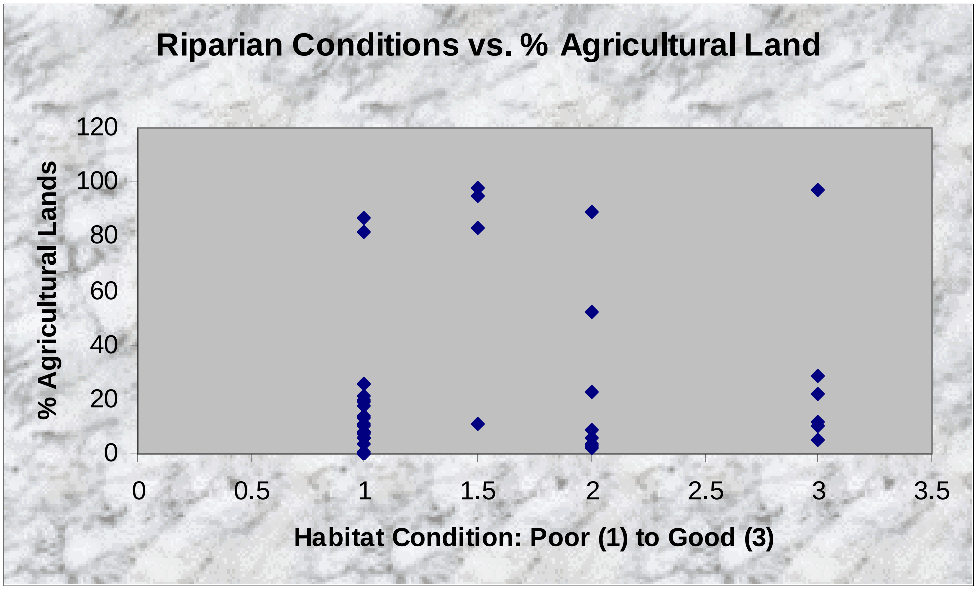


Figure 71. Riparian conditions based upon percent agricultural land.



Data Gaps in Riparian Conditions

There were three basins that were not included in the above analysis due to a lack of data. These were Entiat, Rock/Glade, and Okanogan. In addition, nearly all of the other WRIAs need additional riparian surveys. Many of the ratings were based upon WRIA scale data such as found in Lunetta et al. 1997. While these data were very useful for this statewide analysis, more specific information is needed to aid salmon habitat recovery efforts. Basin-wide riparian analyses that include both shade hazard and LWD recruitment potential are especially needed for basins that lack such data and have known water temperature and sediment problems and likely impacts to shade and LWD recruitment. The Nooksack Basin stands out as an example of an area with excellent riparian data, as complete riparian inventories have been completed throughout most of the basin (Coe 2001).

STATEWIDE SALMONID SEDIMENT CONDITIONS

Introduction

Sediments in an ecologically healthy stream are supplied, moved, and stored in a naturally changing manner that varies based upon stream gradient and size, geomorphic conditions, and hydrological regime. Fine sediments (<0.85 mm) tend to be transported through the system and have relatively little effect on channel morphology. Coarser sediments (>2 mm diameter) tend to travel as bedload, and can have larger effects on channel morphology as they move downstream. In general, the coarsest sediments are found in upper watersheds while the finest materials are found in the lower reaches of a watershed.

Changes in the inputs of fine and coarse sediment to stream channels can have a broad range of effects on salmonid habitat. Increases in coarse sediment can create channel instability and reduce the frequency and volume of pools, while decreases can limit the availability of spawning gravel. Increases in fine sediment fill pools, lower the survival rate of eggs deposited in the gravel through suffocation, and lower the production of benthic invertebrates. Common sources of increased sediment are landslides, roads, and agricultural practices, while decreased gravel availability is often caused by dams and floodplain constrictions. As part of this analysis, four different habitat parameters from the limiting factors reports are summarized and assessed. They are sediment quantity, sediment quality, stability, and road density. Each of these provides a different perspective of sediment-related conditions and is detailed below. In general, sediment data was not abundant, and often, data were found for very few of the categories.

Sediment Quantity

Sediment quantity describes the total amount of sediment entering streams and ideally relates the volume of sediment against background (natural) conditions. The data are even more useful when causes of the sedimentation are identified. The most common type of data used in this report was sediment budgets. Landslide inventories were also included when available, but were rarely found.

As surrogate or ancillary data to sediment budgets and landslide inventories, other types of data were sometimes used. One common measurement is the width-to-depth ratio. The width/depth ratio is the average width of the river channel at a given cross-section divided by the average depth at that same cross-section. In other words, it determines if the channel is wide and shallow (high width/depth ratio) or narrow and deep (low width/depth ratio). In general, a narrow deep channel is more favorable to salmonids than a wide shallow channel. Deep water provides more cover and maintains cooler water temperatures.

Sediment Quality

Sediment quality is an assessment of the type of substrate in the stream. Certain sizes of gravel are ideal for various species of salmonids, and need to be present for proper spawning and early rearing conditions. One common measurement of sediment quality is that of fine sediment.

Fines have a very small diameter and when present in large quantities, reduce the amount of water able to circulate through the gravel deposited over the eggs in the nest. This water infiltration is critical to supply oxygen to the developing salmonids and remove waste products (Bjornn and Reiser 1991, Hicks et al. 1991).

Another parameter used in this report to describe sediment quality is substrate embeddedness. Embeddedness occurs when fine sediment settles to the bottom, cementing gravels and cobbles together. This makes it difficult for female salmonids to construct their nest, and prevents juvenile salmonids from entering or exiting interstices in the substrate that provide important winter cover. Ideally, substrate embeddedness should be very low. Substrate embeddedness is the product of fine sediment washed into stream, and eroding streambanks, forestland, roads, and urban developments all contribute to fine sediments.

Stability

As part of sedimentation, this chapter also summarizes impacts to bank, channel, and streambed stability. Natural streambank stability maintains riverine processes. Root masses of LWD and streamside trees stabilize streambanks, and stable streambanks result in a greater ability for riparian vegetation to maintain and grow. Vegetation has a difficult time recovering from flood damages or other disturbances if it is continually undermined by a failing bank (Naiman et al. 2001). Stable streambanks also contribute to a properly functioning channel depth. A certain volume of water is deeper in a narrow channel than in a wide channel, and depth maintains cool temperatures and cover needed by salmonids. Rapidly eroding banks can lead to wide and shallow channels (Platts 1991). Eroding streambanks can contribute large amounts of fine sediment to the water column as well as large amounts of coarse sediment that is deposited in the stream channel, leading to subsurface flows (Hicks et al. 1991, Ziemer and Lisle 2001). However, naturally eroding streambanks can also be important contributors of gravel necessary for spawning and rearing.

Streambed stability is also assessed where data are available. The degree of bedload movement has important ramifications for the survival of salmonid eggs and juveniles. Streambeds that are unstable tend to scour and fill readily, and these actions increase the mortality of eggs and juveniles using the gravel. Streambed stability is worsened by human-caused impacts such as increased peak flows, increased sediment loads, bank hardening/levees, and constrictions from structures such as bridges. While salmon have adapted to infrequent disturbances, human-caused changes often increase the frequency of disturbance such that a previously 10 year discharge becomes a 2 year discharge and results in a decline of salmon use (Booth 1990; Lucchetti and Fuerstenberg 1992).

Road Density

The fourth sediment category in this report is road density. This is not a direct measurement of sedimentation, but a surrogate that can represent potential sedimentation impacts. High road densities are often associated with increased total sedimentation and increased inputs of fines, thereby altering sediment quantity and sediment quality. These effects are much more pronounced in higher gradient areas and are less pronounced in the lowlands. Certain types of roads are a much higher risk than others. Older roads on forestlands, especially those made from side-cast material are a high risk. Also, older roads may have inadequate culverts that can fail and lead to increased sedimentation.

Sedimentation Results Overview

Of the 38 WRIAs that had sufficient data to assess overall sediment conditions, only 10% were rated good or fair-good (Figure 72). These basins were upper Skagit, Queets, Naches, and Wenatchee. Fair rated basins comprised 34% of the assessed WRIAs with another 8% rating fair/poor. Poor rated basins were the most numerous, making up 48% of the state's assessed WRIAs for sediment conditions.

While the following assessment is based upon a combined sedimentation score from four possible categories (sediment quality, sediment quantity, stability, and road density), maps of each of these four categories are shown below so that individual ratings and data gaps can be clearly demonstrated. Figure 73 shows basin-wide ratings for sediment quantity. Few data are available on a widespread basis to assess this parameter. Only 15 out of 45 basins have sufficient sediment quantity data to compile a rating. Of the 15 basins with ratings, all but two are rated poor. Only upper Skagit is rated good, and West Hood Canal has a mix of good and poor areas.

More data were available to rate basins on sediment quality conditions, and the majority of rated basins were poor, especially in the lower Columbia, Olympic Peninsula, Snake, Walla Walla, and Pend Oreille areas (Figure 74). It is noteworthy that although the Methow rated good for sediment when all streams were included, the rating changed to poor when only the larger Type 1 streams were examined.

Road density data were available on a coarse scale for western Washington, but were rare for eastern Washington basins (Figure 75). Most of the rated basins for road density were poor, particularly in the lower half of western Washington. Stability data were widely scattered both geographically (Figure 76) and by topic. Stability data refers to a variety of data types including bank stability, channel stability, and bedload stability. Overall, these data contributed very little to the overall ratings.

Figure 72. Sediment conditions by WRIA throughout Washington State.

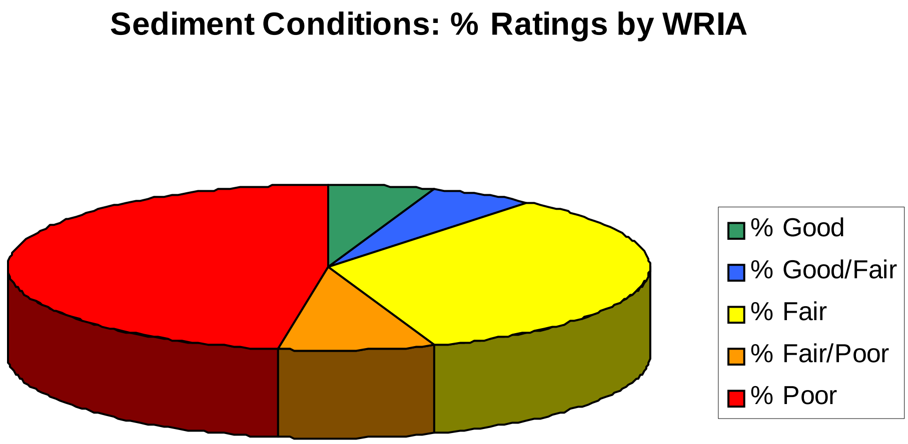


Figure 73. Map of sediment quantity conditions by WRIA in Washington State.

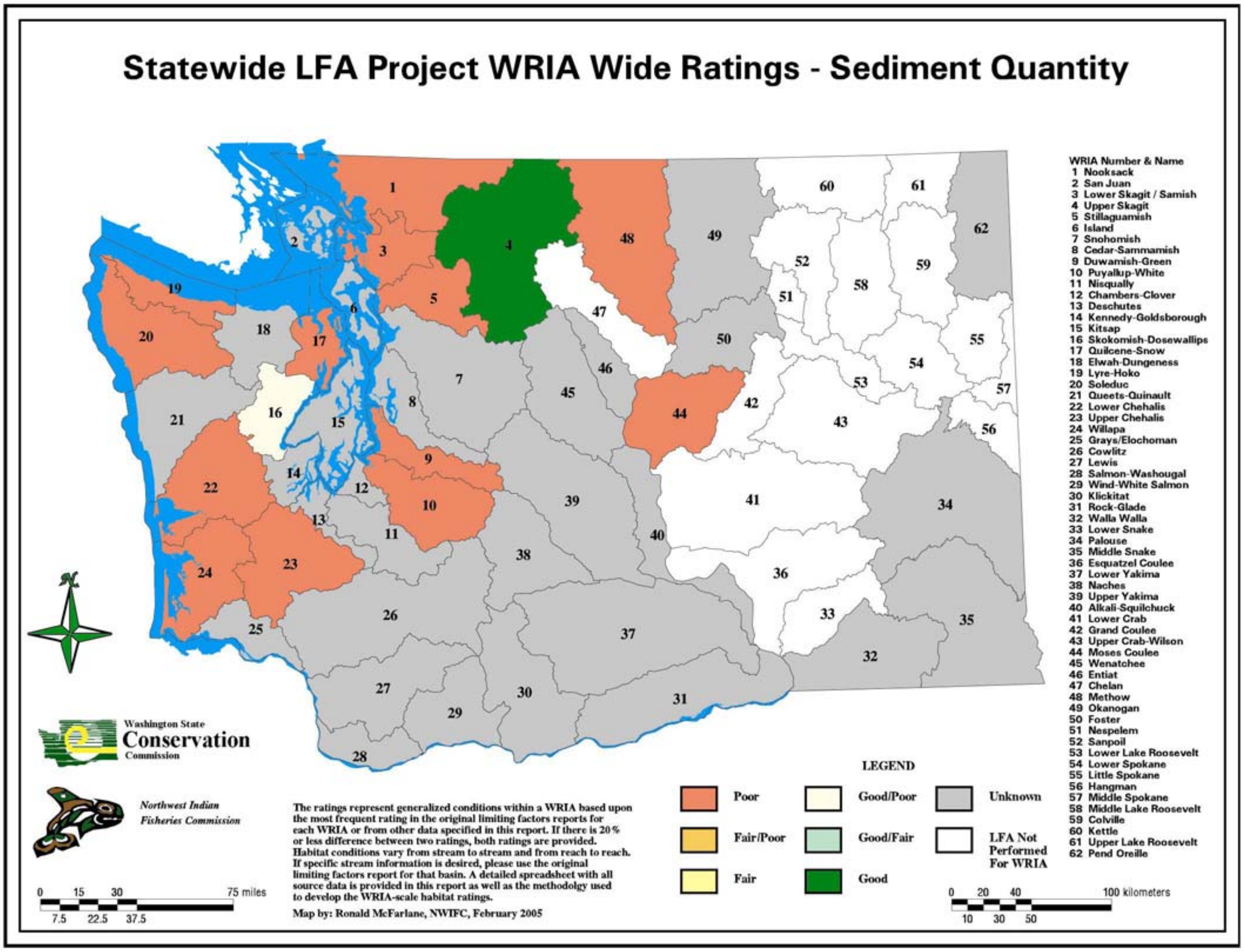


Figure 74. Map of sediment quality conditions by WRIA in Washington State.

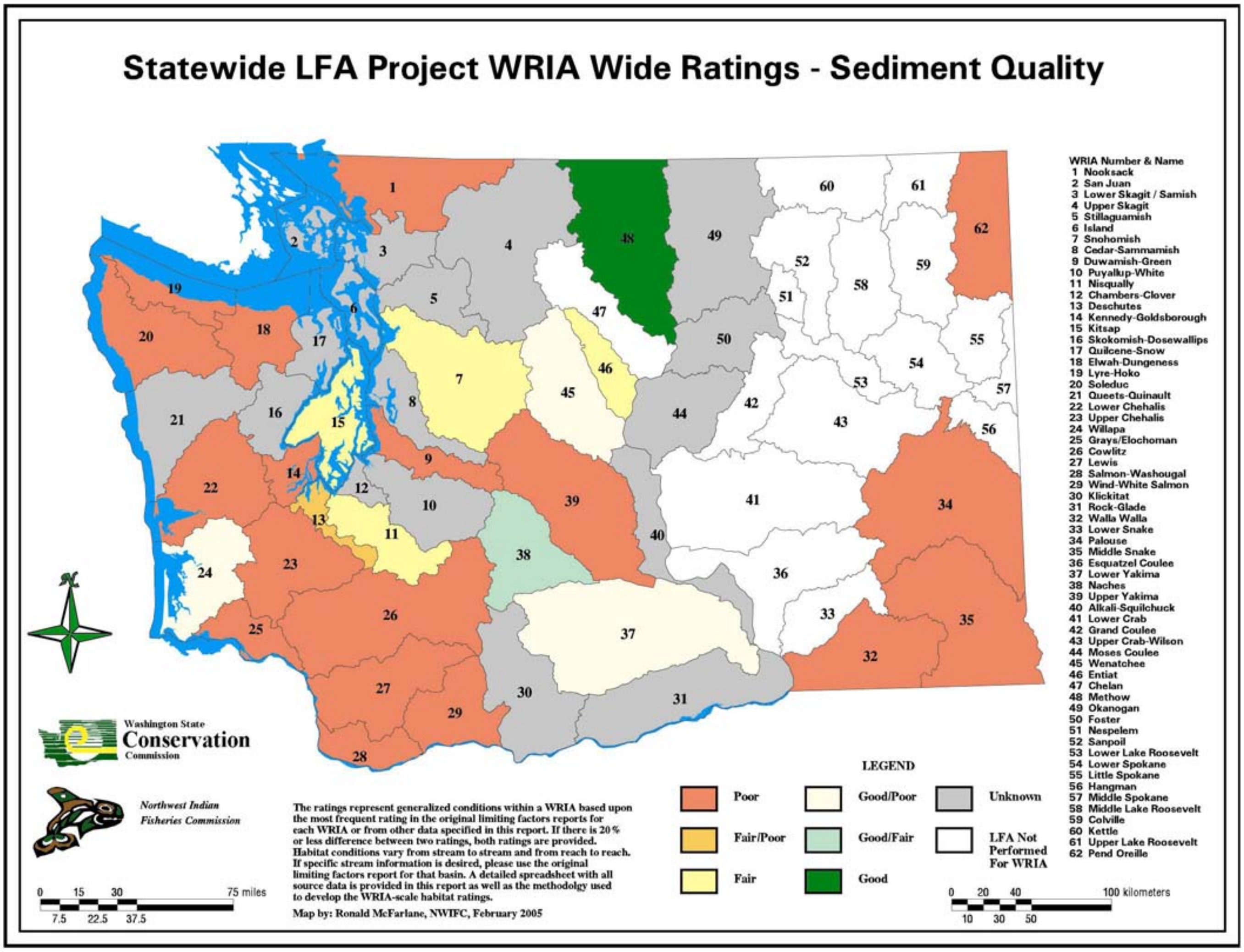


Figure 75. Road density ratings for WRIAs in Washington State.

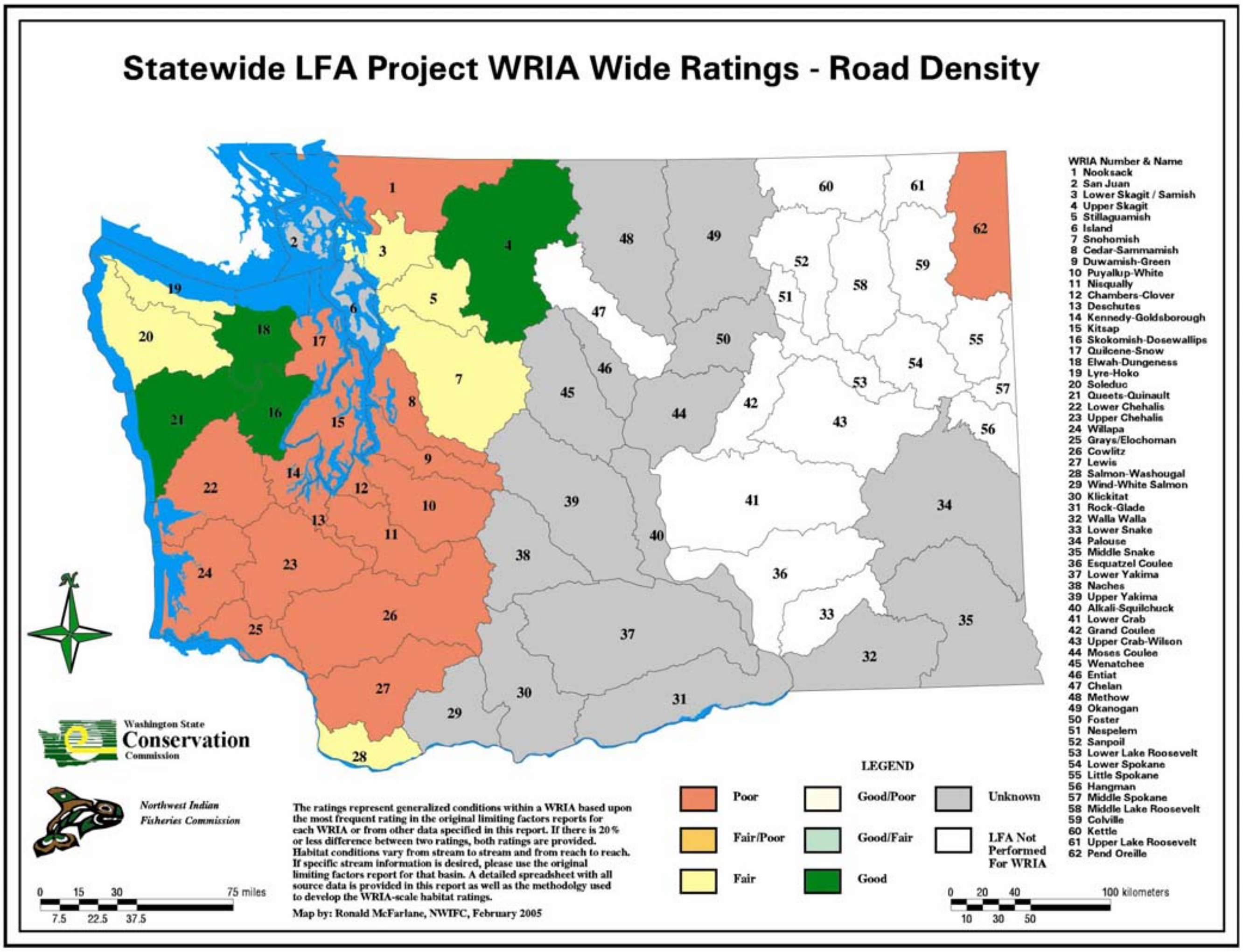
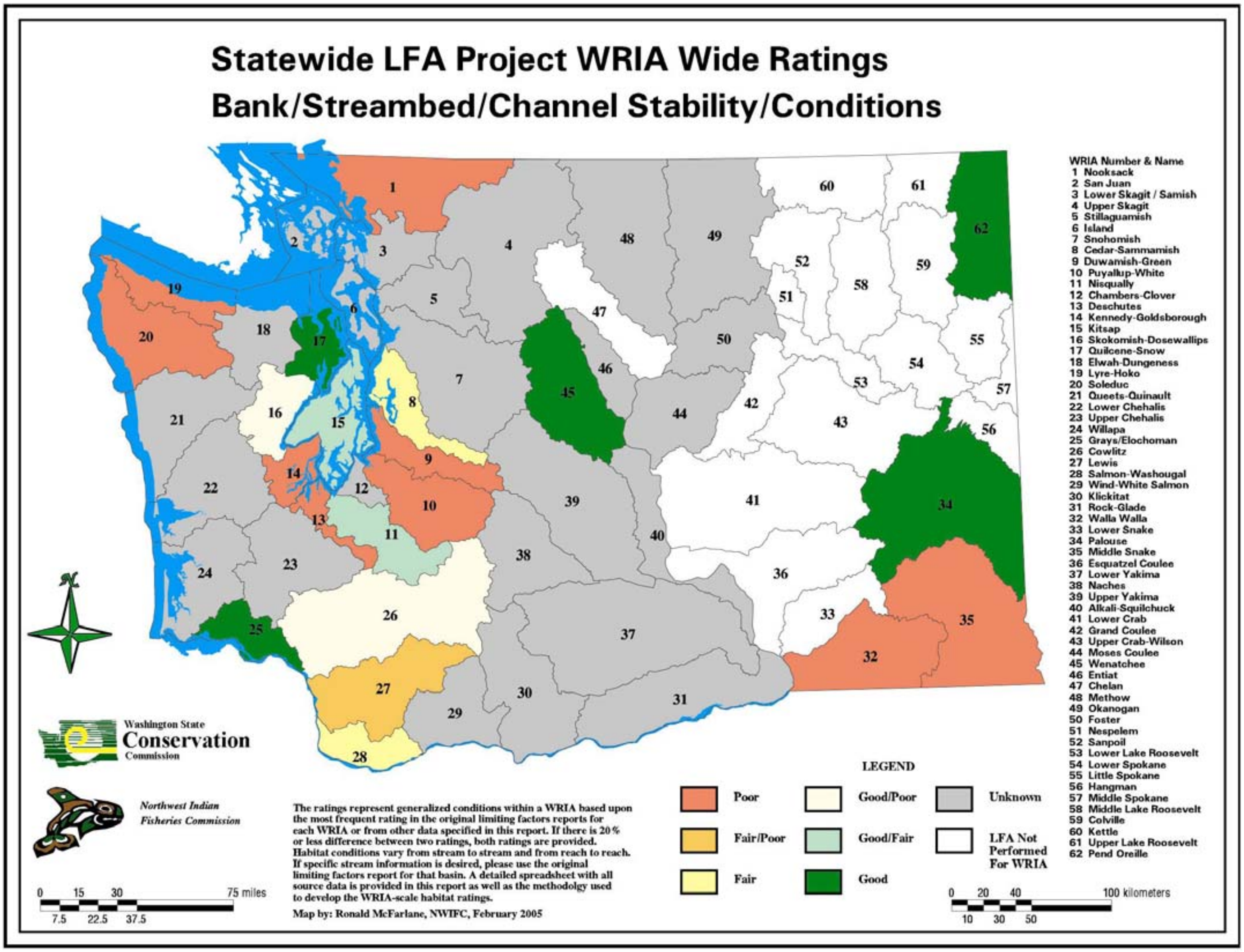


Figure 76. Streambed, channel, and bank stability ratings by WRIA in Washington State.



Sediment Conditions and Land Ownership

There were no poor-rated basins for sediment among those with 60% or greater federal land ownership, and good and good-fair rated basins were only found in basins consisting of 40% or more federal ownership (Figure 77). The opposite pattern emerged for private land ownership. All poor-rated basins for sediment consisted of 30% or greater private lands and all good or fair-good rated basins comprised of less than 25% private lands (Figure 78). No pattern between state-owned lands and sediment conditions were found (Figure 79). It should be noted that none of the patterns show statistical trends because the data were too scattered and parcel specific information was not available.

Figure 77. Sediment conditions based upon federal land ownership.

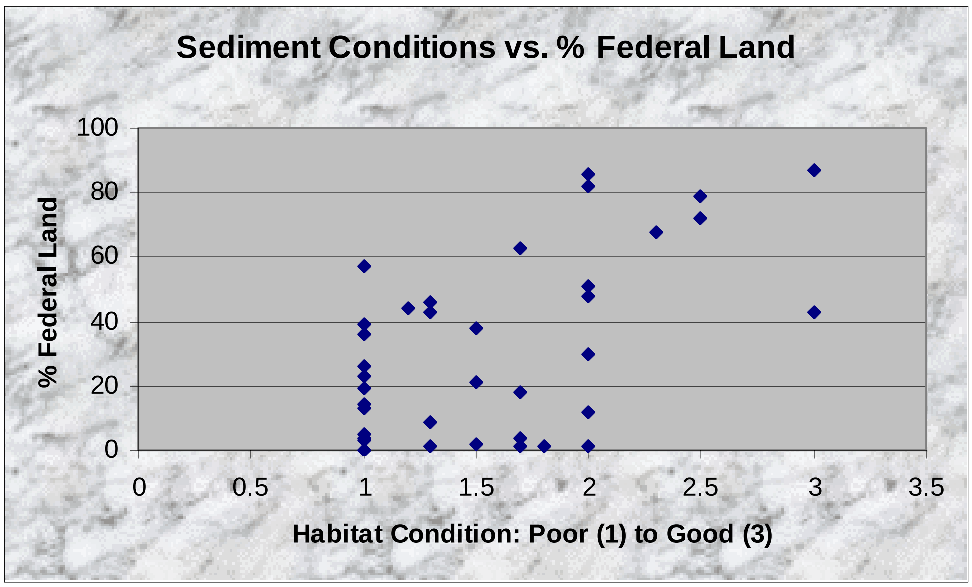


Figure 78. Sediment conditions based upon private land ownership.

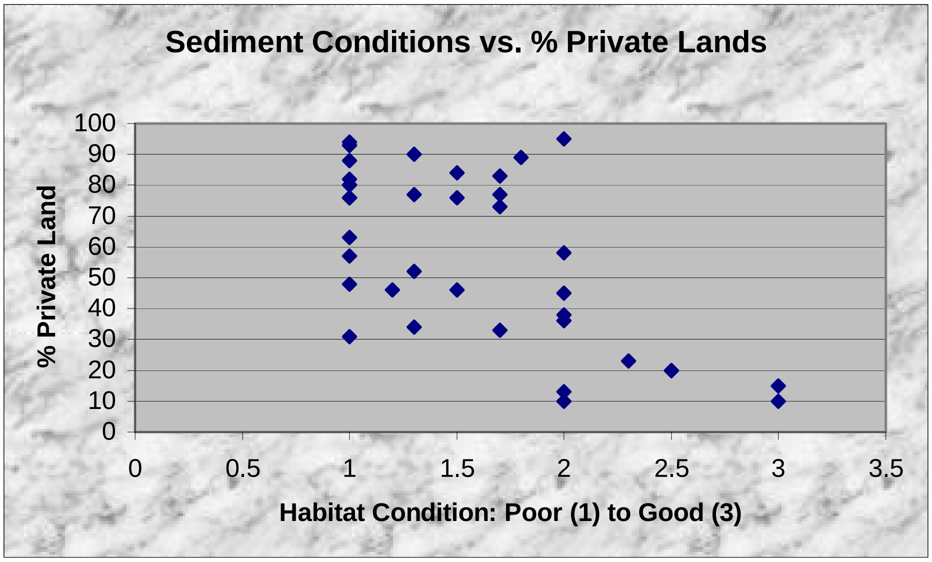
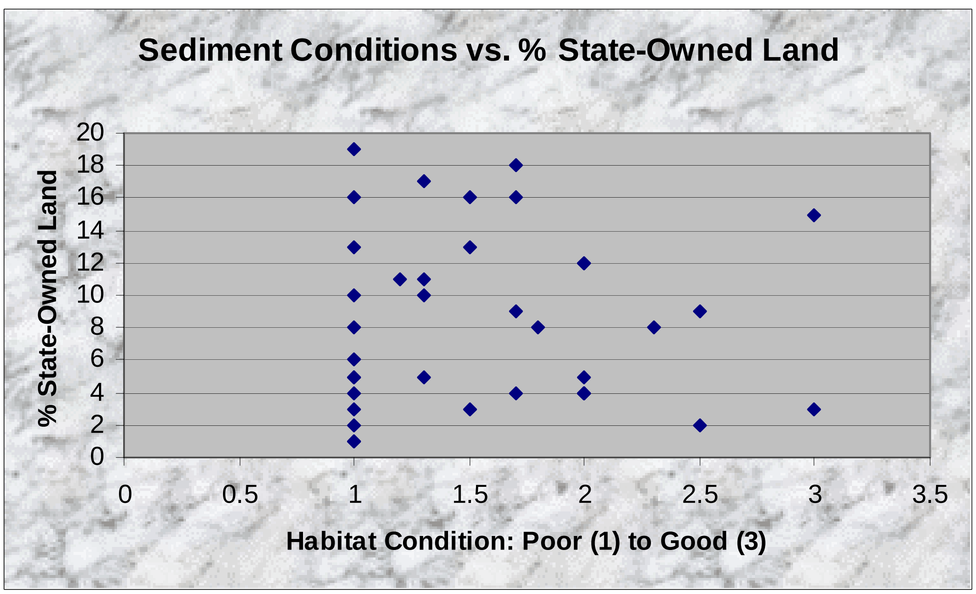


Figure 79. Sediment conditions based upon state-owned land.



Sediment Conditions and Land Use

Sediment conditions were varied throughout the percentages of forestland within a basin (Figure 80). All of the good or fair-good basins had 60% or greater forestland, but there were only four such basins, resulting in a low confidence of this conclusion. Only two non-poor rated basins

(Palouse and lower Yakima) consisted of a low percentage of forestland. For agricultural land, no fair-good or good rated basins were found in agriculturally dominated WRIAs (30% or more agricultural or range lands), although the sample size was very low and the result in not very conclusive (Figure 81). Fair and poor ratings were scattered throughout all ranges of agricultural land. Perhaps the most conclusive land use relationship is between sedimentation and urban lands/human population density. WRIAs consisting of 10% or greater urban lands had no fair or good ratings for sediment (Figure 82), and complimentary to this, high human population density basins also had only poor or poor-fair rated sediment conditions (Figure 83). However poor rated basins were found in areas with low population density and low percentages of urban land as well.

Figure 80. Sediment conditions based upon percent forestland.

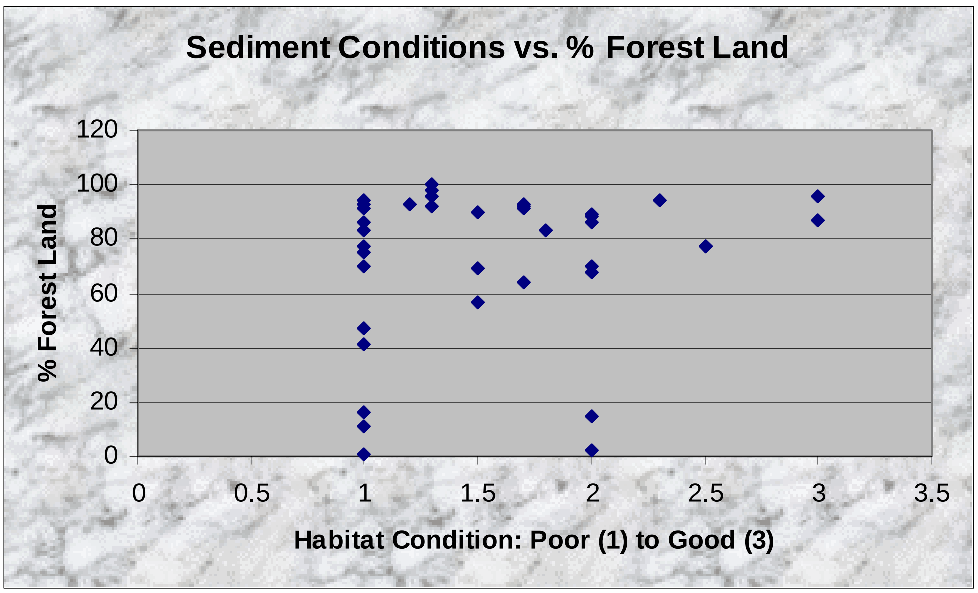


Figure 81. Sediment conditions based upon percent of agricultural lands.

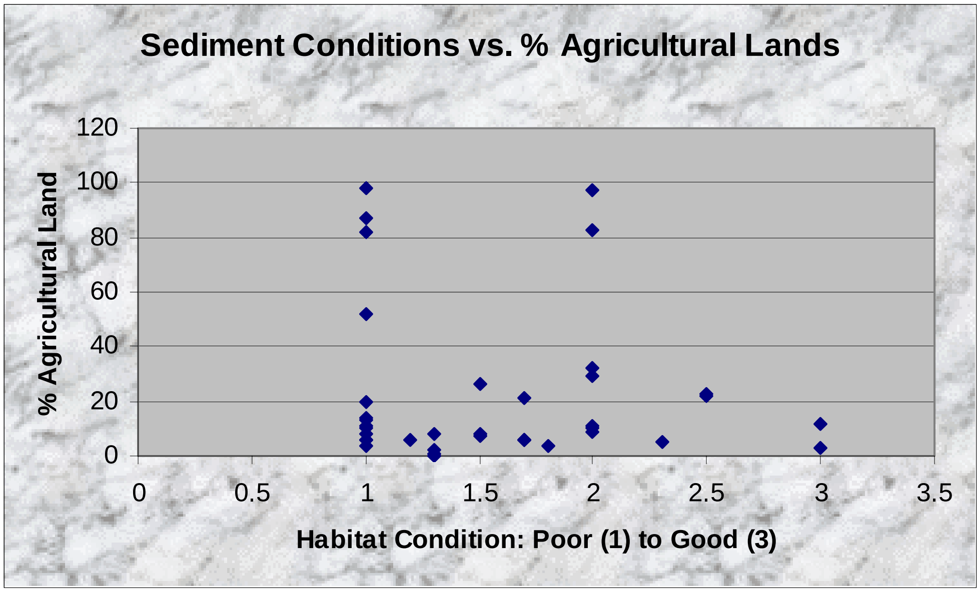


Figure 82. Sediment conditions based upon percent urban land.

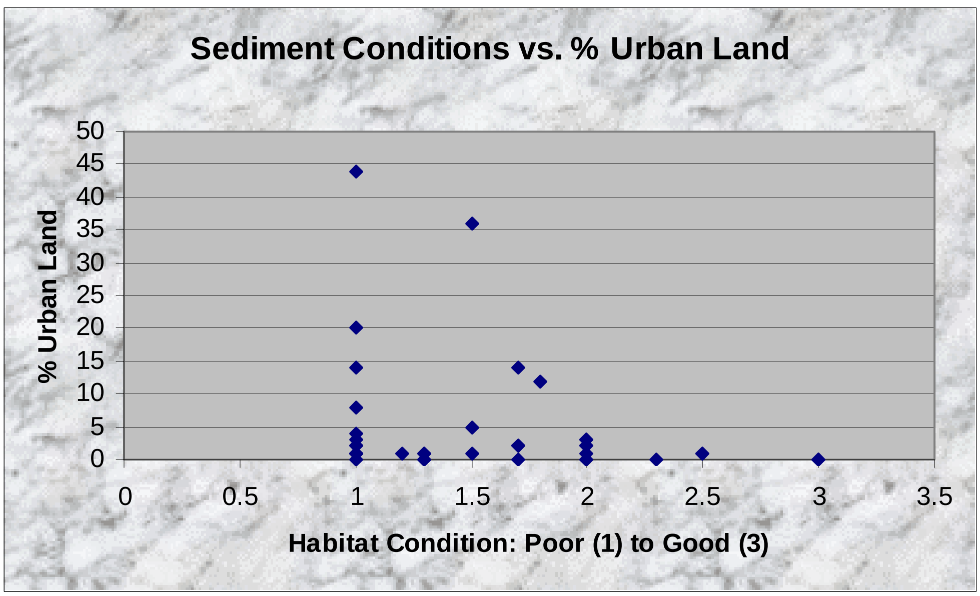
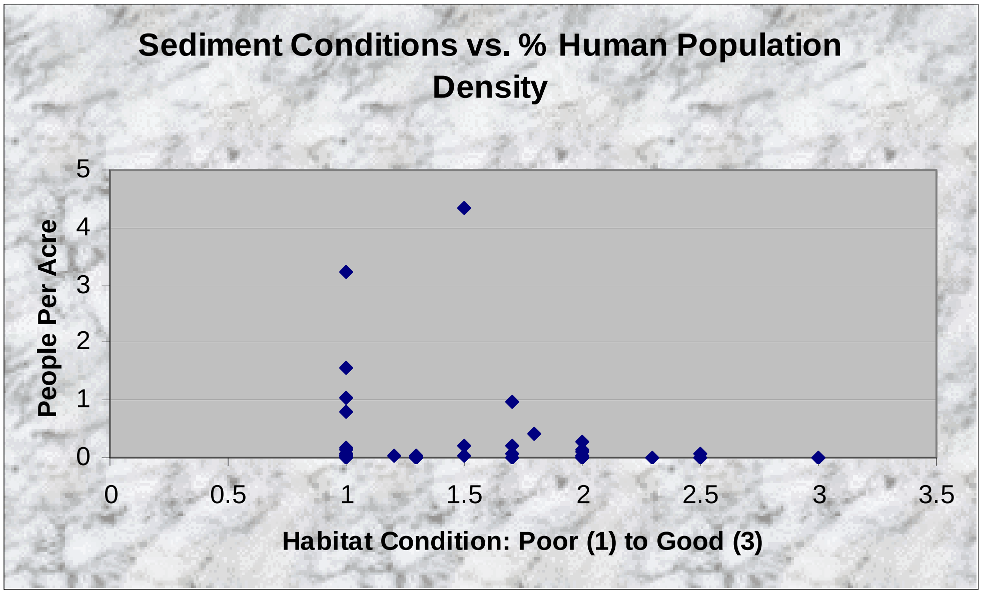


Figure 83. Sediment conditions based upon population density.



Data Gaps for Sediment Conditions in Washington State

All basins have significant data gaps for sediment conditions. And, even with four different sediment-related parameters, several WRIAs lacked data in all of the categories resulting in exclusion from the above analysis. These WRIAs include San Juan, Foster, Rock/Glade, Alkali, Island, Klickitat, and Okanogan.

Of significant note is that very few data exist across a broad scale for sediment quantity, yet in the few basins that have such data, most ratings are poor. Sediment quantity data are important because excess sediment can impact other habitat conditions such as floodplains, riparian, water temperature, and flows. The types of assessments useful for sediment quantity are sediment budgets, landslide inventories, and road inventories that prioritize sites and risks.

STATEWIDE LARGE WOODY DEBRIS CONDITIONS

Introduction

Large woody debris or (LWD) is an important component of stream habitat. Large trees that fall into streams or are deposited by landslides and floods stabilize streambeds, collect spawning gravels, and promote pool formation. Woody debris also provides cover for salmonids and their prey. In the past, LWD was removed to aid boat traffic, transport logs, speed floodwaters, or barriers to salmonid migration, and these actions have contributed to low levels in many streams (Sedell et al. 2000). Another major cause of decreased LWD is the reduction or modification of riparian vegetation (Knutson and Naef 1997). Unfortunately, LWD recruitment is a long-term process because it depends upon the presence of mature trees that then fall into the stream.

Many of our current riparian areas are lacking large mature trees (see section on riparian conditions). Before extensive logging, an estimated 60 to 70% of Pacific Northwest forests consisted of trees >200 years old (Franklin and Spies 1984, Booth 1991). Currently, immature trees (8-12" diameter) dominate riparian areas in western Washington. In addition, the species composition has changed as well. Coniferous trees are larger and last longer as LWD than deciduous trees (Murphy and Koski 1989; Swanson and Lienkaemper 1978), yet red alder is now the most commonly found tree in western Washington riparian areas (Carlson 1991).

Of the 33 analyzed basins for WRIA-scale LWD conditions, an overwhelming number of them (85%) rated poor (Figure 84), and there are more poor rated basins (based on a percentage) for LWD than any other category in this report. Only 6% of the WRIAs rated good, and these are Pend Oreille and Naches. One other basin (Queets) rated fair overall for LWD conditions, and the Methow had an approximately equal number of good and poor ratings (Figure 85). When examining only Type 1 (larger) streams, the two basins that rated good for LWD conditions (Naches and Pend Oreille) fell to a poor rating, and the Kennedy Creek WRIA changed from an overall poor rating to a good rating. Also, the rating for the Methow changed from fair to poor when separating and examining only the Type 1 streams.

Figure 84. Large woody debris conditions by WRIA throughout Washington State.

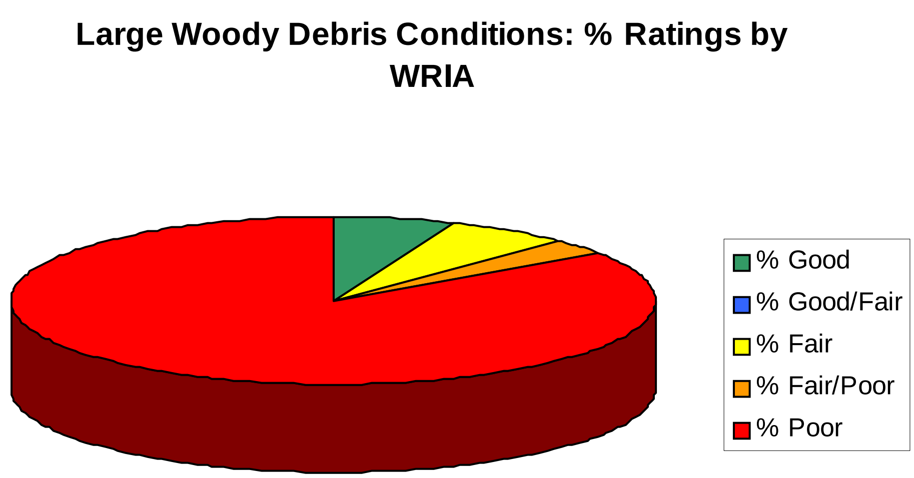
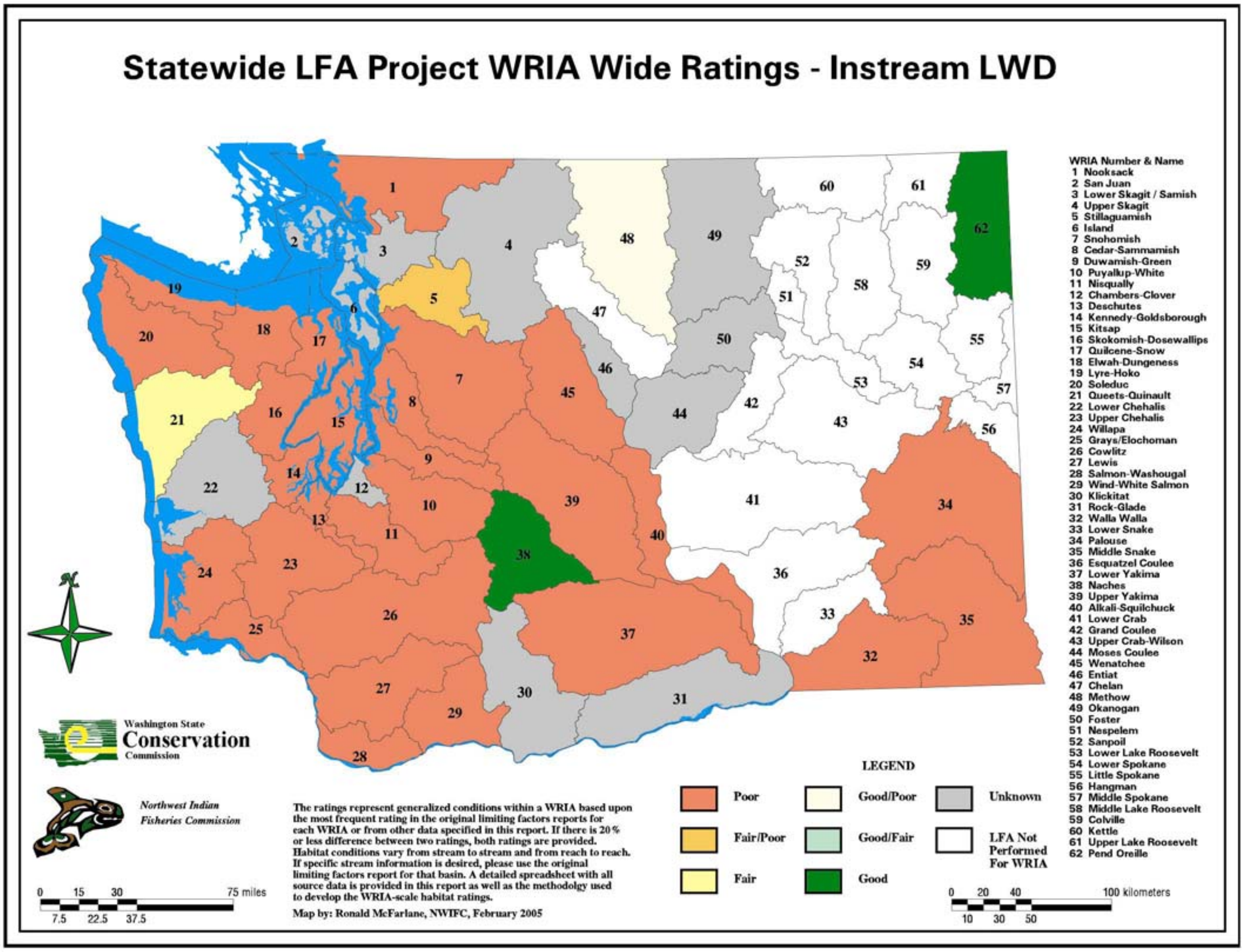


Figure 85. Map of large woody debris conditions in Washington State.



Large Woody Debris Conditions and Land Ownership

Although there were only four basins that did not have a poor or poor-fair rating for LWD, all four consisted of at least 40% federal land (Figure 86). However, poor-rated basins were found throughout all ranges of federal land ownership, including basins with large percentages of federal land. The data for state-owned land were too scattered with too few points in the fair or good categories to ascertain a pattern, although all good and fair rated basins had 15% or less state-owned lands (Figure 87), and many areas with low percentages of state owned lands had poor-rated LWD conditions. Basins with 40% or more privately owned lands had no fair or good rated WRIAs for LWD (Figure 88). To summarize, all fair and good rated LWD basins had generally higher percentages of federal lands and lower percentages of state or privately owned land, but with so few ratings in the non-poor categories, a strong conclusion cannot be made.

Figure 86. Large woody debris conditions based upon percent federal land.

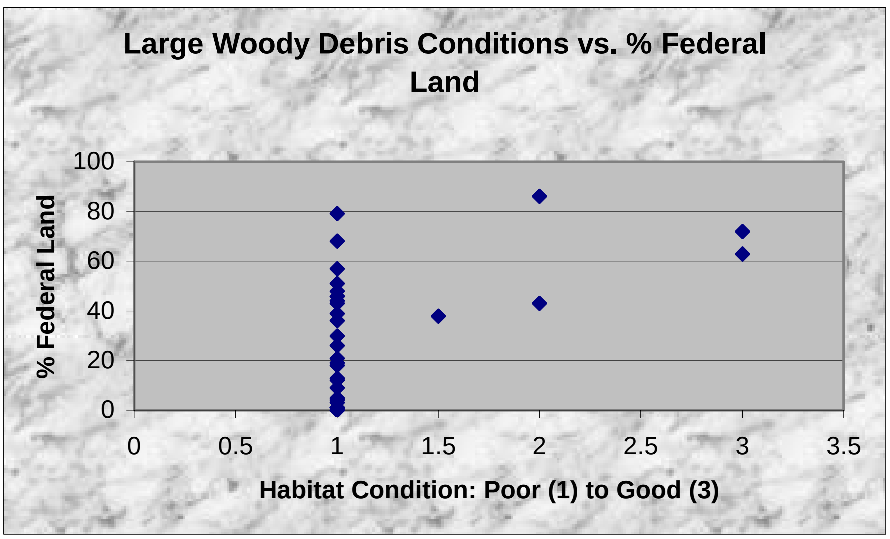


Figure 87. Large woody debris conditions based upon percent state owned land.

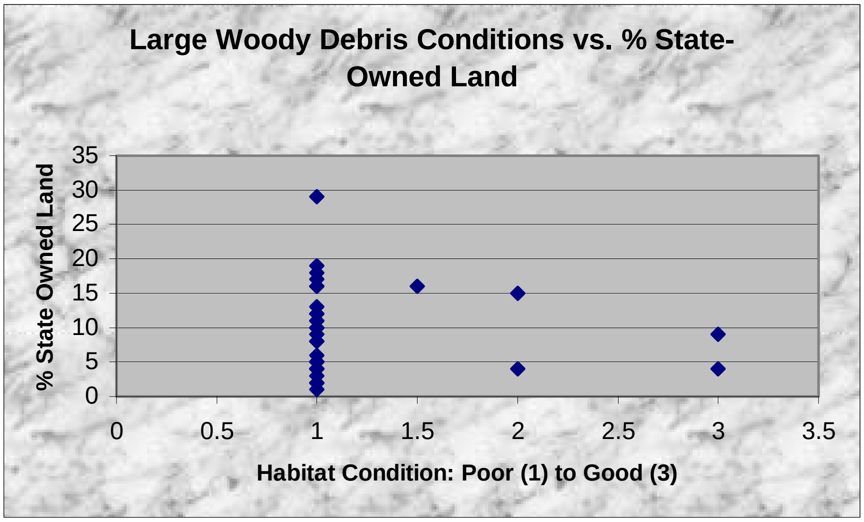
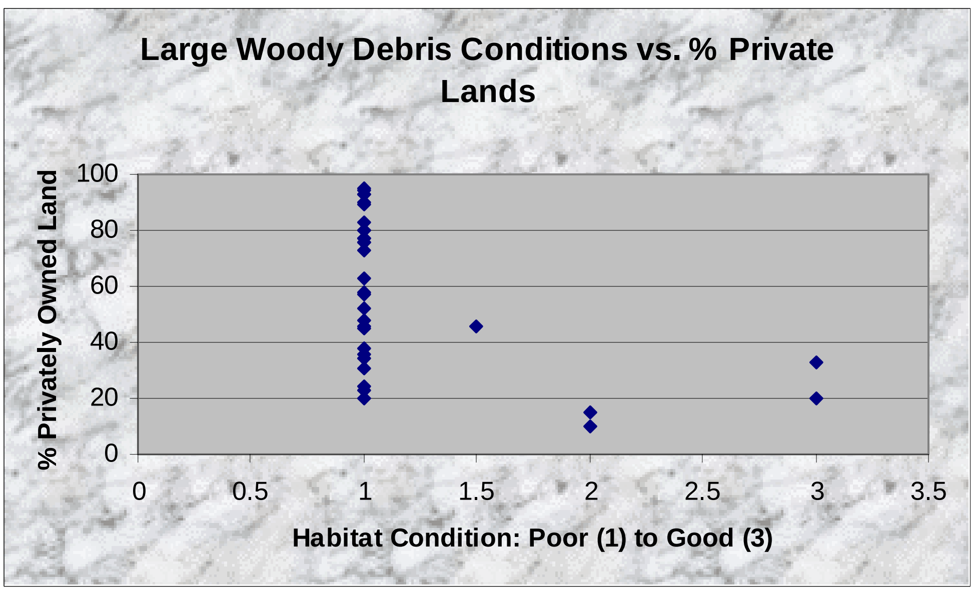


Figure 88. Large woody debris conditions based upon percent private land.



Large Woody Debris Conditions and Land Use

All basins with fair to good LWD conditions consisted of at least 65% forestland (Figure 89). However, high percentages of forested basins also had many poor ratings. Basins with high (40% or more) agricultural or urban (3% or more) lands had only poor ratings for LWD, but poor ratings were found in basins with low percentages of agricultural and urban lands as well (Figures 90 and 91). All basins with high human population densities had poor LWD ratings and all fair and good rated basins were in basins with extremely low human population densities

(Figure 92). Again, poor rated basins in low populated areas were also common, and with so few data available in the fair to good categories, it is difficult to ascertain patterns.

Figure 89. Large woody debris conditions based upon percent forestland.

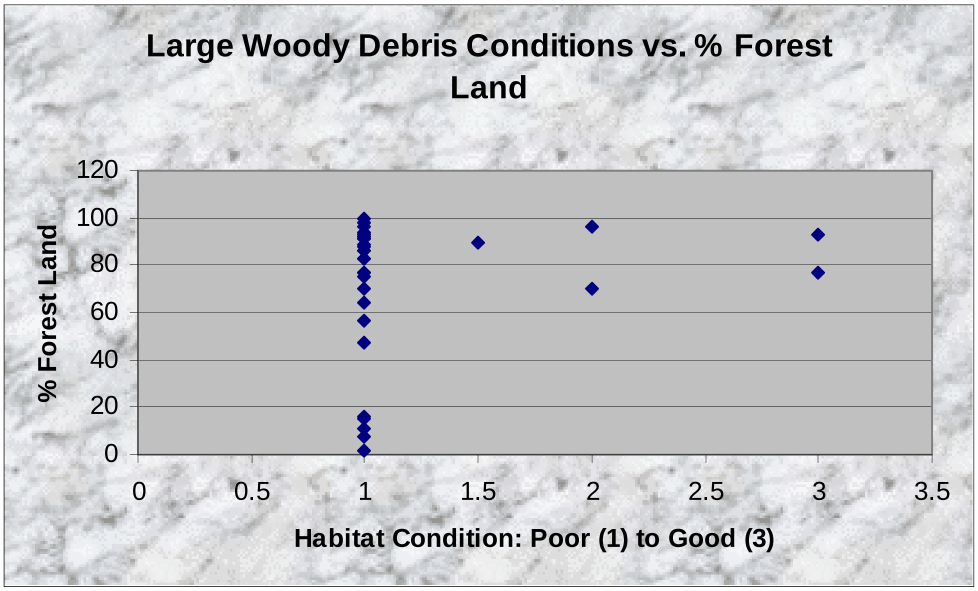


Figure 90. Large woody debris conditions based upon percent agricultural land.

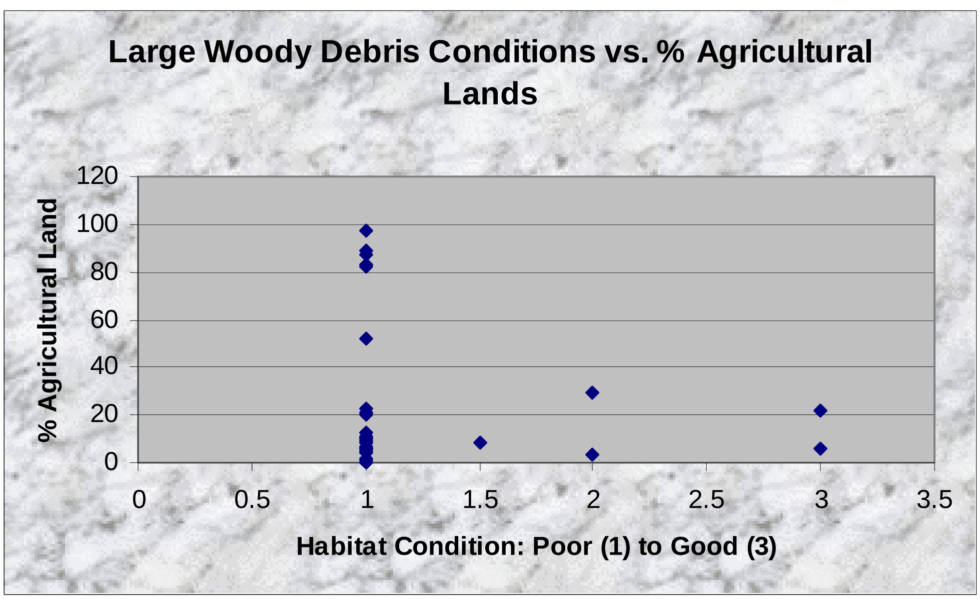


Figure 91. Large woody debris conditions based upon percent urban land.

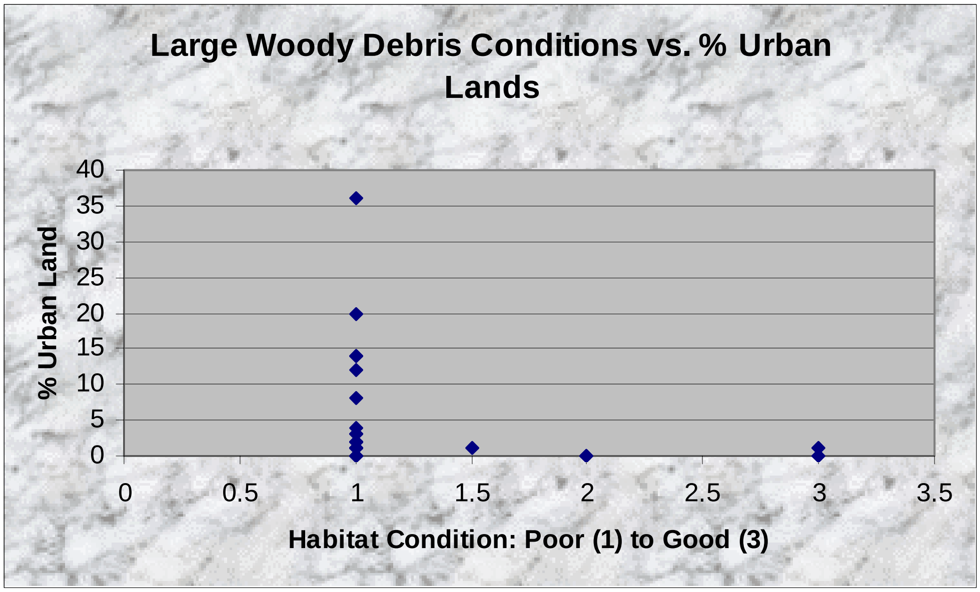
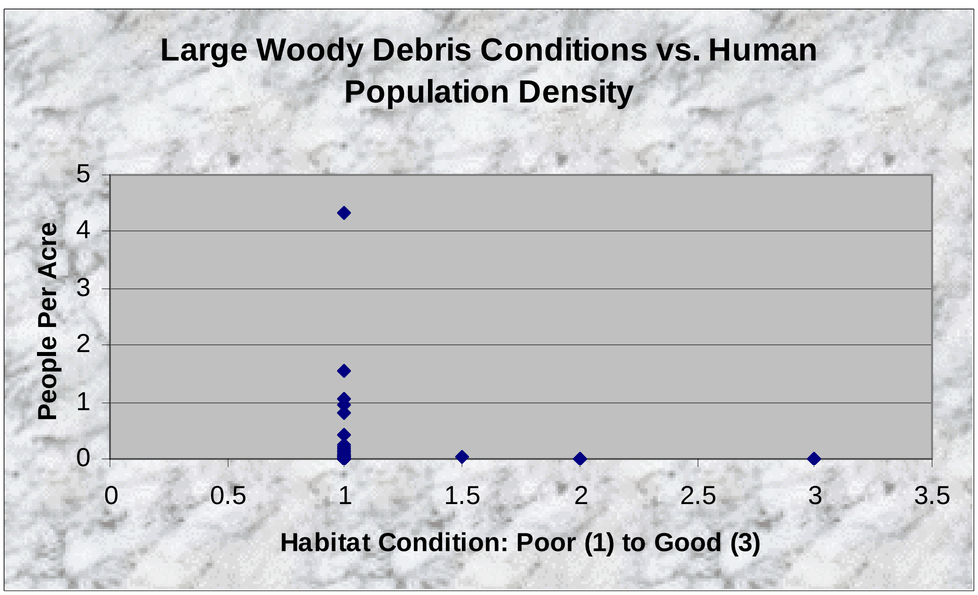


Figure 92. Large woody debris conditions based upon population density.



Data Gaps in Statewide Large Woody Debris Conditions

Twelve salmon-producing basins had insufficient LWD data to result in a rating. These were the lower Skagit, upper Skagit, San Juan, Enitat, Foster, Rock/Glade, Moses Coulee, Island, Chambers, lower Chehalis, Klickitat, and Okanogan WRIAs. All other WRIAs had scattered LWD data with no WRIA having comprehensive information on LWD conditions. The time-scale of recovery for LWD conditions is long. Once an area has poor levels of LWD, it will remain that way for decades unless there is direct intervention (LWD placement) or a mature riparian buffer, and in many of these areas, the riparian conditions are either poor or in recovery (fair). Because of this it makes more sense to monitor the causes of LWD conditions such as riparian zones and sedimentation rather than LWD itself.

STATEWIDE SALMONID POOL HABITAT CONDITIONS

Introduction

Pools are important habitat components for salmonids and their prey. Salmonids use pools for rearing, cover, feeding, and resting during migration. Pools are also important during spawning, as adults can rest and hide in pools that are near the spawning area. Important features of pools are size, depth, location, and cover (both instream and overhead). Generally, the greater size, depth, and cover that are present, the higher the quality of the pool. Large-deep pools with lots of cover provide many hiding areas, more prey (food), and cooler water temperatures. An abundance of pools interspersed with riffles combine to create ideal salmonid habitat.

Only 27 out of 45 WRIAs had sufficient data to lead to a WRIA-wide rating for pool habitat. Of these 27 WRIAs, 59% rated poor, 11% fair-poor, 18% fair, and 11% good (Figure 93). WRIAs that rated good for pool habitat were the Methow, lower Yakima, and Quillayute or Soleduck/Hoh (Figure 94). Fair rated WRIAs include the Nisqually, Naches, Lewis, and Queets. Poor rated WRIAs were scattered throughout the state except none were located along the coast (Figure 94).

When the Type 1 (larger) streams were examined separately, only two changes in ratings were significant. The pool habitat rating for the Methow dropped from good to poor indicating that while pool conditions are good in small streams, they are poor in Methow's larger streams. Also, the pool rating for West Hood Canal increased from poor to fair, suggesting that most of the poor rated areas are small streams in that WRIA.

Figure 93. Salmonid Pool Habitat Ratings by WRIA in Washington State.

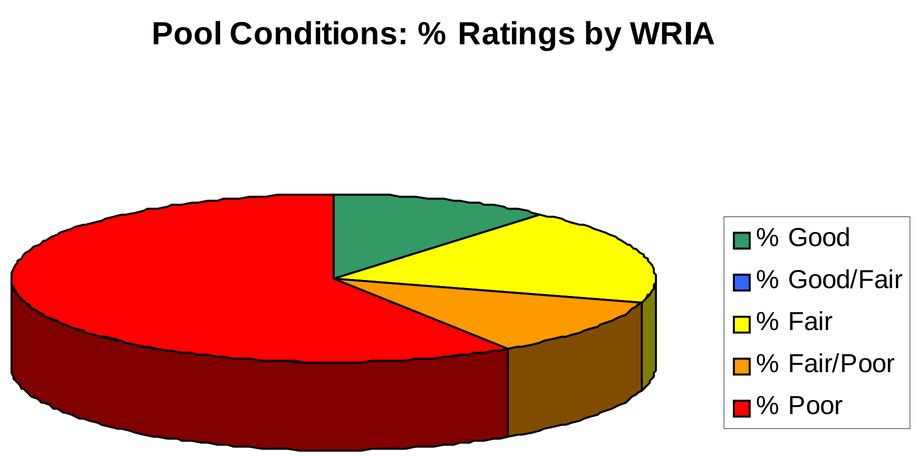
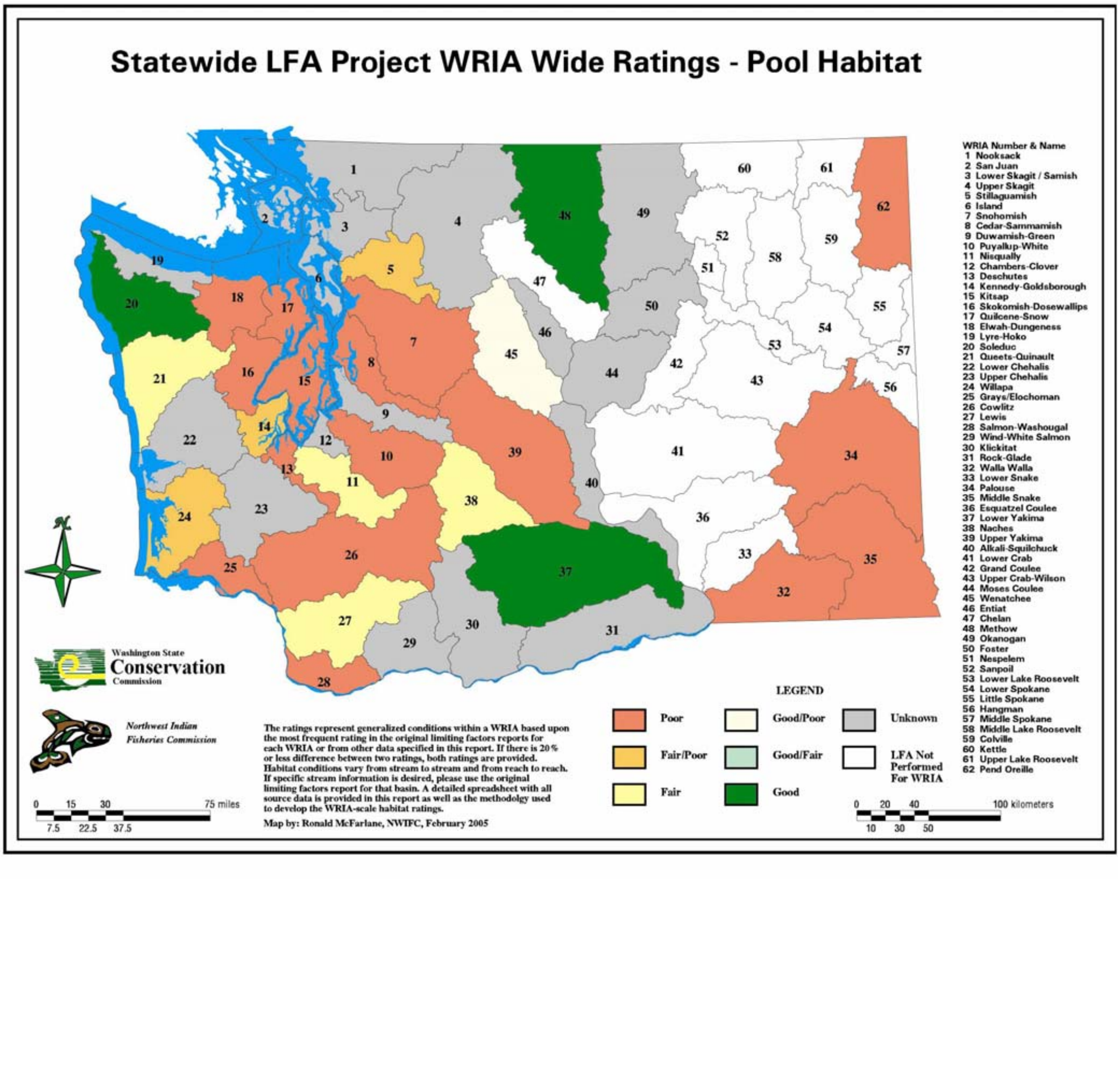


Figure 94. Map of WRIA-wide ratings for salmonid pool habitat in Washington.



Pool Habitat and Land Ownership

Overall WRIA-wide pool habitat ratings were scattered throughout the various percentages of federal and state land ownership such that there appears to be no relationship between these land ownership types and the quality or quantity of pool habitat (Figures 95 and 96). For private land ownership, lower the percentages of private land ownership had generally better ratings. The three WRIAs with good pool ratings had less than 40% private land ownership, and all fair or good rated WRIAs had less than 60% private land ownership (Figure 97). All WRIAs with 60% or greater private land ownership had only poor pool ratings. However, poor ratings were found throughout all private land ownership percentages, even in WRIAs with low percentages of private land.

Figure 95. Salmonid Pool Habitat based upon federal land ownership.

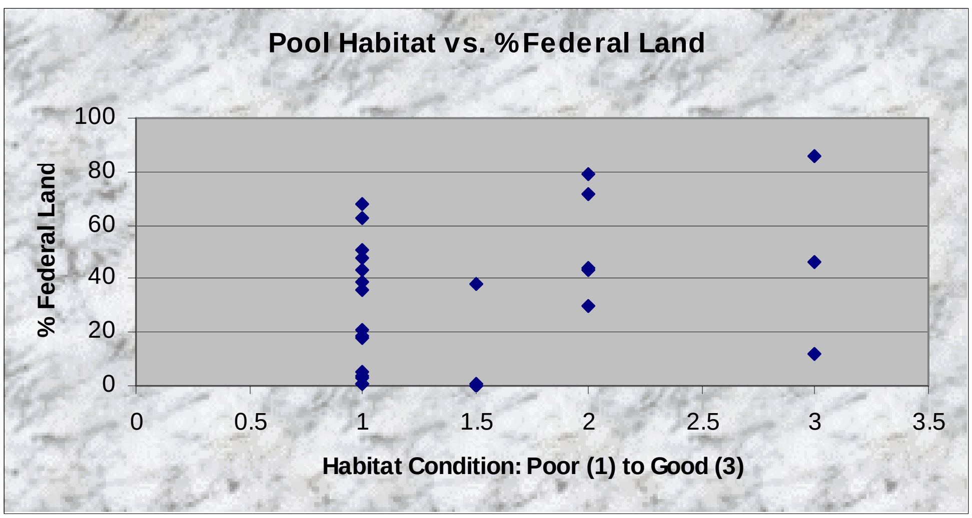


Figure 96. Salmonid pool habitat based upon state land ownership.

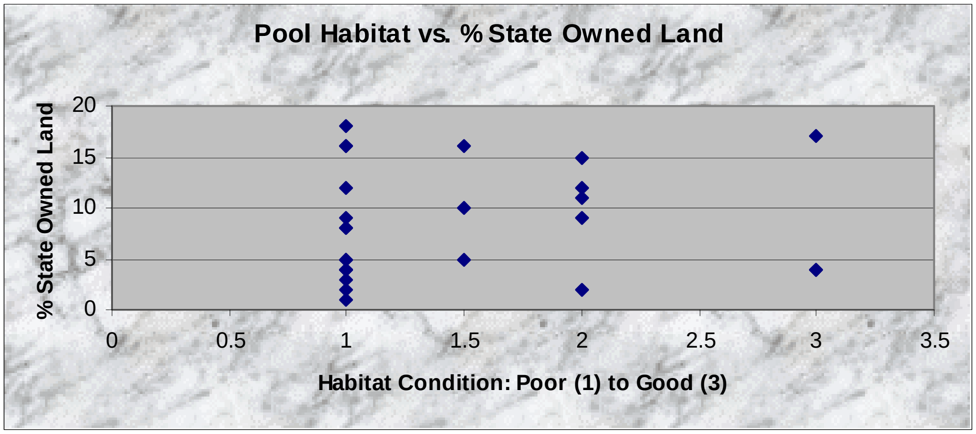
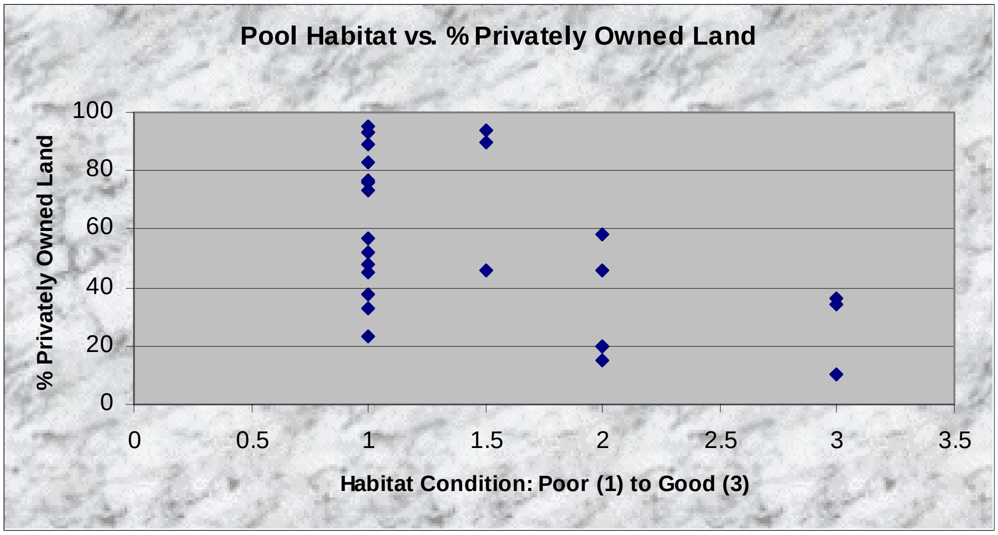


Figure 97. Salmonid pool habitat ratings by WRIA based upon private land ownership.



Salmonid Pool Habitat and Land Use

With the exception of one WRIA (lower Yakima), all WRIAs with overall pool habitat ratings that were better than poor were in WRIAs with a high percentage (70% or greater) of forestland (Figure 98), but poor rated WRIAs spanned the entire percentage range of forestland, including many with a high percentage of forestland. While there appeared to be no relationship between pool habitat rating and agricultural land (Figure 99), urbanization seemed to have a negative effect on pool habitat (Figure 100). WRIAs with 5% or more urban land and high human population densities (0.5 people per acre or more) had only poor ratings for pool conditions

(Figure 101). Poor rated WRIAs for pool habitat were also found in low population density WRIAs.

Figure 98. Salmonid pool habitat by WRIA based upon forestland.

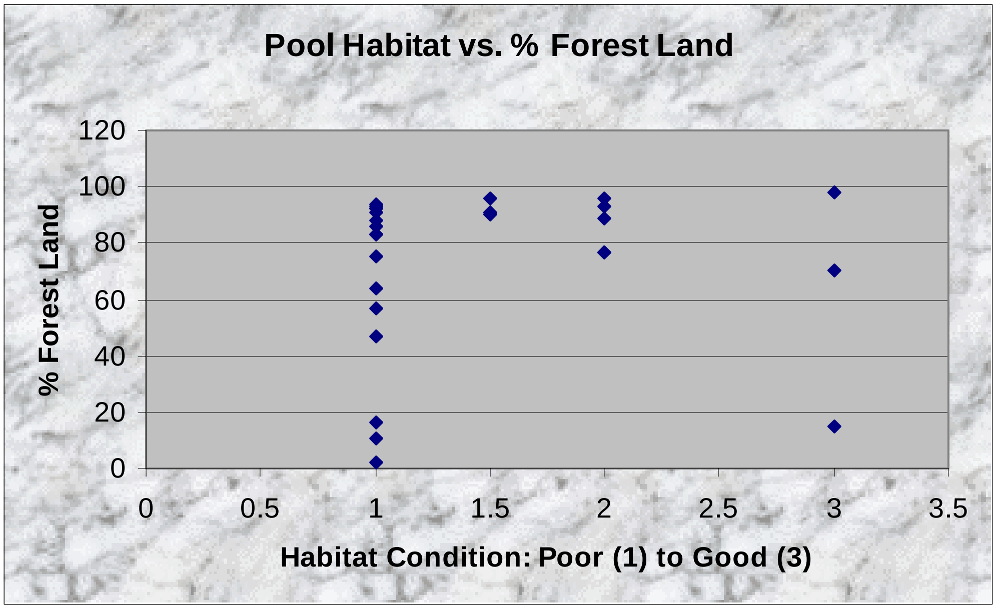


Figure 99. Salmonid pool habitat by WRIA based upon percent agricultural land.

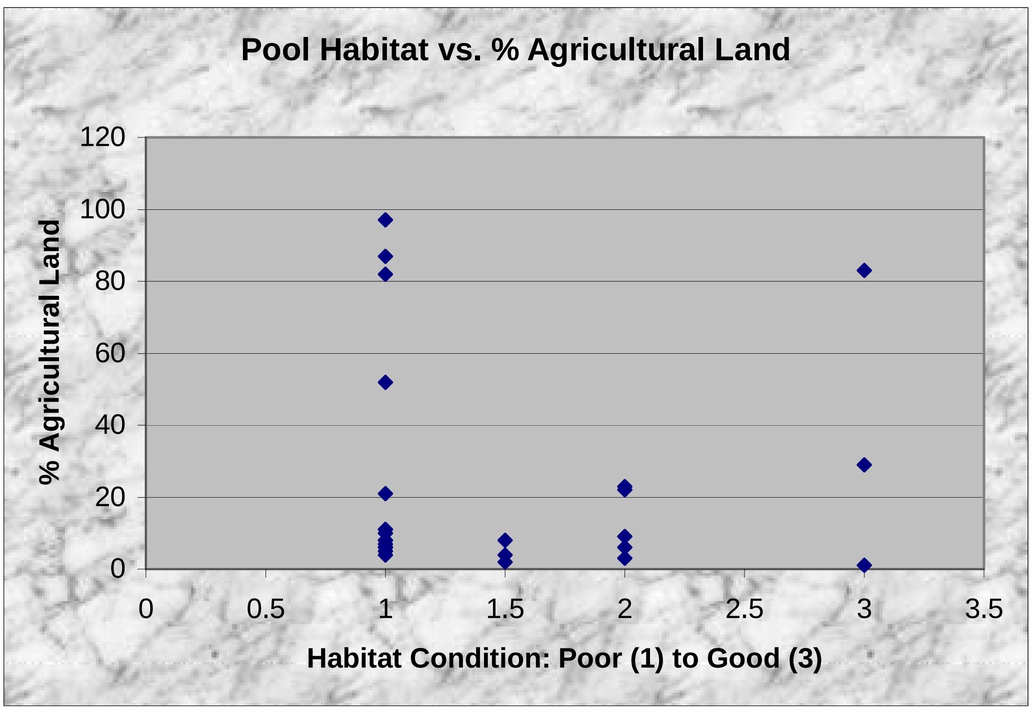


Figure 100. Salmonid pool habitat by WRIA based upon percent urban land.

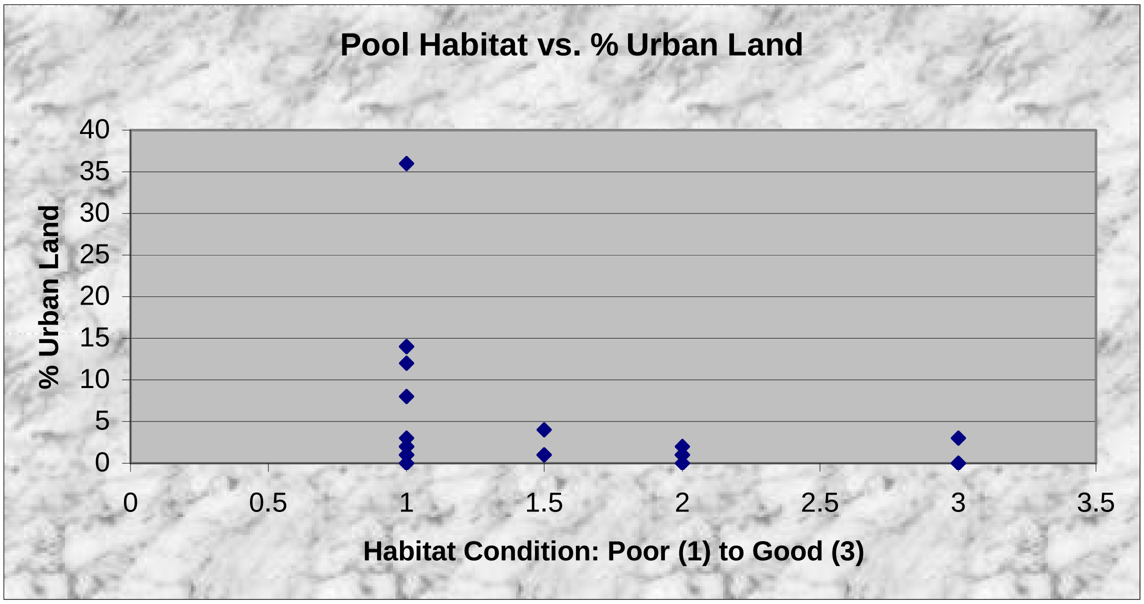
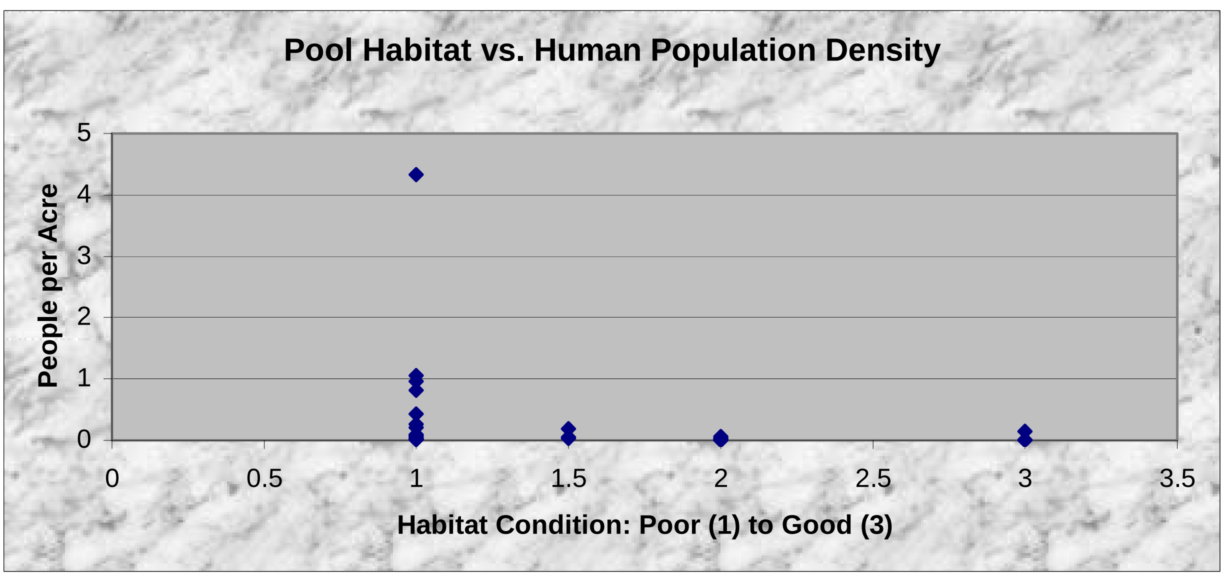


Figure 101. Salmonid pool habitat based upon people per acre.



Data Gaps in Salmonid Pool Habitat Data

Complete data on pool habitat were lacking in all WRIAs, but 18 WRIAs did not have sufficient data to develop an overall rating. These include the: Okanogan, Klickitat, Wind/White Salmon, Chehalis (lower and upper), Chambers, Island, Moses Coulee, Alkali, Nooksack, Green, Hoko, Rock/Glade, Foster, San Juan, Entiat, and Skagit (lower and upper) basins. In WRIAs with overall pool habitat ratings, the ratings were often based upon data in limited areas. The most common source of pool habitat data was watershed analysis. Of particular note is the need for updated pool habitat data for the South Fork Nooksack River. Here, pool habitat has been shown to be very limiting in the past, yet important for spring chinook spawners and coho salmon juveniles in a stream where high sediment loads and degraded riparian conditions have contributed to water temperatures that are much warmer than optimal. Thermal refuges found in deep pools would be vital in this type of environment.

STATEWIDE SALMONID WATER TEMPERATURE CONDITIONS

Introduction

For optimal survival, salmonids need cool, clean water that meets established guidelines for water quality. Temperature, dissolved oxygen (DO), total suspended solids (TSS), pH, toxins, and nutrients are among the important elements of water quality, and standards have been developed for many of these. Water temperature and dissolved oxygen requirements vary depending upon the salmonid lifestage and species, but in general, a water temperature range of 50-57°F (10-14°C) is preferred, and long-term exposure to either temperatures warmer than 75°F (24°C) or dissolved oxygen concentrations of 5 mg/L (or parts per million) or less is fatal to salmonids (Bjornn and Reiser 1991). Water temperature and dissolved oxygen standards have been developed to assess water temperature conditions, and those are described in Table 8 of the Assessment Chapter. Total suspended solids refers to the weight of particles such as soil and algae suspended in a given volume of the water column (Michaud 1991). The U.S. Fish and Wildlife Service recommends that TSS levels should be 80 mg/L or less to protect salmonid fish (Fish and Wildlife Service 1995). Other water quality parameters including pH, nutrients, and toxins can also degrade habitat quality when present in non-optimal ranges.

This chapter summarizes water quality data that pertains directly to salmonids. This includes water temperature, dissolved oxygen, turbidity, phosphorus, nitrogen compounds, pH, and toxins in both the water column and sediments. Fecal coliform exceedances are not discussed because they don't directly relate to salmonid impacts. The water quality standards used for this report are described in detail in Table 8 of the Assessment Chapter. Generally, summer water temperatures are good when below 14^{o}C, fair in the range of 14 to 15.6 ^{o}C, and poor when warmer than 15.6 ^{o}C. Dissolved oxygen levels are considered good when above 8 mg/L, fair in the range of 6 to 8 mg/L, and poor when less than 6 mg/L.

It is important to note that these standards may not be sufficient to describe impacts to bull trout and Dolly Varden. Char are very dependent on the freshwater environment, where they reproduce only in clean, cold, relatively pristine streams. Because of the restrictive habitat requirements, especially as it relates to temperature, bull trout are generally recognized as a sensitive species by natural resource management agencies. Reductions in their abundance or distribution are inferred to represent strong evidence of freshwater habitat degradation. The Environmental Protection Agency (EPA) is in the process of drafting new temperature guidelines for Region 10 (the Pacific Northwest) that take into account the cooler temperatures needed by bull trout. Their recent draft recommendations for summer maximum conditions (7-day average of daily maximum) are for temperatures to be no warmer than 12ºC in areas known to be used for bull trout rearing (Environmental Protection Agency 2002 draft). EPA temperature recommendations for other salmonid species and for bull trout during other life history stages are warmer than the standards used in this report.

There are many human activities that impact water quality. Elevated water temperatures are typically associated with one or more of several causes. The major ones are loss of mature riparian vegetation along the stream corridor, reduced instream flows during late summer resulting from water withdrawals, reduced water depth as a result of increased sedimentation, and increased solar exposure to water impounded behind dams. Dissolved oxygen levels are directly associated with water temperature with saturation higher in colder water, and can be reduced by high nutrient levels. Turbidity refers to the presence of suspended sediment in the water column that may affect survival of eggs or fish. Stormwater runoff (particularly from roads), surface erosion, and increased streambank erosion are the main contributors of turbidity. Natural stream nutrient regimes have been altered by several factors. Some include decreased numbers of salmon carcasses, removal or alteration of riparian vegetation that reduces the entry of litter fall and invertebrates, a lack of LWD in streams that slows the loss of nutrient sources from the stream, and stormwater flows that flush available nutrients from the streams. Increased levels of nutrients result from stormwater runoff with high levels of nitrogen and phosphorus and from failing septics and sewage treatment plant outfalls. Sources of toxics include spills, runoff from roads/parking lots, exposure of the stream or marine water to treated wood, leaching of pesticides, and leaching of heavy metals.

Three different water quality categories were included in this report: water temperature, dissolved oxygen, and other water quality issues, which encompassed nutrients, pH, and toxins. Of these three major categories, data were widely lacking to develop enough WRIA-wide ratings for further analysis of dissolved oxygen and other water quality issues. Instead, maps are provided to show WRIA-wide ratings in all categories where they existed, and only the results for water temperature were compared to land ownership and land use.

Of the 35 WRIAs that had adequate data for a WRIA-wide rating for water temperature, 62% rated poor, 11% fair, and 26% good or good-fair (Figure 102). WRIAs that rated good for water temperature include the upper Skagit, Methow, Wenatchee, Lake Washington, Kitsap, Nisqually, West Hood Canal, and Elwha basins (Figure 103). San Juan rated good-fair, and Puyallup and Quilcene rated fair. Of these, there are several important notes.

- Many of the samples in the Lake Washington WRIA were in the upper Cedar or Issaquah watersheds where overall conditions are good. Few data were available in the lower watersheds and in the smaller independent streams that are more degraded. This likely results in a rating that may not accurately reflect WRIA-wide conditions.

- The rating in the Elwha/Dungeness WRIA also understates water temperature problems in both the lower Dungeness and lower Elwha Rivers. When the lower reaches of a river have degraded conditions, the potential impacts are greater because all anadromous stocks will have to migrate through degraded areas even though they may spawn and rear in the better upstream conditions such as in the Dungeness.

- The poor ratings in the Queets and Solduck/Hoh (Quillayute) WRIAs are likely overstated because few data were available for the streams within the National Park Service lands, where conditions are likely good.

Because of the above concerns, there is low confidence in the accuracy of the WRIA-wide ratings for Lake Washington, Elwha/Dungeness, Queets, and Soleduck/Hoh Basins.

When examining only the Type 1 (larger) streams, the ratings for the Lake Washington and Wenatchee basins fell from good to fair because the small tributaries in the upper basins were no longer included. An even greater decrease in water temperature rating occurred for Quilcene and Elwha/Dungeness, which fell from good to poor once Type 1 streams were examined separately. Two WRIAs had improved ratings for water temperature when Type 1 streams only were examined. Lower Yakima changed from poor to good and upper Yakima changed from poor to fair.

For dissolved oxygen, only nine WRIAs had sufficient data for a WRIA-wide rating. Most (6) rated good, including lower and upper Skagit, Quilcene, Kennedy, Willapa, and Queets (Figure 104). The lower Yakima and Lake Washington basins rated poor in dissolved oxygen.

For the category of other water quality problems, only eleven WRIAs had data for a WRIA-wide rating. Of these, six rated poor and four rated good. The good rated WRIAs include the Methow, upper Yakima, Naches, and Nisqually. The poor rated WRIAs were Nooksack, lower Skagit, Chambers, lower Yakima, Walla Walla, and Middle Snake Basins (Figure 105).

Figure 102. Water temperature ratings by WRIA in Washington State.

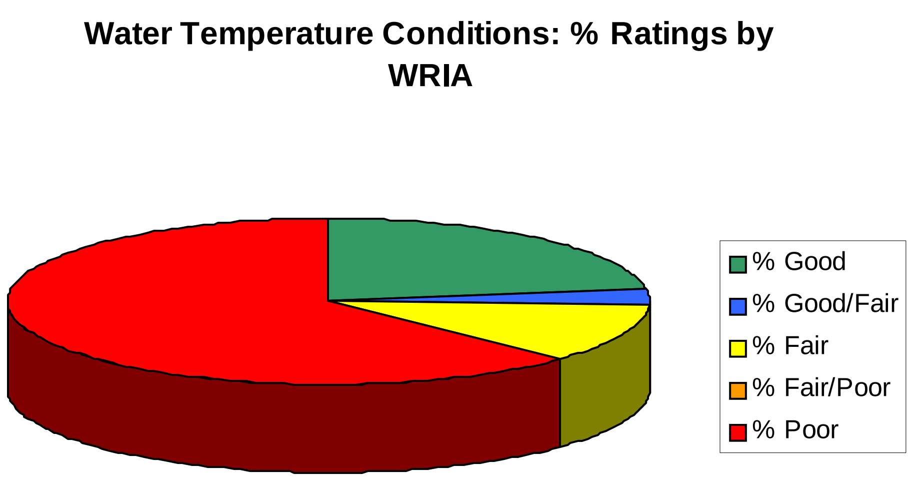


Figure 103. Statewide water temperature ratings by WRIA.

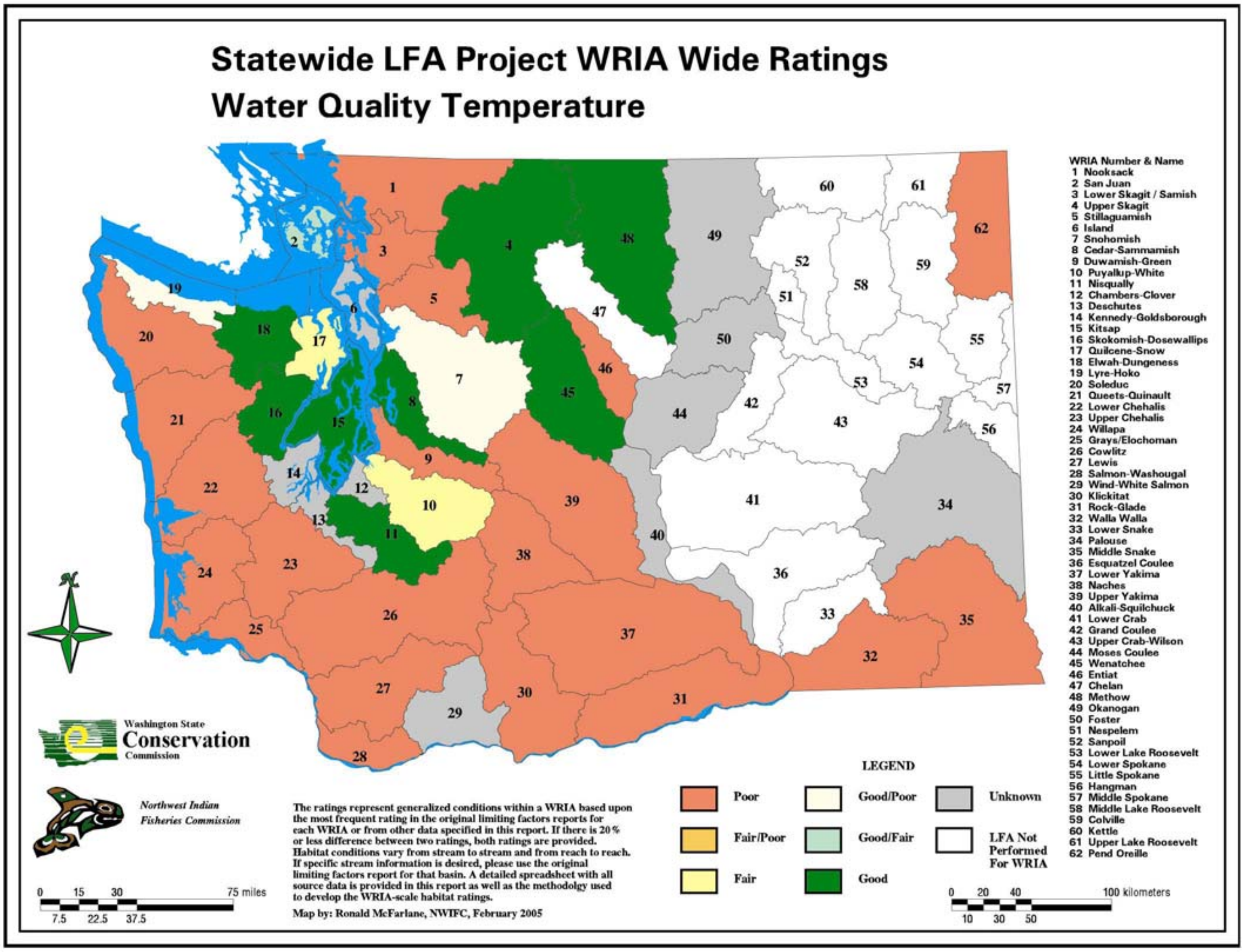


Figure 104. Statewide dissolved oxygen ratings by WRIA in Washington State.

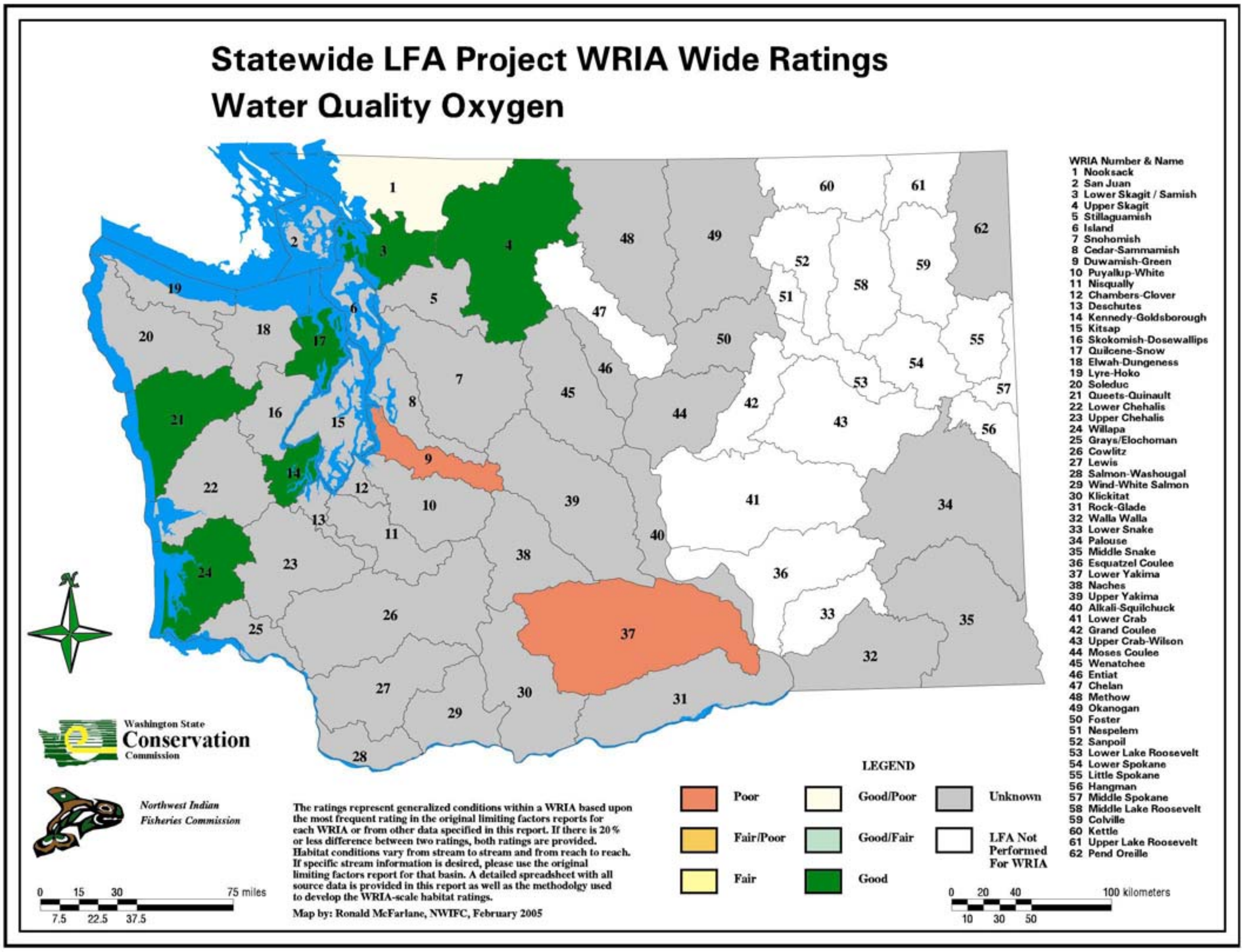
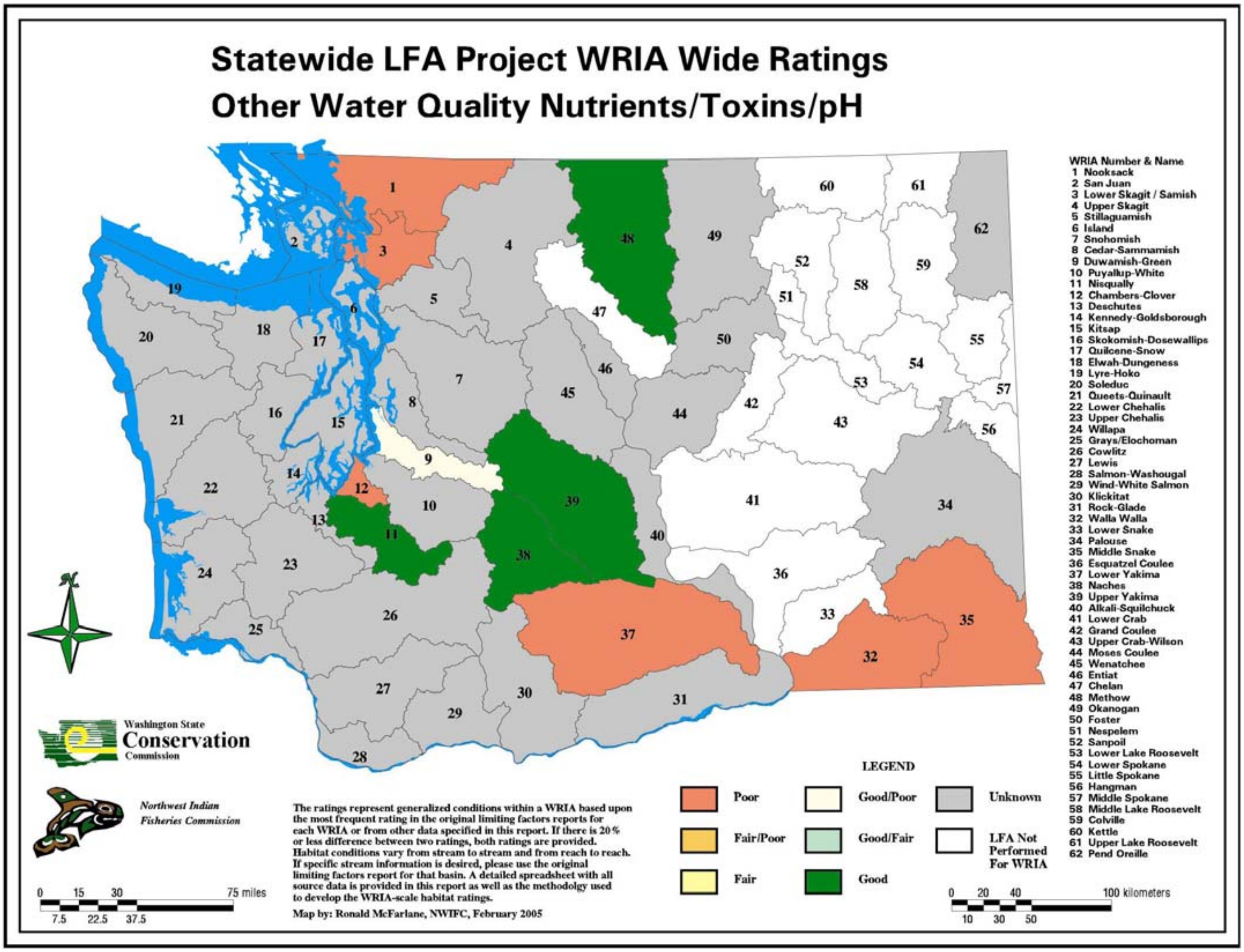


Figure 105. Statewide miscellaneous water quality problems (toxins, nutrients, pH) by WRIA in Washington State.



Water Temperature and Land Ownership

Figures 106-108 show the WRIA-wide ratings of water temperature versus federal, state, or private land ownership. The ratings are spread throughout the various percentages of land ownership types with no apparent relationships to land ownership. However, as noted above, the ratings for several WRIAs are likely not accurate, and this could explain the scattered results.

Figure 106. Water temperature ratings by WRIA based upon federal land ownership.

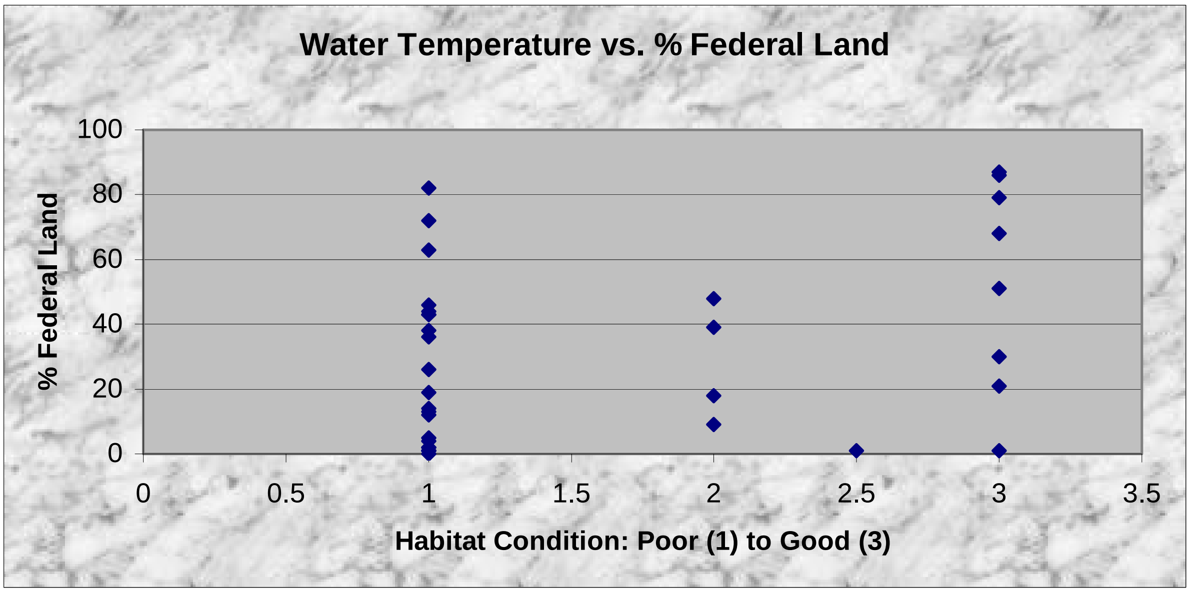


Figure 107. Water temperature ratings by WRIA based upon state owned land ownership.

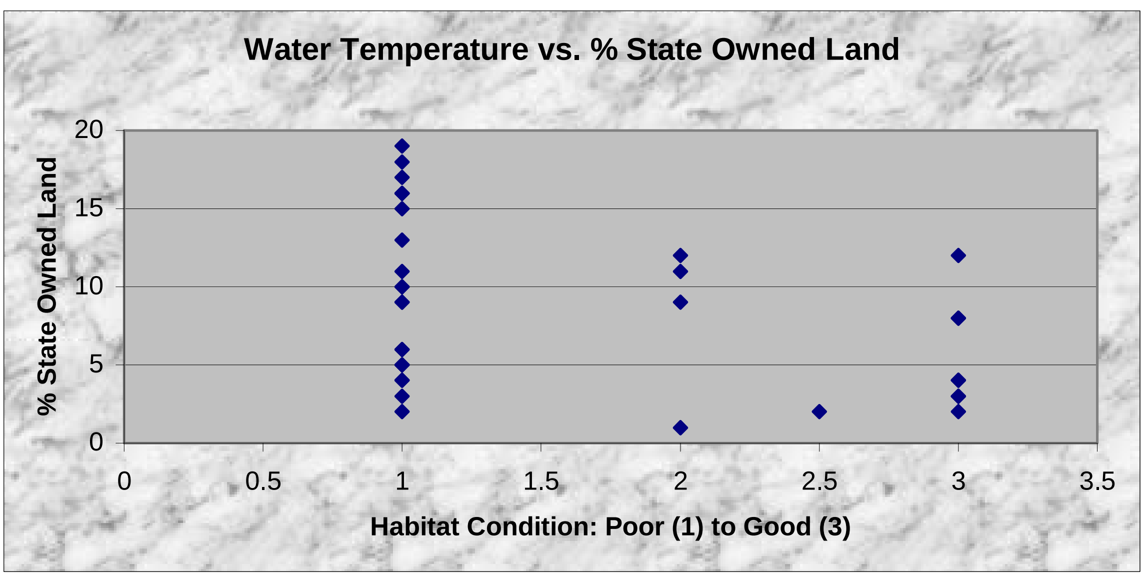
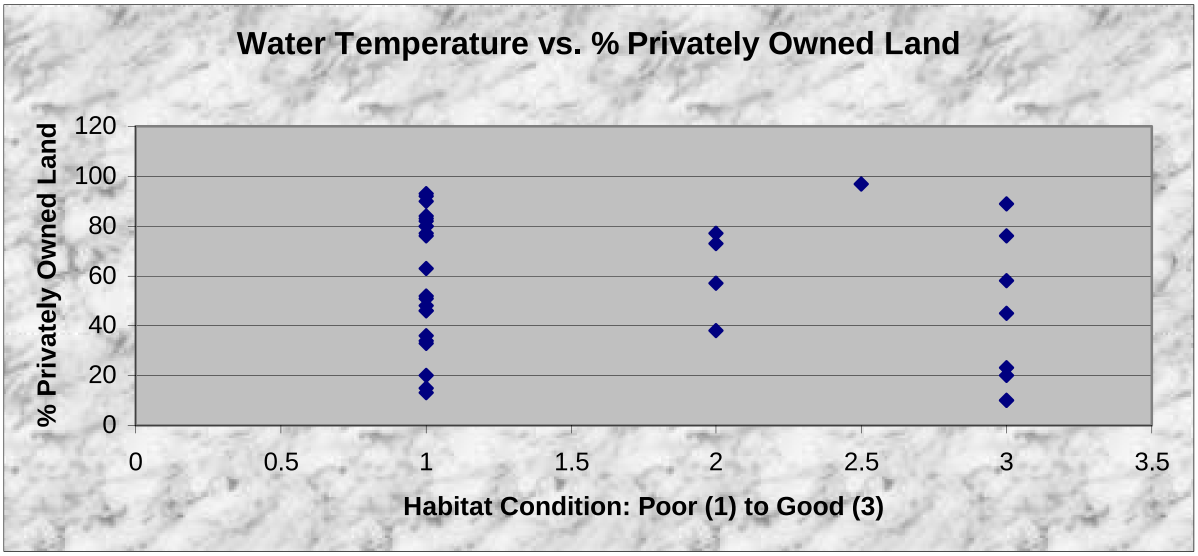


Figure 108. Water temperature ratings by WRIA based upon private land ownership.



Water Temperature and Land Use

Stronger conclusions can be made with respect to water temperature and land use. All good and fair rated WRIAs were those with 58% or greater forestland, although numerous WRIAs with high percentages of forestland had poor ratings as well. All WRIAs with less than 50% forestland had poor ratings (Figure 109). An opposite pattern existed for agricultural lands. WRIAs consisting of more than 30% agricultural lands had only poor ratings. However, poor ratings were also found among WRIAs with low percentages of agricultural or range land (Figure 110). No relationship was found with urban lands or population density (Figures 111 and 112), but one partial reason for this is that ratings in an urban-rich WRIA (Lake Washington) were based upon numerous results in the upper reaches of streams where conditions are good with fewer data available for the lower reaches and small urban streams.

Figure 109. Water temperature ratings by WRIA based upon percent federal land ownership.

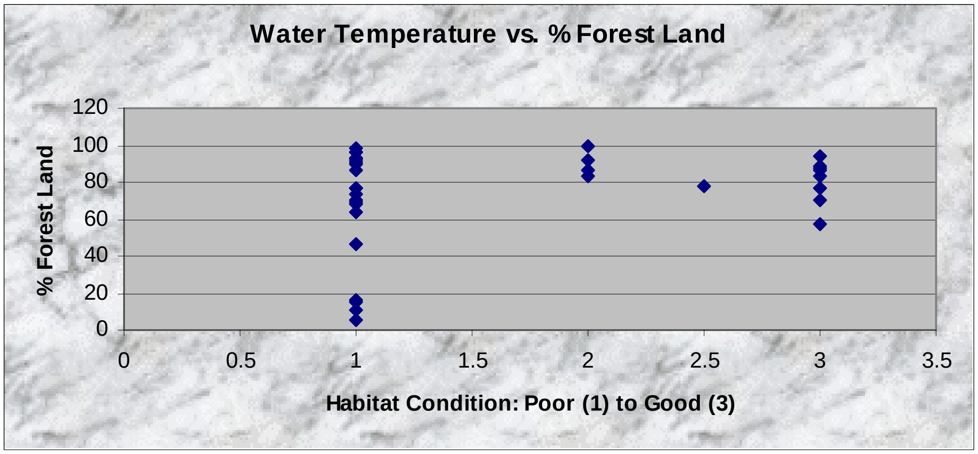


Figure 110. Water temperature ratings by WRIA based upon percent agricultural land use.

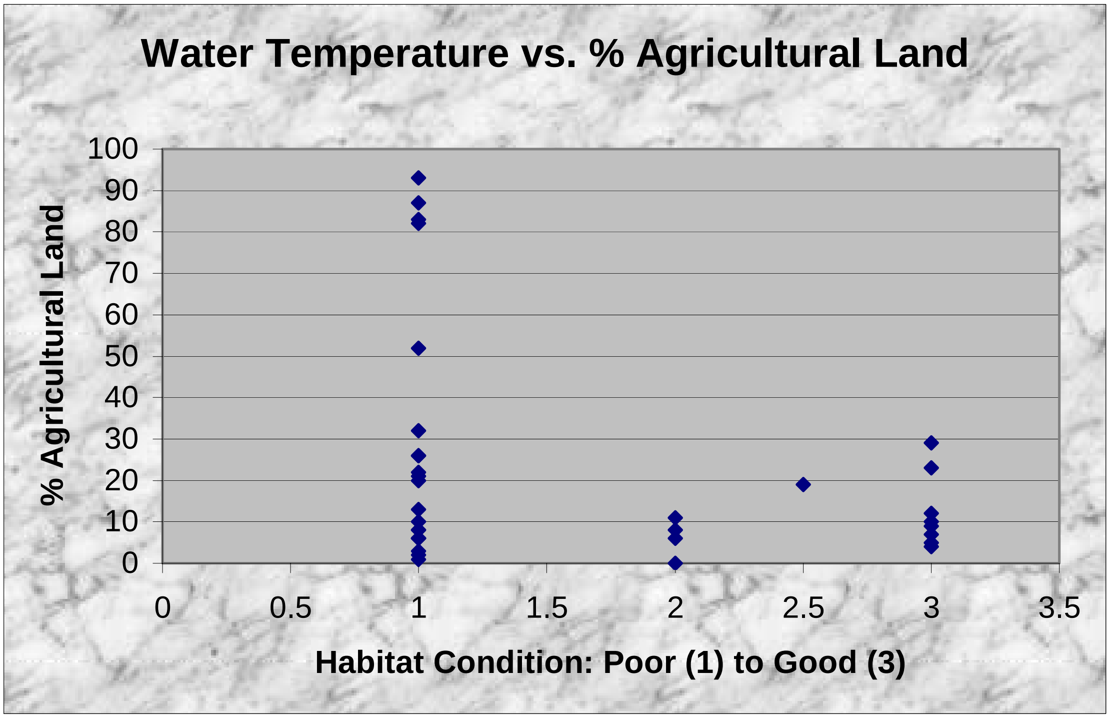


Figure 111. Water temperature ratings by WRIA based upon percent urban land use.

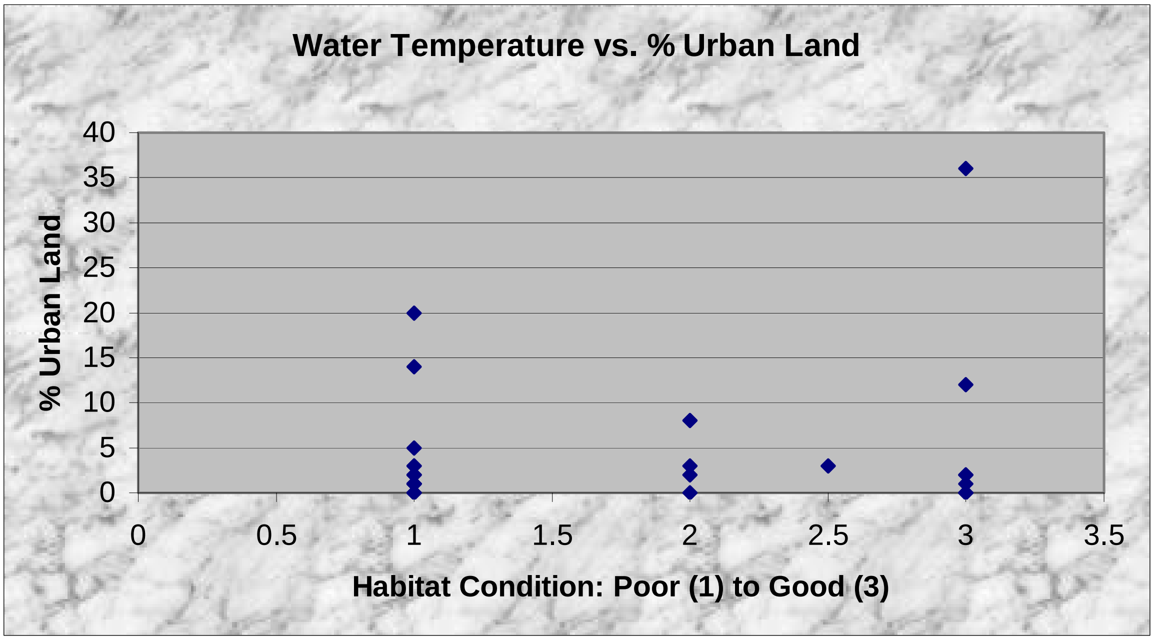
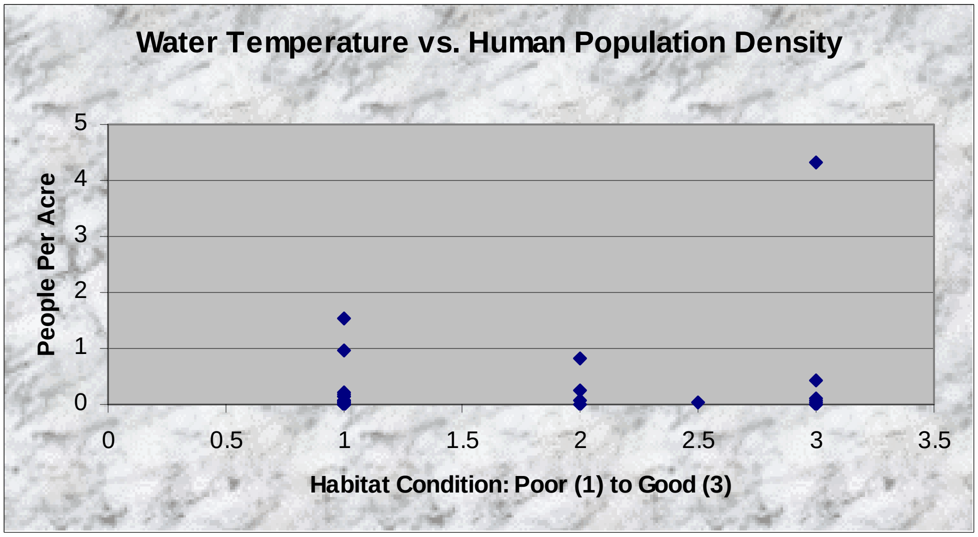


Figure 112. Water temperature ratings by WRIA based upon people per acre.



Data Gaps in Water Temperature

Additional water quality data are greatly needed for all salmonid-producing WRIAs in Washington State. Often, data are only available in a few sporadic locations, and data for dissolved oxygen, nutrients, pH, and toxins are even less available than for water temperature. Ten basins had insufficient water temperature data to assess as a WRIA. These were the Palouse, Kennedy, Foster, Deschutes, Alkali, Moses Coulee, Island, Chambers, Wind/White Salmon, and the Okanogan WRIAs. Data are particularly needed in these basins. In addition, when problem areas are identified, further assessments should be done to ascertain the causes of the problems. Often, action cannot be taken even where problems are known because insufficient information exists to identify the causes.

STATEWIDE SALMONID HIGH FLOW CONDITIONS

Introduction

The frequency and magnitude of floods are important because floods are the primary source of disturbance in streams, playing a key role on channel structure and function. In ecologically healthy systems, changes caused by natural disturbances are not usually sustained, and recovery is rapid to pre-disturbance levels. Human-caused alterations in basin hydrology (water movement) can change the frequency and/or magnitude of flood flows. Common human impacts include changes in soils, decreases in the amount of forest cover, wetlands, and riparian vegetation, and increases in impervious surfaces, sedimentation, and roads. Hydrologic impacts to stream channels can occur at relatively low levels of development, increasing in severity as more of the landscape is converted to from natural forest cover to developed land uses (Hammer 1972; Hollis 1975). Important indicators of hydrologic conditions are the percentage of impervious surfaces and forested land cover (Center for Watershed Protection 2002). Both of these indicators are examined in this report.

Sedimentation and road density can also alter water delivery, but are assessed in the sedimentation section of this report. Increased sediment delivery reduces the depth of many stream channels, worsening the impacts of altered stream flow. For example, annual water yields increase in the first decade of rainy seasons after harvest and roading (Hicks et al. 1991b), leading to an increased magnitude of high flows in watersheds (Jones and Grant 1996). Roads increase the peak flow problem by routing surface water more quickly to streams. The effects of roads on increased flow is independent of quantity of forest harvest, but when both activities are combined, the model developed by La Marche and Lettenmaier (1998) showed a 21% increase in 10 year return floods. Flood effects can be worsened by floodplain impacts as well. For example, high flows coupled with levees and other bank hardening can lead to greatly reduced survival of incubating salmon eggs or fry (Orsborn and Ralph 1994; Williams and Associates Ltd. 1996).

Although flows are monitored in many streams by the U.S. Geological Survey, data are lacking to link flows to salmonid production or to compare current flow regimes to pre-disturbance flows. In this section, data pertaining to potential high flow impacts are presented with the caveat that while a few basins have studies to support a direct relationship between high flows and salmon production, most do not. In basins without such data, ancillary data were often used. The most common data type used was hydrologic maturity or the type and age of vegetation (tree) classes that cover the landscape. The loss of land cover vegetation is thought to decrease the aquifer and wetland storage capacity by disconnecting the wetland hydrologic continuity and altering upland water infiltration and groundwater recharge (Poole and Berman 2000).

Out of 36 total basins assessed for high flows, 53% were rated poor, 19% rated fair, and 28% rated either good or good-fair (Figure 113). Good or good-fair rated basins include the upper Skagit, Methow, Wenatchee, upper Yakima, Naches, Middle Snake, Nisqually, West Hood

Canal, Elwha/Dungeness, and Queets WRIAs (Figure 114). Fair rated basins were Soleduck/Hoh, Pend Oreille, Snohomish, Foster, Alkali, and lower Yakima WRIAs. Poor rated basins were more commonly located on the west side of the Cascade Mountain Range (Figure 114), although several basins with unknown conditions were on the eastside. It should be noted that some of the fair to good rated basins do have problems associated with high flows such as the lower Dungeness (Orsborn and Ralph 1994). However, ratings from other streams in the WRIA and other reaches within that stream have masked the lesser quantity of poor ratings.

In addition to hydrologic maturity, percent impervious surfaces was an additional category in the limiting factors reports. Unfortunately, data for this parameter were extremely lacking, preventing a WRIA-wide analysis. Instead, the few WRIA-wide ratings that could be developed are shown in Figure 115. Good rated basins include the Nooksack, lower Skagit, upper Skagit, West Hood Canal, and Quilcene. Poor rated basins were not surprisingly the Lake Washington and Chambers WRIAs. Mixed conditions existed in the Puyallup/White Basin and fair conditions in Snohomish.

Figure 113. High flow ratings by WRIA in Washington State.

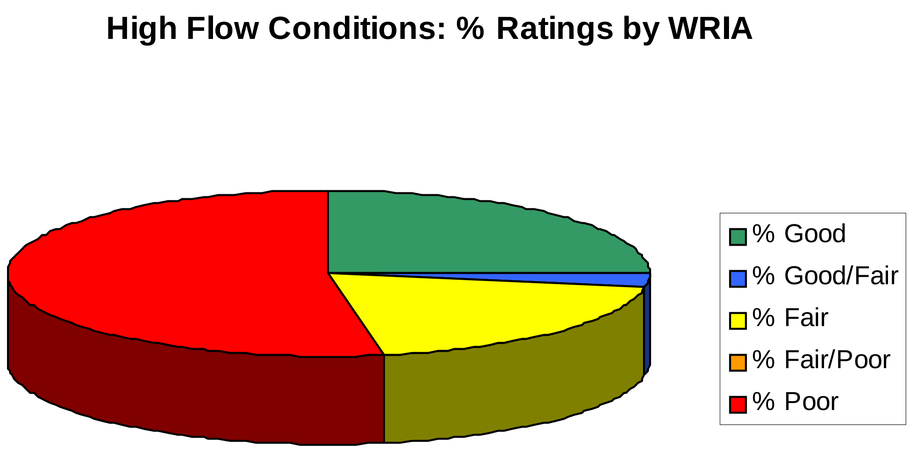


Figure 114. Map of high flow ratings by WRIA in Washington State based upon hydrologic maturity.

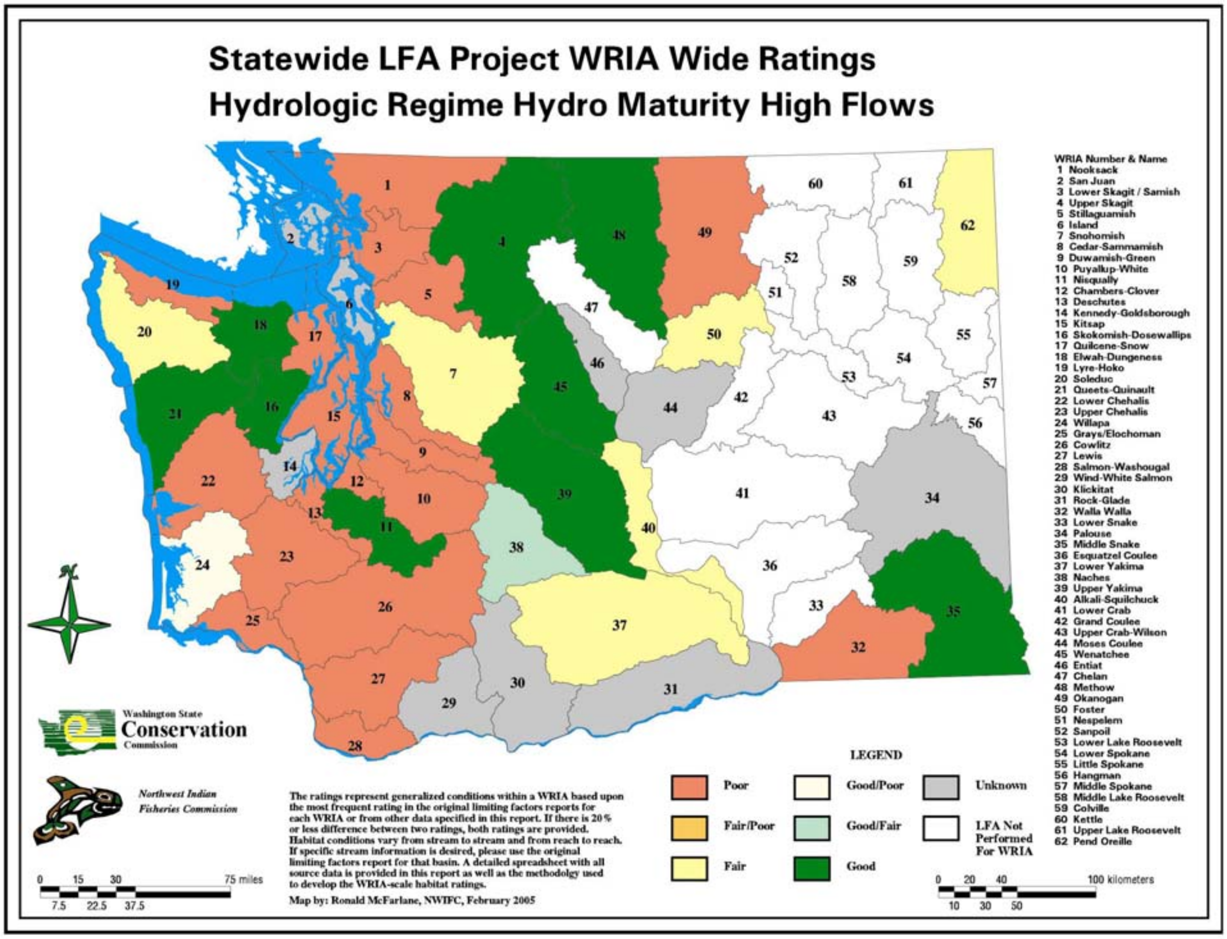
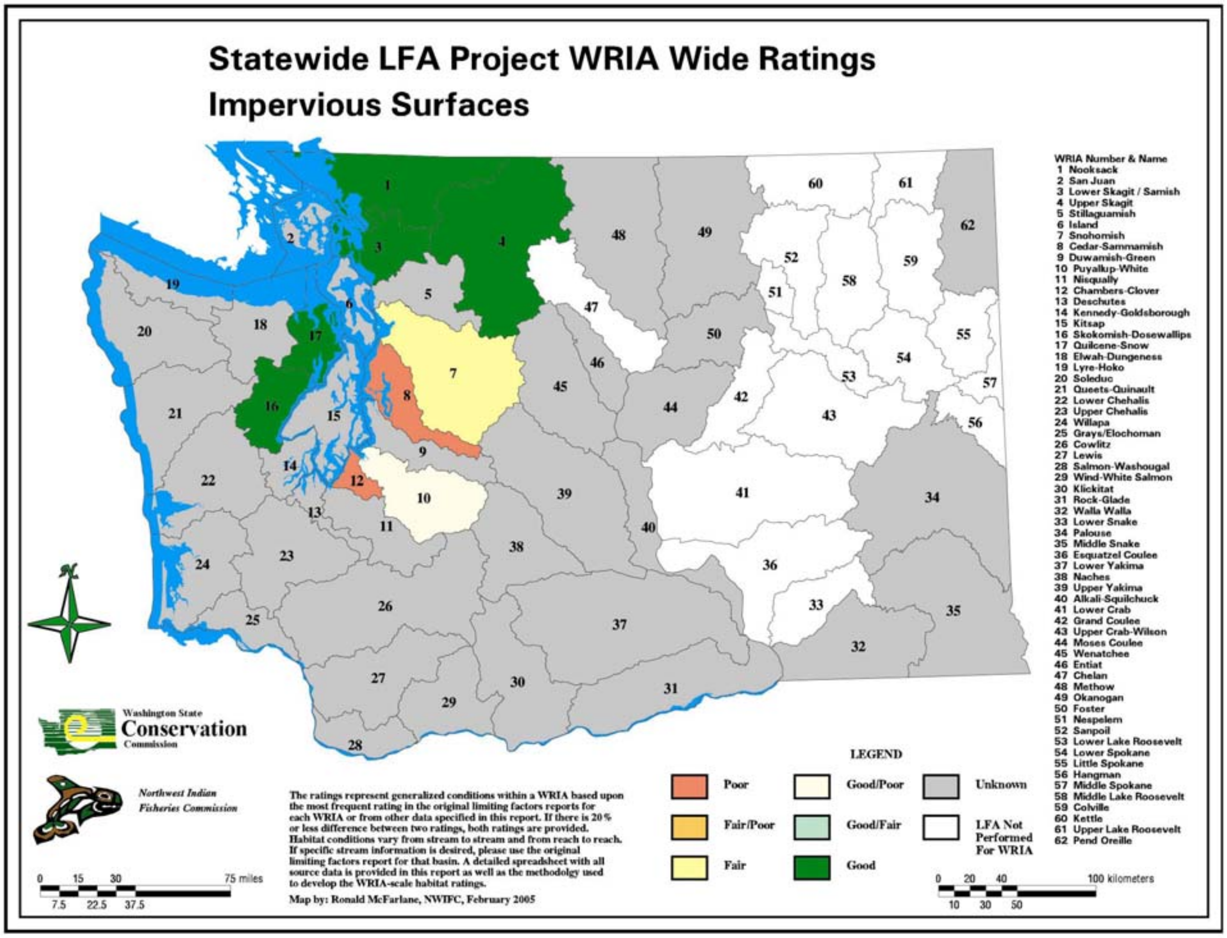


Figure 115. Map of impervious surfaces ratings by WRIA in Washington State.



High Flows and Land Ownership

Ratings for high flow conditions were mostly scattered throughout various percentages of federal and state owned land with one exception: WRIAs with 50% or greater federal land had only fair or better conditions (Figures 116-117). An opposite relationship was found with private land ownership where no poor ratings were found in WRIAs with 40% or less private land (Figure 118). It should be noted though that good and fair conditions were found in areas with low percentages of federal land as well as high percentages of private land.

Figure 116. High flow conditions based upon the percent federal land.

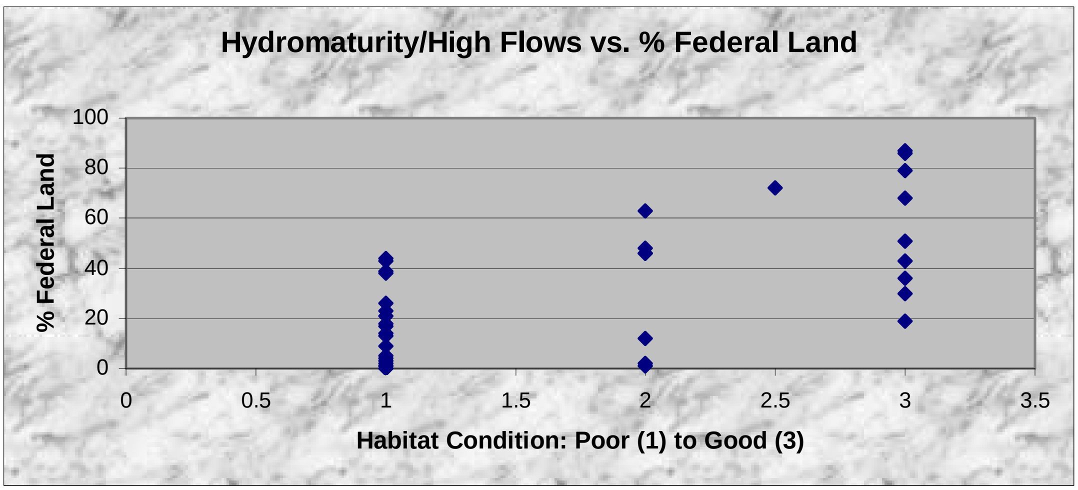


Figure 117. High flow conditions based upon the percent of state owned land.

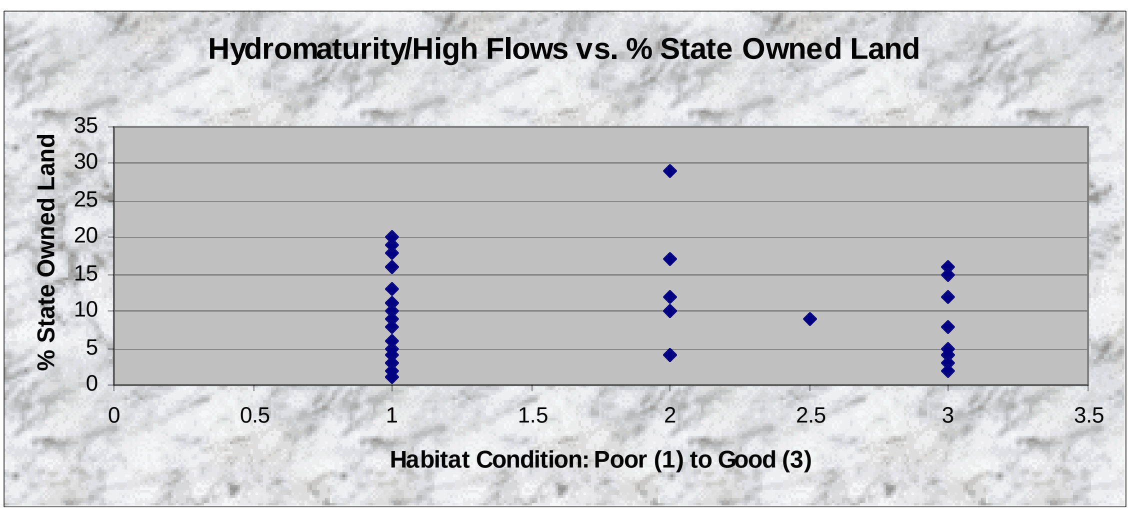
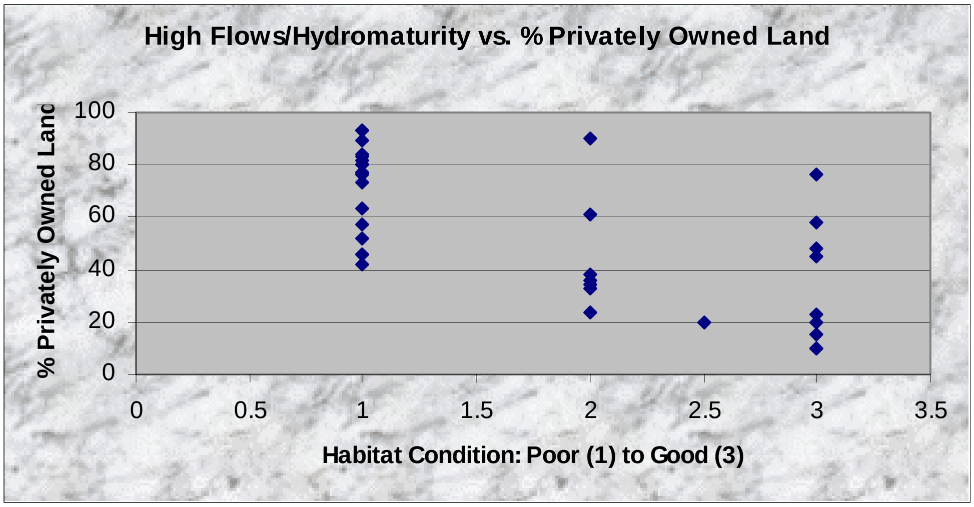


Figure 118. High flow conditions based upon percent of private owned lands.



High Flow Conditions and Land Use

While the results of high flow ratings on forest and agricultural land are scattered without any pattern (Figures 119-120), basins with a high level of urban land or a high human population density had only poor ratings (Figures 121-122). This is not surprising because these high flow ratings are often based upon land cover vegetation type and age, which is generally very altered in urban areas. Poor rated WRIAs also occurred without high urban and population densities, indicating that even though it is relatively certain to have poor land cover in basins with significant urban development, such development is not the only cause of poor high flow conditions.

These same high urban areas have poor floodplain conditions as well, such as levees and bank hardening. The impact of high flows is worsened by bank hardening because it keeps the high energy flows in the channel longer rather than allowing the river to spread out over the banks (Willams P. and Associates Ltd. 1996). The higher flows then scour the bottom where salmon eggs are incubating.

Figure 119. High flow ratings by WRIA based on percent forestland.

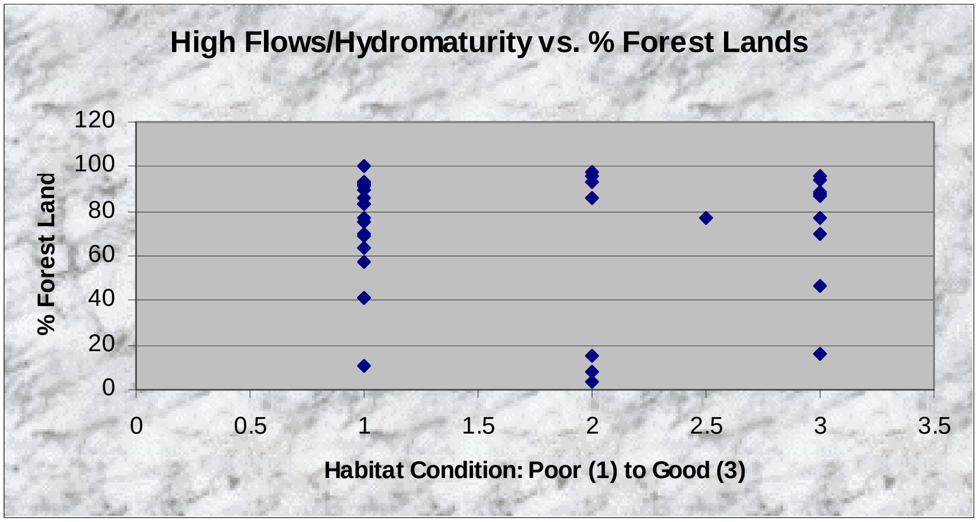


Figure 120. High flow ratings by WRIA based on percent agricultural land.

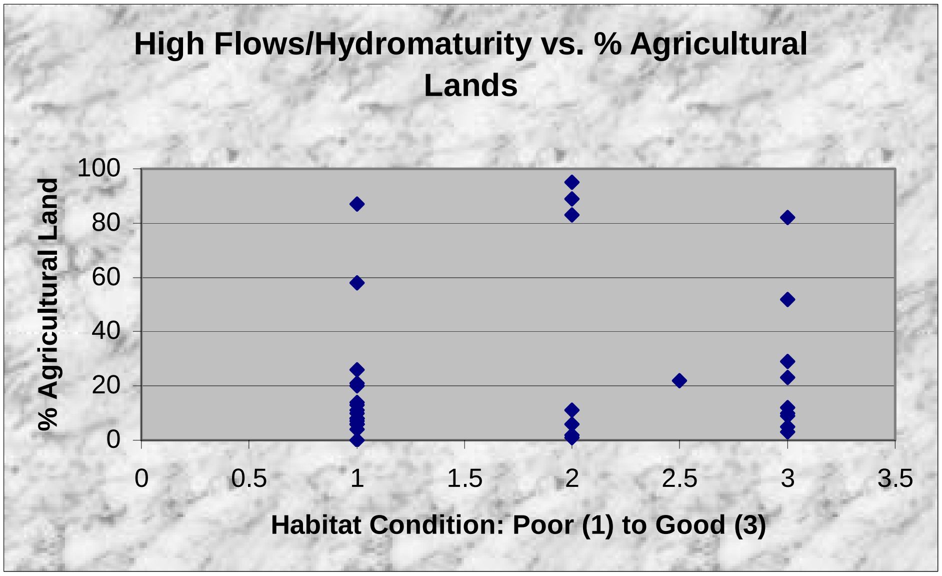


Figure 121. High flow ratings by WRIA based upon percent urban land.

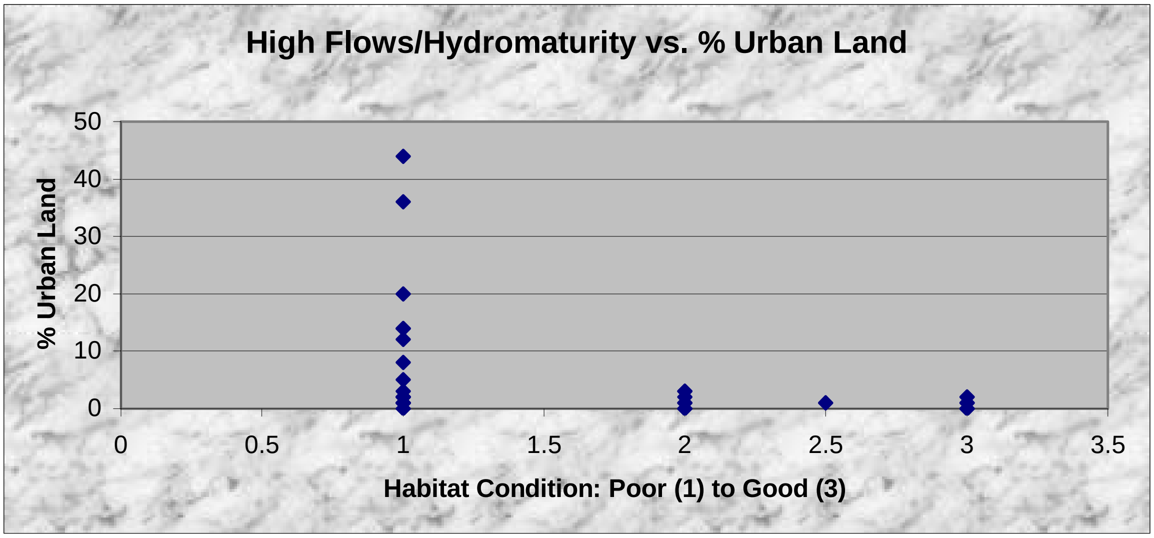
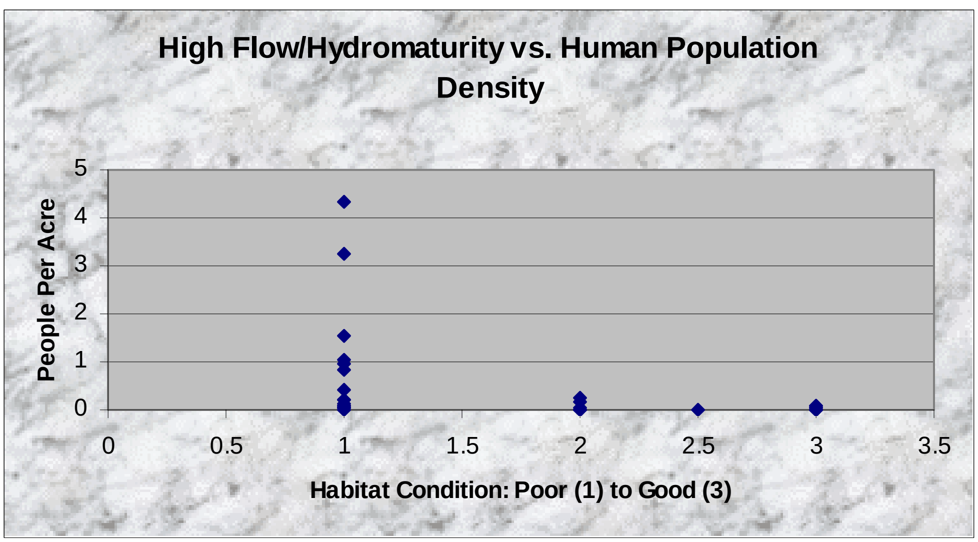


Figure 122. High flow ratings by WRIA based on people per acre.



Data Gaps in High Flow Conditions

The above assessments did not include Palouse, Kennedy, Entiat, San Juan, Rock/Glade, Moses Coulee, Island, Wind/White Salmon, and Klickitat due to a lack of data. However, water quantity data are lacking for all basins in many respects. Linking flows with salmon production is important and only done in very few basins. In addition, tracking trends in flows, flow duration curves, and patterns in high (and low) flows are other important data needs, but when stations are not consistently funded, trends cannot be monitored.

Other data needs include information on natural water storage such as wetlands; the role of groundwater in the basin; runoff impacts including impervious surfaces; and the extent and impact of draining, ditching, and dams.

STATEWIDE SALMONID LOW FLOW CONDITIONS

Introduction

Low stream flows greatly impact salmonids in different ways. In the summer months, low flows reduce juvenile rearing habitat and upstream migration or access to spawning habitat, and can increase water temperatures, predation, and competition. If spawning has already occurred, extreme low flows can dewater redds, killing eggs that are incubating in the gravel. The major cause of unnatural low flows is water withdrawals. This includes irrigation, industrial, domestic use, and water transfers between basins. Removal of water, either directly from the stream channel or from wells that are in hydraulic continuity with stream flows, reduces the amount of instream flow and useable wetted area remaining for support of adult salmonid spawning and juvenile rearing. Other contributing factors include a loss of wetlands (wetlands recharge streams during low flow periods), ditching and drainage which speeds runoff and lowers the quantity available for later recharge, and altered land cover which can effect transpiration (water evaporation from plants).

Lowland streams are more susceptible to low flow impacts than those that receive meltwater from glaciers or snowpacks. Many lowland streams are rainfall dominated with most rainfall occurring from October through May. Summers are relatively dry and ground water supplies are almost entirely recharged from precipitation. Groundwater provides the majority of late summer flow to area streams (Molenaar and Noble 1970). The natural climate, degraded watershed conditions, and surface and groundwater withdrawals may all contribute to low and/or subsurface flows.

Rating low flow conditions is even more problematic than high flows. While smolt traps are in place during part of the high flow season so that freshwater outmigration can be linked to flows, no monitoring of salmon production to low flows is occurring. In addition, thresholds to define low flows have not been generally established for salmon production. In the limiting factors analysis reports, low flow conditions are rated poor under several circumstances. These include 303(d) listing for low flows, known salmon mortality due to flows, stream closures due to over appropriations when the stream produces species known to use the area during the low flow period, and when other studies have documented low flow problems for salmon in a particular stream that are not natural conditions. None of these circumstances are as clearly defined as many other standards such as those for water quality, LWD, and pool habitat.

Of the twenty-six basins that had some degree of low flow information, 77% were rated poor, 8% fair, and 15% good (Figure 123). It is likely that this over-estimates the real problem though because work is usually done where problems are suspected rather than using unbiased sampling. The basins that rated good are Queets, Willapa, Nisqually, and Palouse (Figure 124). Low flow problems are generally thought to be more of an issue on the east side of the state, but nearly equal numbers of basins were rated poor on both sides. Many of the poor rated westside WRIAs have human population density or growth (Snohomish, Lake Washington, Green, Chambers) that have a high demand for freshwater.

Figure 123. Low flow ratings by WRIA in Washington State.

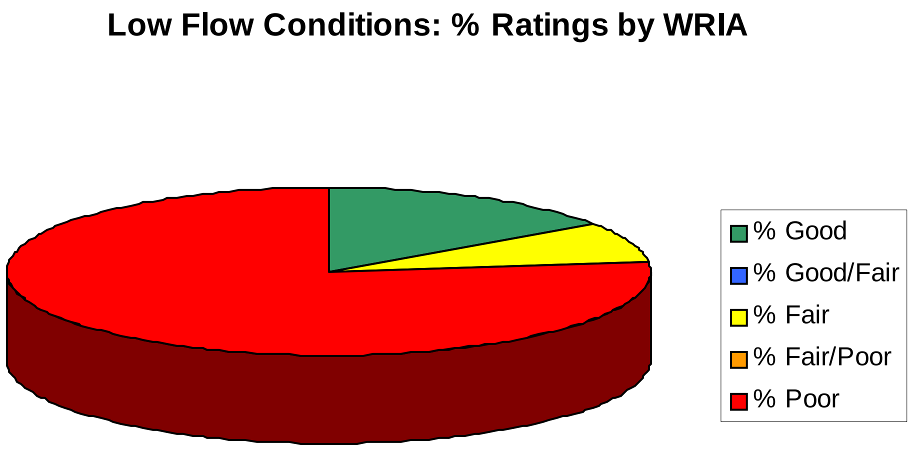
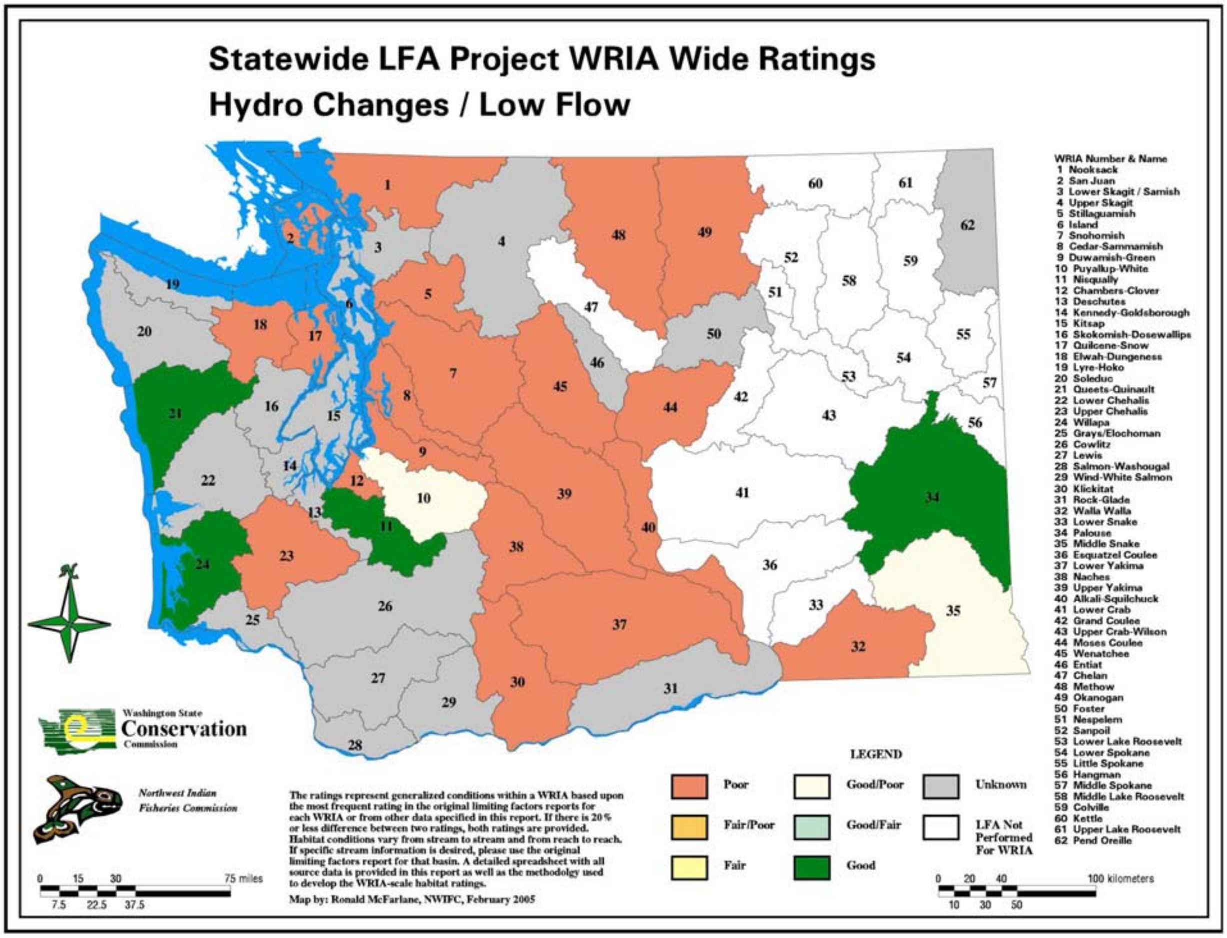


Figure 124. Map of low flow conditions by WRIA in Washington State.



Low Flow Conditions and Land Ownership

Because most basins had either one type of rating (poor) or a lack of data, strong conclusions could not be made regarding low flows and land ownership. The results are shown below, but low confidence exists regarding these results until more data are collected and better linkages to salmon production can be developed. With the sparse data, basins with high percentages of federal land ownership (50% or greater) had only poor ratings for low flow conditions (Figure 125). For state ownership, all of the fair and good rated basins had lower percentages of state owned lands (Figure 126), and results were scattered for private land ownership (Figure 127). Again, there are too many missing ratings to be able to rely on these results.

Figure 125. Low flow conditions based upon percent federal lands.

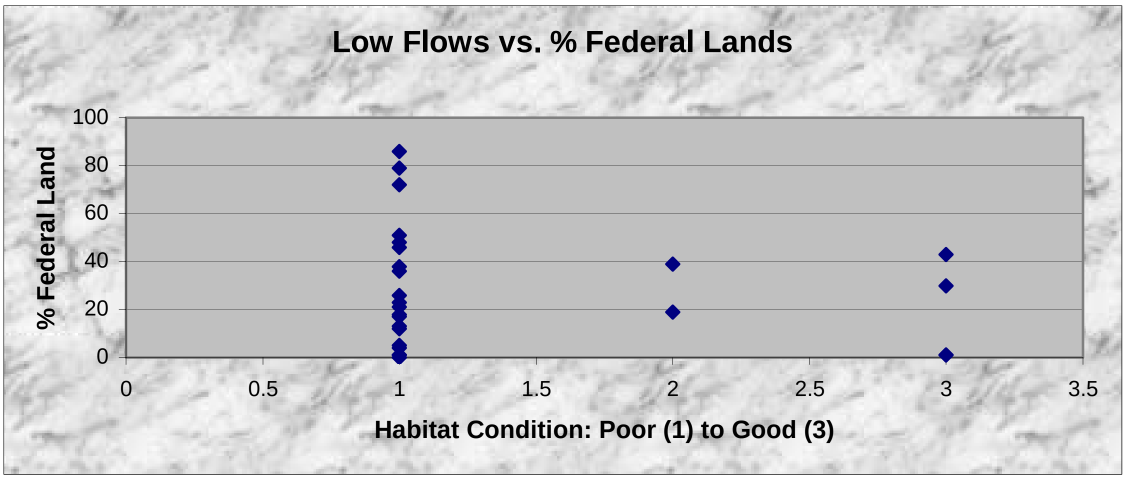


Figure 126. Low flow conditions by WRIA based upon percent state ownership.

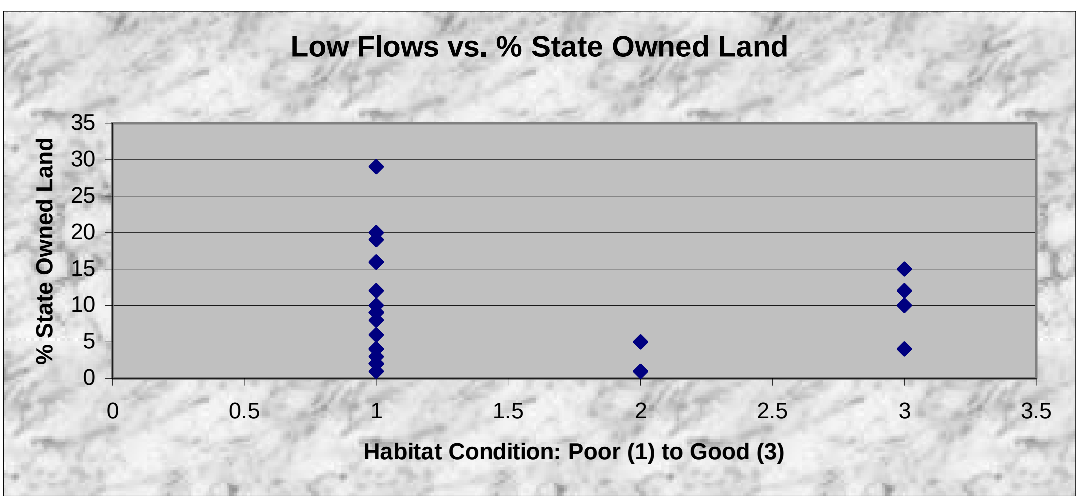
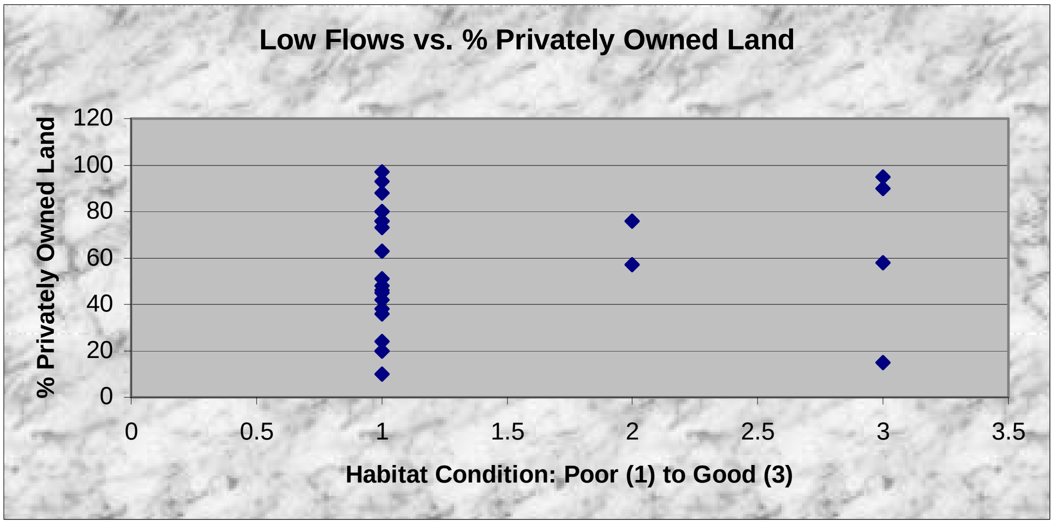


Figure 127. Low flow conditions based upon percent of private land ownership.



Low Flow Conditions and Land Use

The results are also sparse and scattered for land use conditions, particularly for forestland and agricultural land (Figures 128-129). Basins with high percentages of urban land or high human population density had poor ratings for low flow conditions and no fair or good overall ratings (Figures 130-131). Many poor rated basins for low flows also had low levels of human population and urban lands.

Figure 128. Low flow conditions by WRIA based upon percent forestland.

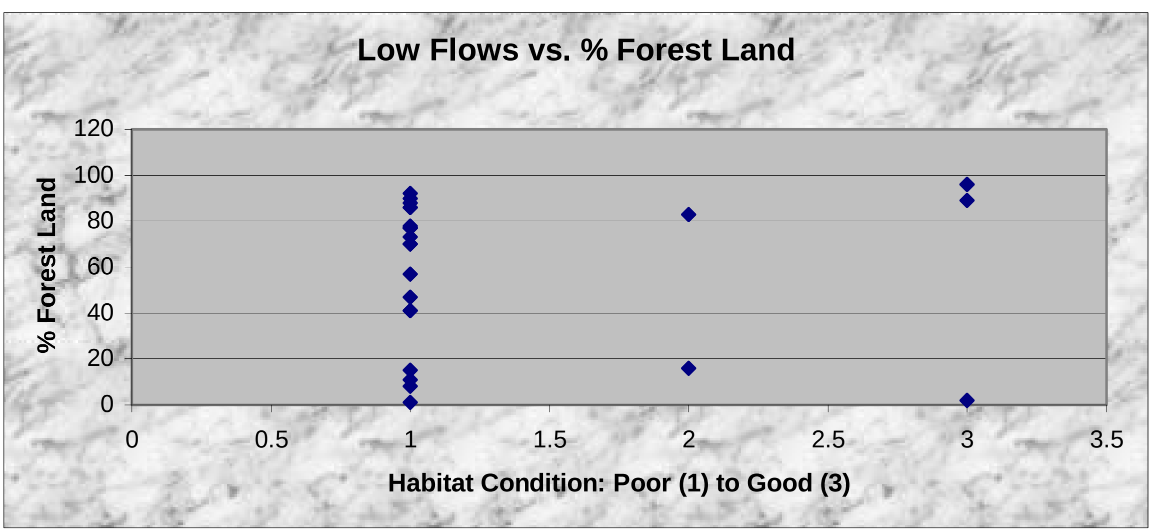


Figure 129. Low flow conditions by WRIA based upon percent agricultural land.

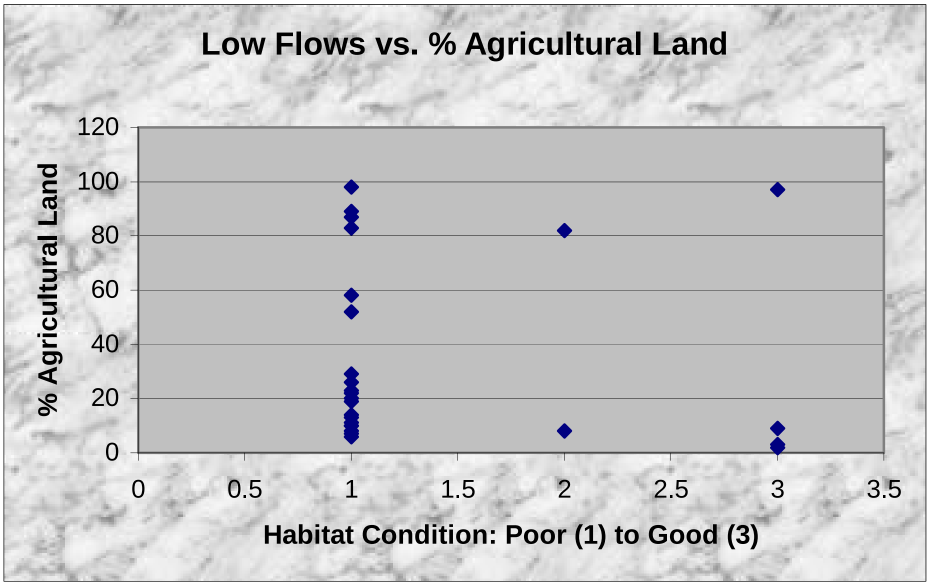


Figure 130. Low flow conditions by WRIA based upon percent urban land.

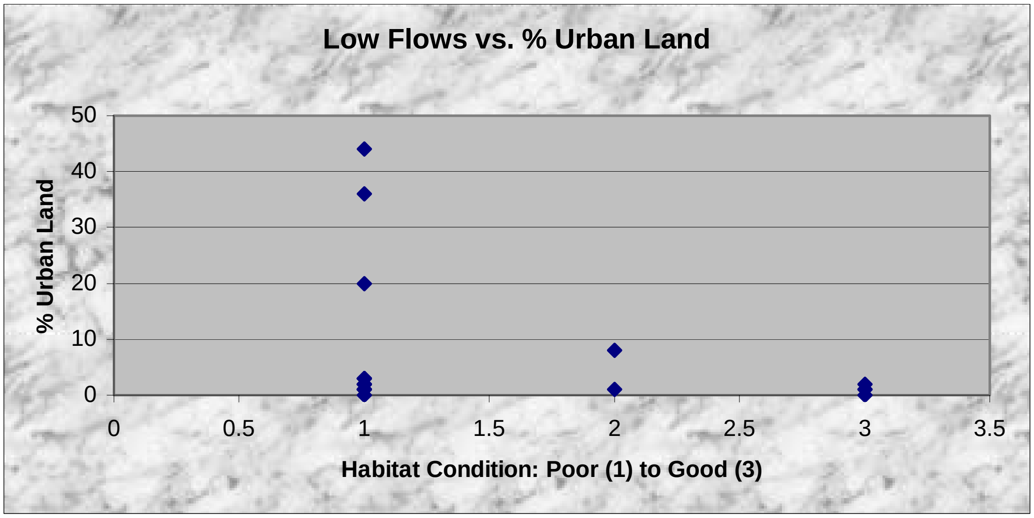
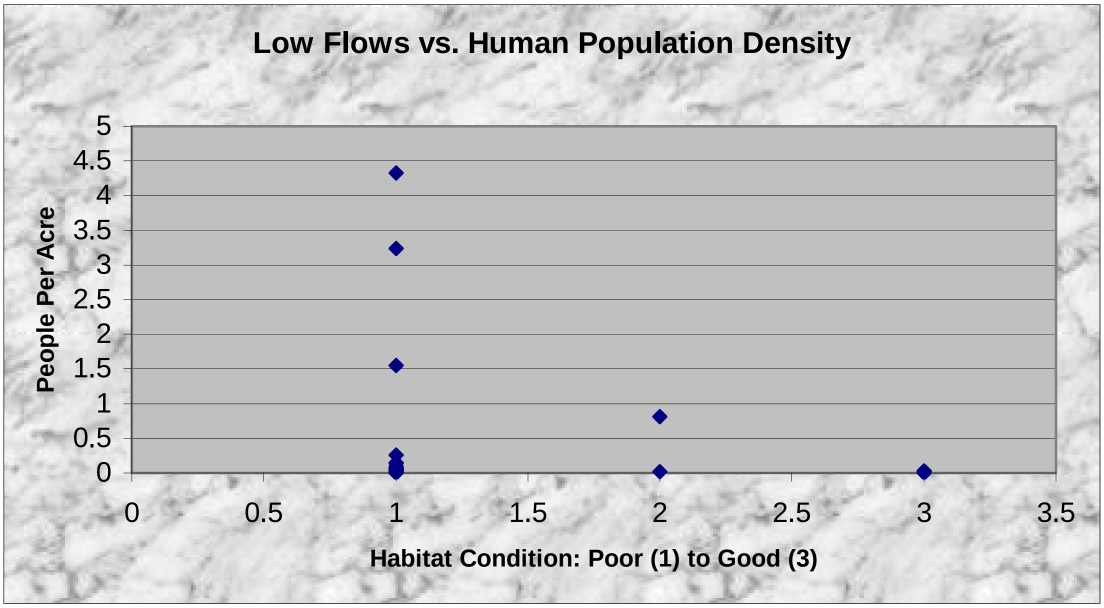


Figure 131. Low flow conditions by WRIA based upon people per acre.



Data Gaps and Low Flow Conditions

The data gaps for low flow conditions are extensive and the above results are inconclusive. While known low flow problems have been documented in select streams, there is a lack of linkage to salmon production, a lack of standardization regarding low flow thresholds, and a lack of trend monitoring of flows. These data needs are widespread. Many WRIAs were not included in the above analysis due to a greater lack of data. This reduces the sample size and the ability to detect patterns. Basins not included are lower Chehalis, Wind/White Salmon, Island, Grays, Rock/Glade, Entiat, Washougal, Lewis, Cowlitz, Hoko, Deschutes, Foster, Soleduck/Hoh, Kennedy, Kitsap, lower Skagit, upper Skagit, Pend Oreille, and West Hood Canal.

ESTUARINE AND NEARSHORE HABITAT

Estuary Habitat and Function

The estuarine delta in this report refers to a body of water adjacent to freshwater systems where saltwater mixes with freshwater. Estuaries serve many important functions such as providing habitat for smoltification, migration, rearing, and refuge, as well as contributing to habitat complexity and ecological processes, such as detritus (decaying plants) cycling (Williams and Thom 2000; Aitkin 1998). Vegetative biomass produced in the estuaries is exported as detritus, and is the primary fuel source for the estuary and nearshore marine detritus-based food webs upon which juvenile salmonids depend. For anadromous fish species, estuaries provide a critical mixing zone of fresh and salt water where juvenile and adult life stages can transition between freshwater and saltwater habitats. If the habitats necessary for successful rearing and predator refuge are not available within this mixing zone, the survival of these fish is jeopardized.

Estuary habitats produce a host of prey species important to juvenile salmonids and forage fish species, that are in turn, prey of adult salmonids. Certain prey items appear to be selectively chosen over others depending on the salmonid life history stage. For example, juvenile chum salmon feed on a certain type of copepod that lives on the bacteria near decaying eelgrass (Simenstad and Salo 1982). In order to support the diverse prey needs of the different salmon species and life history stages in the estuary, a mosaic of habitat types in an estuary need to be available and hydrologically accessible (via channels).

The blind (closed at one end) and distributary (open at both ends) channel habitats in the estuary provide juvenile salmonids access to estuary habitats producing preferred prey species (Shreffler and Thom 1993). In addition, the interaction of tides and channel habitats provides a delivery system that transports preferred prey species from estuary habitats that are not accessible by juvenile salmonids to obtainable areas.

Shallow channels also serve as migration corridors for juvenile salmonids, while deeper water distributary channels serve as migration corridors for adults (Shreffler and Thom 1993). These habitats provide juvenile salmonids protection and refuge from avian and fish predators, and serve as refuge from high water river discharge events. Distributary channels provide critical migration and movement routes between habitats.

Nearshore Habitat and Function

The nearshore environment is the interface between marine and terrestrial habitats, and extends from the outer limit of the photic zone to coastal landforms such as bluffs, sand spits, and coastal wetlands, including the riparian zone on or adjacent to any of these areas. Nearshore habitat functions as important migration corridors, rearing and refuge habitat, habitat for prey species, and detritus input (Williams and Thom 2000). Specifically, the nearshore intertidal and shallow sub-tidal habitats provide a critical migration corridor for juvenile salmonids, which use these areas for feeding, shelter from predators, and rearing. The nearshore riparian, intertidal, and shallow sub-tidal habitats produce a variety of prey species important to juvenile salmonids and forage fish species. The nearshore terrestrial, salt marsh, eelgrass, and macro-algae habitats are a valuable source of detritus that fuels the nearshore detritus-based food chain (Thom and Williams 2001). In addition, juvenile salmonids are dependent upon the intertidal, shallow sub-tidal, and marine vegetation communities for refuge from avian and fish predators until they transition to deep-water habitats. These are some examples of how the complex variety of nearshore intertidal, shallow sub-tidal, and sub-tidal habitats provide a wide range of diverse rearing and refuge opportunities to accommodate different juvenile chinook out-migration and survival strategies (reviewed in Cederholm et al. 2000).

The nearshore intertidal, eelgrass, and macro-algae habitats provide important spawning habitats for forage fish species that are important prey for juvenile and adult salmonids (reviewed in Cederholm et al. 2000). Examples of macro-algae are kelp beds, which provide food and shelter for a variety of species, including salmonids, and floating vegetation mats that provide transport in addition to food and shelter (Simenstad et al. 1991; Shaffer et al. 1995). Adult chinook and coho salmon use kelp beds for feeding and staging prior to freshwater re-entry (Shaffer 1998). Kelp also provides a spawning substrate for herring (Harrold et al. 1988). WRIA 20 (north coast) has 34% of state's kelp resources (Van Wagenen 1998), and has the highest density of kelp in the world (Dayton 1985).

Eelgrass provides several benefits for salmonids, including nursery habitat, food, protection from predators, and shoreline stabilization (Levings and Thom 1994). In eelgrass beds, about half of the primary productivity comes directly from eelgrass, while the other half comes from algae and diatoms that live on the eelgrass blades (Thom 1987). It is also an important component of nutrient cycling. Eelgrass beds have the greatest variety of epibenthic animals compared to salt marsh and mudflat habitat, with two of three species of copepods that are a major food source for fish, found only on eelgrass (Simenstad et al. 1988). Chum salmon feed on copepods that live on the bacteria near decaying eelgrass (Simenstad and Salo 1982), and eelgrass provides spawning substrate for herring, another prey item of salmonids (Humphreys and Hourston 1978).

Types of Estuarine and Nearshore Habitat Impacts

Shoreline modifications, such as dikes, dredging, and fills, have had a considerable influence on estuarine habitat in many areas of Puget Sound. These types of impacts interrupt the riverine and tidal hydrologic processes that create and support estuarine delta and nearshore habitats. Shoreline modifications can be detrimental by fragmenting the nearshore habitats, reducing habitat complexity, reducing sediment recruitment (erosion), and disrupting longshore sediment transport processes that support and sustain beaches of the upper intertidal habitats (Clark 1996). Other impacts caused by shoreline modifications include the loss of habitat and complexity that reduces refuge opportunities for juvenile salmonids. Shoreline modifications can also result in a loss of eelgrass and macro-algae habitats and the loss of associated prey and detritus production (reviewed in Nightingale and Simenstad 2001a).

Nearshore fills and dredging are other impacts to the nearshore habitat. They have been shown to be an obstacle to juvenile salmonid nearshore migration (reviewed in Nightingale and Simenstad 2001a). When the migration behavior of juvenile salmonids is altered, the risk of predation by avian and fish species is potentially increased.

Tidegates are openings in dikes to allow drainage of water from the land behind the dike and to prevent saltwater from intruding this land. Most tidegates pose a partial barrier to often historic estuarine habitat, but more importantly, they isolate significant estuary habitat and disconnect the riverine and tidal hydrologic processes that create and support estuary habitats (Brian Williams, WDFW, personal communication). This contributes to the loss and fragmentation of migration corridors, rearing habitats, and refuge habitats for juvenile salmonids.

Gravel/sand beaches provide spawning substrate for surf smelt and sand lance and are dependent on the longshore transport of sediment from feeder bluffs (Clark 1996). Large increases and decreases in the level of sedimentation can have impacts on the food web that supports salmonids. Excess sediment from land alterations is likely detrimental for certain plants, surf smelt, and herring (Levings and Moody 1976; Morgan and Levings 1989). For example, the densities of algae were significantly different following a landslide along Puget Sound that resulted in a sediment plume that lasted weeks (Shaffer and Parks 1994). Sediment transport processes are disrupted by shoreline modifications, filling, and dredging, as discussed above. However, specific sediment transport analyses are needed throughout Puget Sound, and no conclusions regarding sediment transport can be provided in this report.

Additional impacts to salmonids can occur from overwater structures. The shadow cast by overwater structures fragments the nearshore habitats (reviewed in Nightingale and Simenstad 2001b). The shadow cast by overwater structures has also been shown to change juvenile salmonid nearshore migration, and this altered behavior can potentially increase the risk of predation by avian and fish species, as well as reduce feeding success (reviewed in Nightingale and Simenstad 2001b). The shadow reduces the light available for photosynthesis thus impacting the health, survival and productive functions of the epiphyte, eelgrass, and macro-algae habitats and reducing the production of prey and detritus (Fresh et al. 1995; reviewed in Nightingale and Simenstad 2001b). One of the major concerns with overwater structure is their effect on eelgrass beds, although dredging, filling, and increased sediment (turbidity) are other common types of impacts to eelgrass beds.

The riparian vegetation along estuarine and nearshore environments constitutes a transition zone between tidally influenced aquatic habitat and terrestrial habitat, and provides several important functions. These can include shade, detritus input, marsh plant colonization, bank stability, wave energy deflection and absorption, large woody debris (LWD), and terrestrial insects which serve as salmonid prey, depending on the type of vegetation (Volk et al. 1984; Simenstad and Wissmar 1985; Everett and Ruiz 1993; Whitehouse et al. 1993; Maser and Sedell 1994). For example, Pentilla (2001b) compared the effect of shade on surf smelt egg survival, noting 36% dead eggs in shaded areas compared to 60% in non-shaded areas, underscoring the importance of riparian vegetation. Numerous species of marine riparian vegetation can be found, determined by environmental conditions such as salinity and soils. Residential bulkheads, residential view corridors, commercial shoreline armoring, dikes, culverts, and commercial fills are among the more common types of impacts that reduce riparian vegetation.

Invasive species are another common problem in some areas of Washington State. *Spartina* has been documented in the south coast and Puget Sound regions.

Another type of impact to estuarine habitat is water quality. Toxins and degradations that alter dissolved oxygen and water temperatures can be detrimental to salmonids or to the food web that supports salmonids. These problems are often related to industrial, urban, and agricultural activities. Elevated fecal coliform levels indicate degraded water quality conditions, and are most likely the result of failing septic systems, failures from sewage treatment plants, or farm animals.

Contaminated sediments are an important impact to estuarine habitat. Phthalates are a waste product of plastics and can accumulate in fish. Increased levels of organochlorines such as polynuclear aromatic hydrocarbons (PAHs) and polychlorinated biphenyls PCBs can be toxic, and accumulate in tissue, causing tumors and suppressing the immune systems in salmonids (Varanasi et al. 1993). These chemicals can also be lethal to benthic organisms, which serve as food for salmonids, resulting in a potential reduction of prey, and the toxins accumulate in benthic organisms, contaminating the food web. And, at least two studies have indicated that these toxins can impact herring (see EVS Environment Consultants 1999).

Estuarine and Nearshore Habitat Conditions in Washington State

From the expansive estuaries of the Columbia River and the south coast to small pocket estuaries of the north coast and the low-flushing, protected Puget Sound, the available data to assess conditions are as varied as the habitat itself. In Puget Sound, an extensive inventory of shoreline modifications, riparian vegetation, and overwater structures has been conducted by DNR (Berry et al. 2001), and it is important that continued monitoring occur for these parameters. Because some of the LFA reports were completed prior to this inventory, more data exists for nearshore conditions than what is found in many LFA reports, and readers are encouraged to seek estuarine and nearshore information in additional sources. For example in Island County, a recent compilation of eelgrass, sediment transport shore forms, and forage fish data can be found in the May 2005 WRIA 6 Multi-Species Salmon Recovery Plan (http://www.islandcounty.net/health/Envh/WRAC/WRAC%20Main.htm).

Many data gaps exist for the coastal estuaries with the exception of Willapa Bay, and while estuarine information exists for the Columbia River, none was included in the LFAs for two reasons. The primary focus of LFAs was on freshwater habitat rather than estuarine and marine, and in the Columbia River Basin, the focus was on tributary systems to the Columbia River not the mainstem and associated estuary. This report summarizes the available information that was provided in the individual LFAs, and doesn’t include information for the Columbia River estuary or studies that have been completed after individual LFA reports. Also, estuarine and nearshore habitat ratings are not provided in this report due to a lack of comparison standards.

The most common impacts reported in the LFAs include shoreline modification, loss of estuarine habitat by diking, loss of riparian vegetation, overwater structures, contaminated sediments, and *Spartina* invasion. Most of these impacts have been documented in Puget Sound with some areas much more heavily impacted than others. *Spartina* invasion is a large issue in Willapa Bay (WRIA 24) as well in some areas of Puget Sound and a small quantity in Grays Harbor. Shoreline modifications, loss of riparian vegetation, and overwater structures are considerable in the more urbanized areas of the state. Dikes, draining, and filling have resulted in a significant loss of estuarine habitat in several Puget Sound estuaries (Nisqually, Puyallup, Green, Snohomish, Stillaguamish, and Skagit) as well as in Willapa Bay, and huge alterations have occurred in the Lake Washington (WRIA 8) and Deschutes (WRIA 13) estuaries. Contaminated sediments are a particular concern in the industrialized basins, including Puyallup, Duwamish, Snohomish, and Bellingham Bay. Table 6 lists the known impacts reported in the original LFAs.

Table 6. General WRIA-wide estuarine concerns as listed in LFA reports.

WRIA	Estuarine Loss	Coastal Erosion	Shoreline Mods	Riparian Loss	Overwater Structures	Upland Sedimen-tation	*Spartina* or ulvoid	Sediment Contamination
1	Localized	NA	Moderate	Overall impact not quantified	Yes	NR	NR	Bell. Bay
2	NR	NA	NR	NR	Yes	NR	NR	NR
3	71% loss	NA	Localized	Overall impact not quantified	Localized	NR	Low Levels *Spartina*	Small localized areas
5	85% loss	NA	Good	NR	NR	NR	*Spartina*	NR
6	NR	NA	NR	Overall impact not quantified	NR	NR	*Spartina*	NR
7	Yes, but NR	NA	NR	NR	NR	NR	NR	NR
8	Yes	NA	Yes	Yes	Yes	NR	Low	NR
9	97% loss	NA	Yes not quantified	Overall impact not quantified	NR	NR	NR	Yes
10	99% loss	NA	Yes not quantified	Yes not quantified	NR	NR	NR	Yes

11	54% loss	NA	Yes not quantified	NR	NR	NR	NR	NR
12	NR	NA	NR	NR	NR	NR	NR	NR
13	Deschutes estuary greatly altered	NA	19-47%	NR	NR	NR	NR	Budd Inlet
14	NR	NA	Localized problems	NR	NR	NR	NR	NR
15	NR	NA	Yes, central	Yes, central	Overall impact not quantified	NR	NR	Yes, central area
16	NR	NA	NR	NR	Overall impact not quantified	NR	NR	NR
17	NR	NA	Yes	Yes not quantified	Overall impact not quantified	NR	NR	NR
18	NR	NA	Yes	NR	NR	Yes	Ulvoid	Port Angeles
19	NR	NA	Some reported, not large quantities	NR	NR	Yes	NR	NR
20	Quillayute	Southern WRIA	NR	NR	NR	NR	NR	NR
21	Good	Yes	NR	NR	NR	NR	NR	Not Likely an Issue
22	Inner Harbor	Yes	NR	NR	NR	NR	Low Level	Inner Harbor
24	North, Palix, Bear, Willapa	NR	NR	NR	NR	NR	Yes	NR

NR= Not Reported as quantifiable data in the original LFA.

NA=Not Applicable in this area

CONCLUSIONS AND DISCUSSION

Fish Stocks and Status Conclusions

- Out of 161 independent drainages in Washington State, three (Chehalis, Quillayute, and Skagit) produce 14% of the total, 17% of the wild, and 19% of the native salmon and steelhead stocks in the state.

- Twelve out of 161 drainages produce 35% of the total, 45% of the wild, and 38% of the native salmon and steelhead stocks in the state. The twelve drainages that produce the greatest number of total stocks are the Chehalis, Quillayute, Skagit, Snohomish, Cowlitz, Nooksack, Queets, Stillaguamish, Puyallup, Quinault, Lewis, and Dungeness.

- The percent of healthy stocks (versus healthy plus depressed or critical) varies widely across Washington State. The Snake River, upper Columbia, and lower Columbia regions have very low percentages of healthy wild salmon and steelhead stocks (0%, 0% and 11% respectively), while the mid-Columbia has 40%, Puget Sound 56%, and the coast 78% healthy wild salmon and steelhead stocks. Results are similar for native and total stocks. These percentages do not include stocks that have become extinct, many of which were in the Columbia River system. They also do not include stocks of unknown status.

Overall Freshwater Habitat Conclusions

- Washington ranks 20th in the nation in size and 15th in human population with ¾ of the State's human population located in the Puget lowlands.

- Coniferous forest covers 37% of the State, agriculture accounts for 21%, and urban lands comprise 2.5% (Cassidy et al. 1997).

- There is much that we don't know about habitat conditions, and where we have information, most of it suggests degraded habitat. Most (43%) of the WRIA-scale habitat ratings are data gaps followed by poor habitat conditions (38%) (Table 7). Only 13% of the ratings are good and 7% are fair.

- Data gaps are especially prevalent for water quality (particularly for water quality parameters other than temperature), sedimentation other than road density, and low flow categories. Data on pool habitat are even less common, but poor ratings in this category are often the result of impacts in landscape processes such as sedimentation, LWD, and riparian conditions, and these should be directly measured rather than measuring symptoms of a degraded process.

- Only one WRIA (Upper Skagit) had overall good habitat ratings in all categories that were not data gaps. Methow, Naches, and Nisqually had an overall fair-good rating with

11 additional basins rating fair overall. Nine basins rated poor-fair, but more (21) basins rated poor than any other rating.

Table 7. Percent of WRIA-wide habitat ratings by habitat categories.

Habitat Category	Percent Data Gap	Percent Poor	Percent Poor-Fair	Percent Fair	Percent Fair-Good	Percent Good
Access	24	31	4	18	0	22
Floodplain	9	62	16	11	2	4
Riparian	7	53	9	18	0	13
Sedimentation	16	40	7	29	4	4
LWD	27	62	2	4	0	4
Pools	40	36	7	11	0	7
Water Temperature	22	49	0	9	2	18
High Flows	20	42	0	16	2	20
Low Flows	42	44	0	4	0	9

Land Ownership and Freshwater Habitat Conditions

Habitat ratings in nine categories (access, floodplain, sedimentation, riparian, LWD, pool, water temperature, high flow and low flow) were related to land ownership, but most of the ratings were poor across all land ownership percentages and types with a low number of good or fair ratings. Also, parcel specific habitat information was not available. This resulted in an inability to produce correlations with p-values of .05 or less (statistically significant). However, some broad conclusions can be made.

- WRIAs with higher percentages of federal land had generally better ratings for nearly all of the habitat categories including: access, floodplain, large woody debris (LWD), riparian, high flow, and sedimentation conditions. Two of the three remaining categories (pools, and water temperature) were not associated with any specific extent of federal land ownership.

- Lower percentages of state owned land had typically better ratings for access, floodplain, and LWD conditions. Habitat data in other categories were too scattered to suggest a relationship with various percentages of state owned land.

- Lower percentages of private land ownership were generally associated with better ratings for floodplain, sedimentation, LWD, pool, and high flow conditions. Data in other categories were too scattered to suggest a relationship.

- Water temperature conditions were scattered across all land ownership types and percentages.

Land Use and Freshwater Habitat Conditions

- Forestry dominated WRIAs had generally better ratings for riparian, water temperature, and pool conditions, and nearly all of the fair to good rated WRIAs for access, floodplain, and LWD were in forestry dominated WRIAs.

- WRIAs with significant urban land use and/or higher human population densities had overall poor ratings in all but one habitat category. Poor rated categories include: access, floodplain, LWD, riparian, sedimentation, low flow, high flow, and pool conditions. The one category without a poor rating was water temperature, and this was due to widely scattered results.

- WRIAs dominated by agricultural lands had generally poor access, floodplain, and LWD conditions, while riparian and pool condition results were scattered across all percentages of agricultural land. Lower percentages of agricultural land were associated with better water temperature conditions.

Discussion

Habitat categories with the greatest percentage of poor ratings were floodplain, LWD, and riparian, while access (culverts), high flows (land cover), and water temperatures had the greatest percentage of good ratings. Data coverage was better for riparian conditions than any other category due to broad scale data from Lunetta et al. (1997). However, newer data are needed to continue to assess conditions in the future. Data collection programs exist for water quality data as well as for basic flow data in certain streams, but assessments are needed to monitor trends and relate flows to salmon use and production. At this time, there are no programs that are funded on a regular basis to monitor and assess access, floodplain, sedimentation, riparian, and instream habitat conditions.

When habitat conditions are related to land use, urbanized basins had generally the worst habitat conditions in most categories. Documented impacts include increased impervious surface area, which increases flooding frequency and magnitude (Hollis 1975) and decreased floodplain habitat by hardening banks and filling wetlands (Booth 1990; Beechie et al. 1994; Bradford and Irvine 2000). Urbanization often leads to a loss of native mature riparian vegetation as well. Salmon status and land use relationships have mixed results, and likely depend upon the species, life history stage, and geographic scale used. Ward (1999) found that depressed or critical chinook stocks were found throughout all types of land uses in the Snohomish Basin, while coho fry densities were negatively correlated with urban land use in British Columbia (Morlin 2000).

Basins dominated by forestry had the best habitat ratings compared to other land uses. This conclusion is supported by Pess et al. (2002) who reported greater numbers of fish in reaches surrounded by forestland. Adult coho salmon numbers decreased with increases in rural, agriculture, and urban lands (Pess et al. 2002).

WRIAs dominated by agriculture had ratings that were not as good as forestry-dominated basins, but generally not as bad as the overall ratings in more urbanized drainages. Agriculture has been associated with decreased floodplain habitat due to filled wetlands and hardened banks (Booth 1990; Beechie et al. 1994; Bradford and Irvine 2000). However, agricultural lands have a greater potential for salmon restoration compared to rural residential and urban lands because they are less altered than urban lands and because fewer owners own larger tracts of lands. Also, voluntary efforts have been underway to improve riparian conditions on agricultural lands. Broader scale monitoring is needed to determine the results of these efforts.

SALMONID HABITAT RATING STANDARDS FOR IDENTIFYING LIMITING FACTORS

Under the Salmon Recovery Act (passed by the legislature as House Bill 2496, and later revised by Senate Bill 5595), the Washington Conservation Commission (WCC) was charged with identifying the habitat factors limiting the production of salmonids throughout most of the state. The primary purpose was to guide lead entity groups and the Salmon Recovery Funding Board in prioritizing salmonid habitat restoration and protection projects seeking state and federal funds. Identifying habitat limiting factors required a set of standards that could be used to compare the significance of different factors and consistently evaluate habitat conditions in each WRIA throughout the state. In order to develop a set of standards to rate salmonid habitat conditions, several tribal, state, and federal documents that use some type of habitat rating system were reviewed (listed below). The goal was to identify appropriate rating standards for as many types of habitat limiting factors as possible, with an emphasis on those that could be applied to readily available data. Based on the review, it was decided to rate habitat conditions into three categories: good, fair, and poor. For habitat factors that had wide agreement on how to rate habitat condition, the accepted standard was adopted by the WCC. For factors that had a range of standards, one or more of them were adopted. Where no standard could be found, a default rating standard was developed by WCC, with the expectation that it will be modified or replaced as better data become available.

Salmonid Habitat Rating Criteria Source Documents.

Code	**Document**	**Organization**
Hood Canal	Hood Canal/Eastern Strait of Juan de Fuca Summer Chum Habitat Recovery Plan, Final Draft (1999)	Point No Point Treaty Council, Skokomish Tribe, Port Gamble S'Klallam Tribe, Jamestown S'Klallam Tribe, and Washington Department of Fish and Wildlife
ManTech	An Ecosystem Approach to Salmonid Conservation, vol. 1 (1995)	ManTech Environmental Research Services for the National Marine Fisheries Service, the US Environmental Protection Agency, and the US Fish and Wildlife Service

NMFS	Coastal Salmon Conservation: Working Guidance for Comprehensive Salmon Restoration Initiatives on the Pacific Coast (1996)	National Marine Fisheries Service
PHS	Priority Habitat Management Recommendations: Riparian (1995)	Washington Department of Fish and Wildlife
Skagit	Skagit Watershed Council Habitat Protection and Restoration Strategy (1998)	Skagit Watershed Council
WSA	Watershed Analysis Manual, v4.0 (1997)	Washington Forest Practices Board
USFWS Guidelines	A Framework to Assist in Making Endangered Species Act Determinations of Effect for Individual or Grouped Actions at the Bull Trout Subpopulation Watershed Scale	U.S. Fish and Wildlife Service
NMFS Criteria	Juvenile Fish Screen Criteria and the Addendum for Juvenile Fish Screen Criteria for Pump Intakes.	National Marine Fisheries Service
TAG 2002	The assessment of conditions is based on the professional knowledge and judgment of the Technical Advisory Group.	2496 WRIA 14 Habitat Limiting Factors Technical Advisory Group (See Acknowledgements)
WAC	Washington Administrative Code	State of Washington
WSP	Wild Salmonid Policy (1997)	Washington Department of Fish and Wildlife

The ratings adopted by the WCC are presented in Table 8. These ratings were used as a coarse screen to identify the most significant habitat limiting factors in a WRIA, not as thresholds for regulatory purposes. They provided a level of consistency between WRIAs that allows habitat conditions to be compared across the state. However, where data are unavailable or where analysis of data has not been conducted, the professional expertise of the TAG was sometimes used. In some cases, there may be local conditions that warrant deviation from the rating standards presented here.

Habitat Condition Rating

Habitat ratings by stream are summarized in a separate spreadsheet file as representative habitat condition ratings: good, fair, and poor by watershed. When insufficient information was available to make a habitat rating, it is listed as a data gap (DG). In addition, qualitative notes were added to ratings. If the rating is based upon old data, coarse data, modeled data (not verified by field visits in that stream, or professional judgment, the poor, fair, or good rating is followed by a DG1, DG2, DG3, or DG4. The DG denotes a data gap uncertainty regarding the rating and the number following the DG corresponds to a reason for the uncertainty. The number codes are listed in the spreadsheet with the rating data.

Table 8. Ratings Standards Used in the Limiting Factors Analysis Reports.

Habitat Factor	Parameter/Unit	Channel Type	Poor	Fair	Good	Source
Access and Passage						
Artificial Barriers	% known/potential habitat blocked by artificial barriers	All	>20%	10-20%	<10%	WCC
Floodplains						
Floodplain Connectivity	Stream and off-channel habitat length with lost floodplain connectivity due to incision, roads, dikes, flood protection, or other	<1% gradient	>50%	10-50%	<10%	WCC
Loss of Floodplain Habitat	Lost wetted area	<1% gradient	>66%	33-66%	<33%	WCC
Channel Conditions						
Fine Sediment	Fines < 0.85 mm in spawning gravel	All – Westside	>17%	11-17%	≤11%	WSP/WSA/ NMFS/Hood Canal
	Fines < 0.85 mm in spawning gravel	All – Eastside	>20%	11-20%	≤11%	NMFS
Large Woody Debris	pieces/m channel length	≤4% gradient, <15 m wide (Westside only)	<0.2	0.2-0.4	>0.4	Hood Canal/Skagit

Habitat Factor	Parameter/Unit	Channel Type	Poor	Fair	Good	Source
	or use Watershed Analysis piece and key piece standards listed below when data are available					
	pieces/channel width	<20 m wide	<1	1-2	2-4	WSP/WSA
	key pieces/channel width*	<10 m wide (Westside only)	<0.15	0.15-0.30	>0.30	WSP/WSA
	key pieces/channel width*	10-20 m wide (Westside only)	<0.20	0.20-0.50	>0.50	WSP/WSA
	* Minimum size	BFW (m)	Diameter (m)	Length (m)		
	to qualify as a key	0-5	0.4	8		
	piece:	6-10	0.55	10		
		11-15	0.65	18		
		16-20	0.7	24		
Percent Pool	% pool, by surface area	<2% gradient, <15 m wide	<40%	40-55%	>55%	WSP/WSA
	% pool, by surface area	2-5% gradient, <15 m wide	<30%	30-40%	>40%	WSP/WSA
	% pool, by surface area	>5% gradient, <15 m wide	<20%	20-30%	>30%	WSP/WSA
	% pool, by surface area	>15 m	<35%	35-50%	>50%	Hood Canal
Pool Frequency	channel widths per pool	<15 m	>4	2-4	<2	WSP/WSA

Habitat Factor	Parameter/Unit	Channel Type	Poor	Fair	Good	Source
	channel widths per pool	>15 m	-	-	chann width / pools/ mile / cw/ pool 50’ 26 4.1 75’ 23 3.1 100’ 18 2.9	NMFS
Pool Quality	pools >1 m deep with good cover and cool water	All	No deep pools and inadequate cover or temperature, major reduction of pool volume by sediment	Few deep pools or inadequate cover or temperature, moderate reduction of pool volume by sediment	Sufficient deep pools	NMFS/WSP/ WSA
Streambank Stability	% of banks not actively eroding	All	<80% stable	80-90% stable	>90% stable	NMFS/WSP
Sediment Input						
Sediment Supply	$m^3/km^2/yr$	All	> 100 or exceeds natural rate*	-	< 100 or does not exceed natural rate*	Skagit
	* Note: this rate is highly variable in natural conditions					
Mass Wasting		All	Significant increase over natural levels for mass wasting events that deliver to stream	-	No increase over natural levels for mass wasting events that deliver to stream	WSA
Road Density	mi/mi^2	All	>3 with many valley bottom roads	2-3 with some valley bottom roads	<2 with no valley bottom roads	NMFS
	or use results from Watershed Analysis where available					
Riparian Zones						

Habitat Factor	Parameter/Unit	Channel Type	Poor	Fair	Good	Source
Riparian Condition	• riparian buffer width (measured out horizontally from the channel migration zone on each side of the stream) • riparian composition	Type 1-3 and untyped salmonid streams >5' wide	• <75' or <50% of site potential tree height (whichever is greater) OR • Dominated by hardwoods, shrubs, or non-native species (<30% conifer) unless these species were dominant historically.	• 75'-150' or 50-100% of site potential tree height (whichever is greater) AND • Dominated by conifers or a mix of conifers and hardwoods (≥30% conifer) of any age unless hardwoods were dominant historically.	• >150' or site potential tree height (whichever is greater) AND • Dominated by mature conifers (≥70% conifer) unless hardwoods were dominant historically	WCC/WSP
	• buffer width • riparian composition	Type 4 and untyped perennial streams <5' wide	<50' with same composition as above	50'-100' with same composition as above	>100' with same composition as above	WCC/WSP
	• buffer width • riparian composition	Type 5 and all other untyped streams	<25' with same composition as above	25'-50' with same composition as above	>50' with same composition as above	WCC/WSP
Water Quality						
Temperature	degrees Celsius	All	>15.6° C (spawning) >17.8° C (migration and rearing)	14-15.6° C (spawning) 14-17.8° C (migration and rearing)	10-14° C	NMFS
Dissolved Oxygen	mg/L	All	<6	6-8	>8	ManTech

Habitat Factor	Parameter/Unit	Channel Type	Poor	Fair	Good	Source
Hydrology						
Flow	hydrologic maturity	All	<60% of watershed with forest stands aged 25 years or more	-	>60% of watershed with forest stands aged 25 years or more	WSP/Hood Canal
		or use results from Watershed Analysis where available				
	% impervious surface	Lowland basins	>10%	3-10%	≤3%	Skagit

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