and isolated populations that were once connected, such as those in the Middle Fork Nooksack, upper and lower Skagit, Puyallup, Elwha, Skokomish and White Rivers: although information on historic use of upper watersheds by bull trout is incomplete in many locations, it is thought that diversion dams, hydroelectric facilities and pipeline crossings have formed migratory barriers in the Nisqually and lower Green Rivers (USFWS, 2004).

"The Sound might have absorbed some environmental impact 100 years ago, but we have pushed our Puget Sound ecosystem to the limit."

Christine Gregoire, Governor

Habitat Factors Limiting Salmon Production

None of the pioneers and their followers who were drawn to Puget Sound to farm, produce lumber, or build communities and jobs came with the intent of destroying salmon, but incrementally and collectively these activities degraded the habitat and caused long term declines in fish abundance, productivity, spatial distribution and diversity. Some of the change was obvious to the naked eye, as trees were removed, dams built and areas paved. Other changes that affected stream temperatures, water chemistry and the food web for salmon were more insidious. Despite the change, salmon continued to return for generation after generation, but in the late 20th century the collective impacts exceeded their capacity to continually perpetuate themselves.

Loss of Habitat-Forming Processes

Salmon depend on habitat variety to find food and avoid predators — the suite of pools, riffles, boulders, logjams, side channels, wetlands and other features of their rivers; and the saltwater sloughs, marshes, eelgrass and kelp beds in the marine environment. The simplification of habitat features caused by vegetation removal and construction along streambanks and shorelines has had a pervasive and cumulative effect. The structural diversity that enabled salmon to thrive was built over centuries by the complex interaction of light, water, soil, vegetation and nutrient cycles. Salmon evolved to stream conditions that had cyclical disturbances varying by days, decades and centuries. Human activities modified these constant cycles of change by increasing the frequency of disturbance, altering the magnitude of disruption, and affecting the ability of the stream channel to respond.

Most devastating to the long term viability of salmon has been the modification of the fundamental natural processes which allowed habitat to form, and recover from disturbances such as floods, landslides, and droughts. So critical are these driving processes that Spence et al. (1996) state that " ...salmonid conservation can be achieved only by maintaining and restoring these processes and their natural rates." Among the physical and chemical processes basic to habitat formation and salmon persistence are floods and droughts, sediment transport, heat and light, nutrient cycling, water chemistry, woody debris recruitment and floodplain structure. Important biological processes that depend on habitat dynamics include migration, adaptation, the complex energy transfers of the food chain, and the metabolism of the fish.

Vegetation removal has also altered the hydrologic system in many watersheds, affecting the watershed's retention of moisture and increasing the magnitude and frequency of peak and low flows. Wetlands play an important role in hydrologic processes, as they store water which ameliorates high and low flows. The interchange of surface and groundwater in complex stream and wetland systems helps to moderate stream temperatures. Forest wetlands are estimated to have diminished by one-third in Washington State. (Spence et al., 1996; FEMAT, 1993)

Despite the improvement in timber practices, many long lasting effects from timber harvest continue to degrade aquatic habitat. Surface erosion and slope failure from logging roads are an ongoing

Land Use Activity	Habitat-Forming Processes						
	Vegetation / Organic matter	Hydrology	Thermal Regime (temperature/ light)	Soils	Nutrients	Chemical Composition	Riparian Function and Floodplain Dynamics
Forestry	Timber harvest removes the forest canopy, changes the composition of tree species, and modifies the type and rate of input of leaves and other organic matter into streams, thereby affecting the food supply for salmon.	Vegetation removal alters the water storage capability of the watershed, changes the timing of runoff, and may increase the magnitude and frequency of peak flows and low flows. Peak flows may scour redds and cause mortality to juveniles. Low flows limit spawning and migration.	Summer stream temperatures are documented to increase by 3-8°C following clearcutting and up to 16°C in small watersheds, and may take many years to recover. High temperatures stress salmon and in extreme cases can cause mortality.	Mass failures may result from road construction or vegetation removal on unstable slopes. Surface erosion from bare soil also changes the rate of soil input to a river system. Soil compaction results from equipment use during harvest. Soil transfer alters availability of spawning gravel. Fine sediments can severely impact eggs and juveniles.	Vegetation removal leads to a loss or reduction of the nutrient supply and changes the normal rate of decomposition and input of nutrients.	Use of fertilizers herbicides, pesticides and other chemicals alters water chemistry and some substances are toxic to salmon, resulting in direct mortality, reducing resistance to disease, or ability to reproduce.	Timber harvest removes the large woody debris that provides structure for stream channel features such as pools and riffles.
Agriculture	Conversion of woodlands and wetlands removes riparian vegetation.	Forest clearing alters soil retention of water, which is further exacerbated by ditching and draining to create crop lands. Runoff timing and patterns are altered. Irrigation directly removes instream flows, affecting the availability of spawning and rearing habitat.	Loss of shade along riparian corridor increases stream temperatures as do return flows from irrigation. Low flows, sedimentation and nutrient input further exacerbate temperature problems.	Agricultural crop practices may increase surface erosion with substantial sediment input into streams.	Runoff from animal waste and other farm activities increases the nutrient load and depletes the oxygen available for salmon	Use of fertilizers, herbicides and pesticides alter the water chemistry and may result in direct mortalities or the alteration of physical condition of salmon.	To create and protect agric. lands, stream channels have been straightened and banks have been armored removing low velocity side channels. Diking of estuarine sloughs has removed the quantity and quality of lower river rearing habitat.
Urbanization	Severe, permanent alteration of vegetation.	Impermeable surfaces create permanent loss of water infiltration to soil and stormwater runoff is rapid and severe. Water withdrawals for urban and industrial supplies deplete instream flow.	Loss of shade increases summer maximum and may decrease winter minimum stream temperatures. Disruption of groundwater input will reduce its moderating effects on stream temperatures.	Construction activities create intensive short term sediment input.	Loss of leaf matter from vegetation is replaced with nutrient input from sewage, fertilizers and other sources.	Stormwater runoff includes oils, pesticides, metals and other toxic substances.	Permanent severe alteration of meandering stream channel and wetland structures. Bank hardening, fill and dikes remove other habitat features. Dikes isolate or fragment habitat and increase stream velocity.

Figure 3.7 Relationship of forestry, agricultural and urban land use activities to habitat processes affecting salmon.*

A more complete discussion of these relationships including other land use activities is contained in “An Ecosystem Approach to Salmonid Conservation” also known as the “Man Tech” report by Spence, et al. 1996. Additional discussion of applying information on habitat characteristics to recovery planning is contained in, “Ecosystem Recovery Planning for Listed Salmon: An Integrated Assessment Approach for Salmon Habitat” by Beechie, et al., 2003.

Figure 3.7 outlines the ways that some of the major land use activities in the Pacific Northwest have modified the fundamental and interlinking processes that egetation is a key component of the light and temperature regimes in stream systems. The logging, farming and development activities described previously removed streamside veget

survive. Summer stream temperatures have been documented to increase by 3 to 8°C (5.4 -14.4°F) following clearcutting and up to 16oC (28.8°F) in small watersheds (Spence, et al., 1996). High temperatures may stress or kill salmon outright, or limit the production of organisms they need for food. Water temperatures above the tolerance threshold for Chinook migration, rearing or emergence have been found in the Nooksack, Dungeness, Elwha, Green/ Duwamish, Skagit, Snohomish and Stillaguamish Rivers.

Poor riparian conditions can result in higher water temperatures which may stress or kill salmon. Photo courtesy the Washington State Salmon Recovery Funding Board.

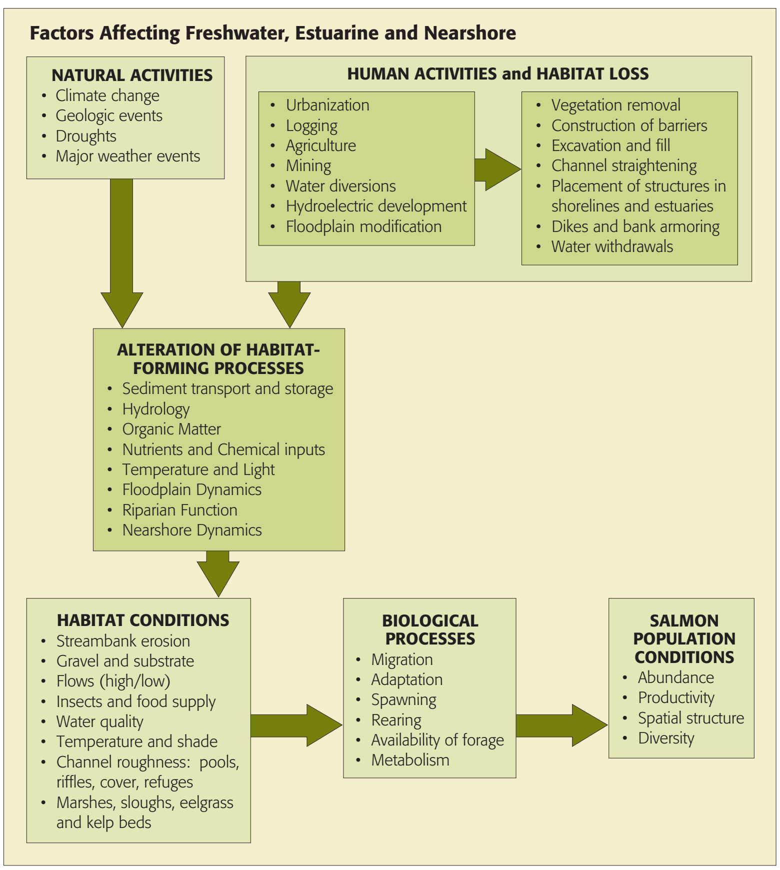


Figure 3.8

source of fine sediment and debris, with detrimental effects to salmon habitat. (Spence, et al., 1996; National Research Council, 1996) Sedimentation filled in many of the large deep pools in rivers and many river systems have been unable to recreate these essential habitat features for salmon, since the large wood that would serve as the structural raw material has been removed. Sediment input also results from urban construction and agricultural practices and the excessive input of fine sediments has been identified as a problem in every watershed into Puget Sound.

The toxic mix of oil, grease, pesticides and other pollutants carried by stormwater runoff alters the chemical processes of urban streams and creates dramatic shifts in their flow patterns. Recent studies by NMFS and the Seattle Public Utilities have also documented high rates of outright mortality to adult salmon still full of eggs and sperm, even in a creek where habitat had been restored. While the restoration of these urban creeks is essential to allowing greater numbers to spawn, the studies suggest that the control of polluted runoff from urban streets, lawns and parks and restoration of chemical balance is imperative to fish productivity (Scholtz, 2003).

Riparian function depends on vegetated banks, and the removal of large trees precludes the recruitment of large woody debris, essential to a varied channel structure. Dikes and levees generally have maintenance requirements that prohibit vegetation, largely eliminating the production of food for salmon and the recruitment of large woody debris for cover and diverse channel structure. Channelization and floodplain structures such as dikes reduce river sinuosity, increasing water velocity and reducing the volume of habitat. In many cases, floodplain structures eliminate the connection to side channels and wetland complexes where salmon once could rest and feed.

Guidelines for salmon recovery emphasize the need to address fundamental ecosystem processes by restoring vegetation, hydrology, channel structure and essential food supplies for salmon.

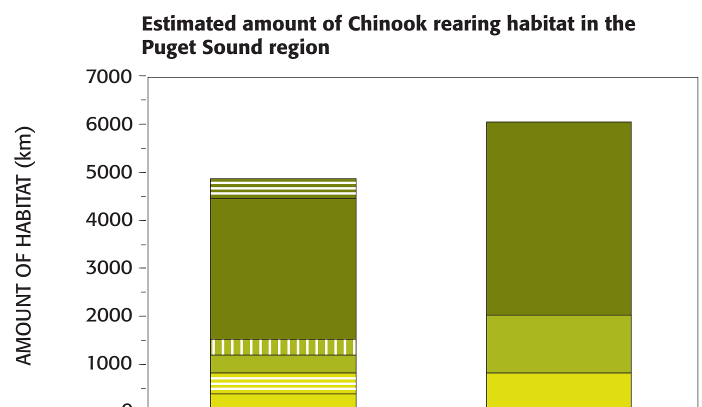
"Salmon are adapted to local environmental conditions....[that] vary in space and time due to landscape processes and land use. Because landscape processes (e.g., sediment supply, wood recruitment to streams) create and sustain habitats over time, an approach to habitat recovery that focuses on preserving or restoring ecosystem processes should provide good quality salmon habitat over the long term." (Beechie, et al.; 2003)

Technical Assessments of the Potential to Recover Chinook populations at the ESU Scale

Several "broad-brush" looks at habitat conditions in the entire Puget Sound ESU indicate that the potential capacity of watersheds to support Chinook spawning and rearing is still present in many watersheds. Coarse scale assessments of this nature are unable to factor in the varying levels of detail that have gone into habitat analysis in each watershed. Some watersheds have been able to assemble the resources to conduct studies of habitat factors in more depth than others. Additionally, the Sound-wide review has so far focused primarily on the quantity of potential habitat, and generally has yet to fully incorporate qualitative information. The individual watershed plans submitted in the Spring of 2005 contain a large amount of habitat information that will need to be assimilated into an ESU-wide assessment of habitat and its effect on VSP parameters.

Figure 3.9 contains a map depicting current and historical spawning capacity for Puget Sound Chinook populations, to display the varying levels throughout the Sound. Several watersheds still retain habitat with the potential to support spawning at historical capacity levels, although the quality may have been modified by flow diversions and other impairments. The Elwha River represents the opposite case, as it has lost approximately 85% of historical spawning capacity, but the quality of habitat above the dams has been fully retained since these areas are located in Olympic National Park. Dam removal, scheduled to begin in 2008, will restore access to these spawning areas.

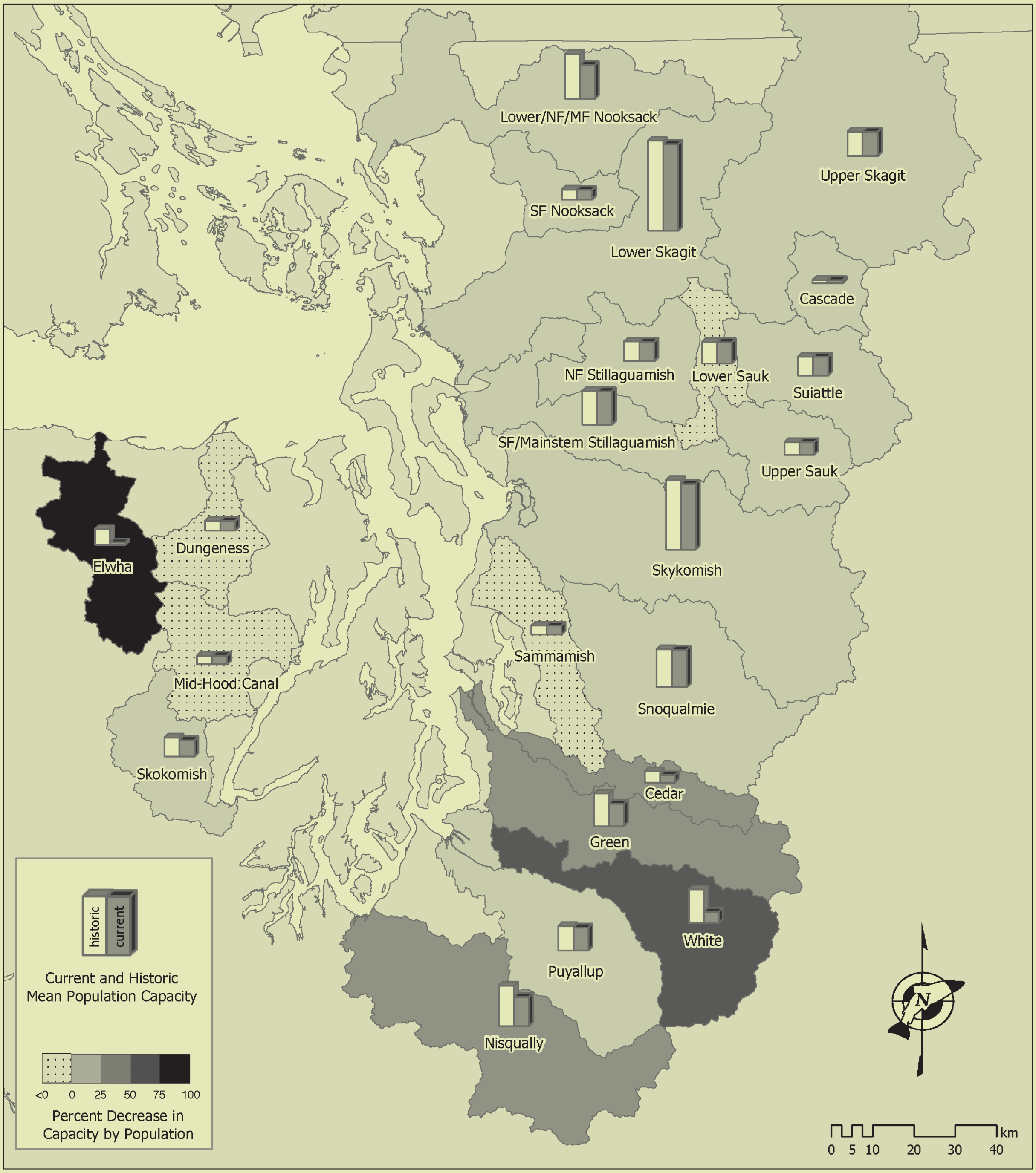
In addition to spawning capacity, NOAA Scientists have begun to collectively estimate changes in the amount of freshwater, estuary and nearshore rearing habitat in the Puget Sound region. Through airphotos, map layers and historical reports covering wetlands, vegetation and stream channel locations, rough estimates can be made of the amount



	Current (km)	Historical (km)
Freshwater habitat - modified	406.89	0.00
Freshwater habitat	2924.79	4011.35
Estuary habitat - modified	333.69	0.00
Estuary habitat	361.09	1186.91
Nearshore habitat - modified	440.82	0.00
Nearshore habitat	396.90	837.71

Notes: This graph depicts current and historical estimates of juvenile rearing habitat in the Puget Sound Region. Rearing habitat is divided into three habitat types: freshwater, estuary and nearshore. Current habitat is further divided into modified and unmodified amounts.

Figure 3.10 Courtesy NOAA Fisheries, NW Fisheries Science Center; M. Ruckelshaus



Historical Population Capacity Changes of Adult Chinook in Puget Sound ESU

Chinook Potential Spawning Capacity Estimates and Percent Decrease by Population

Population	Mean Capacity		% Decrease	Population	Mean Capacity		% Decrease
	Historic	Current			Historic	Current	
Lower/NF/MF Nooksack	62,027	47,046	24.2	Snoqualmie	52,525	51,828	1.3
SF Nooksack	13,648	13,392	1.9	Sammamish	12,406	12,468	0
Lower Skagit	124,563	119,786	3.8	Cedar	15,086	10,076	33.2
Upper Skagit	33,684	33,286	1.2	Green	45,247	31,419	30.6
Lower Sauk	29,437	29,378	0.2	White	46,232	15,601	66.3
Cascade	4,030	3,961	1.7	Puyallup	33,900	31,745	6.4
Suiattle	25,958	25,672	1.1	Nisqually	56,500	40,898	27.6
Upper Sauk	17,512	17,340	1	Skokomish	26,008	22,546	13.3
NF Stillaguamish	27,195	26,821	1.4	Mid-Hood Canal	12,166	12,288	0
SF/Mainstem Stillaguamish	46,108	45,837	0.6	Dungeness	12,852	12,912	0
Skykomish	96,501	91,279	5.4	Elwha	21,617	3,318	84.7

Figure 3.9 Courtesy NOAA Fisheries, NW Fisheries Science Center; M. Ruckelshaus

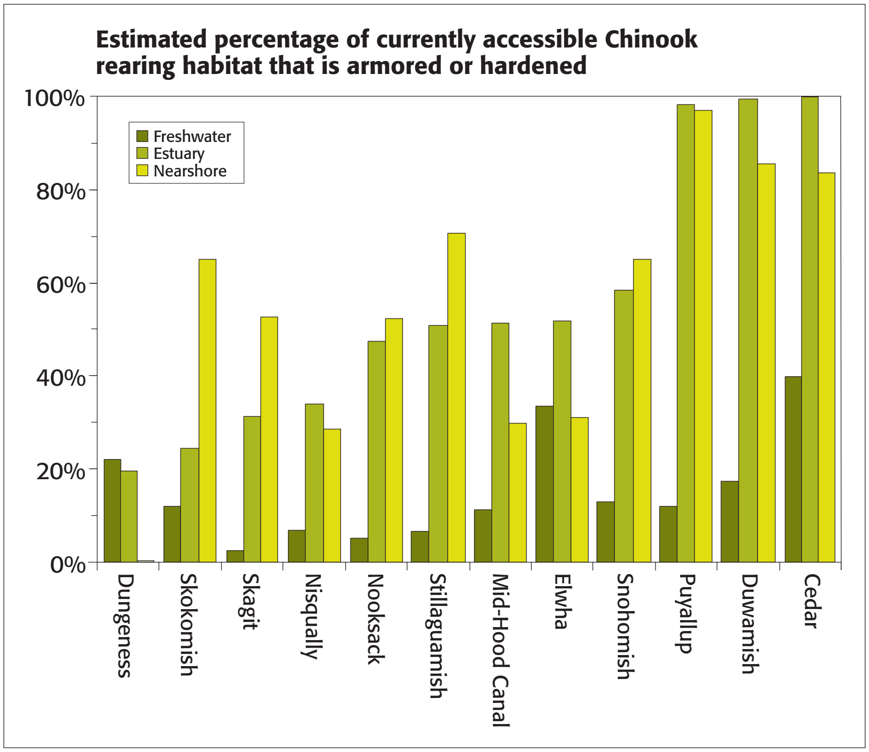


Figure 3.11 Courtesy NOAA Fisheries, NW Fisheries Science Center; M. Ruckelshaus

of Chinook rearing habitat in the region and the proportion that has been modified (figure 3.10). These estimates indicate that large quantities of juvenile rearing habitat remain relatively unmodified in portions of Puget Sound, and the connectivity and protection of these ecosystem features should be a focus for future study and action.

Additional analysis has been made of the percentage of bank armoring or hardening that has occurred in freshwater, estuary and nearshore environments. The extent of modification varies around the Sound, with extensive bank armoring or hardening in most of the river basins in South Puget Sound.

Studies such as these are assisting scientists with assessing the potential for improvements in VSP parameters at the scale of the entire Puget Sound Chinook ESU. This is particularly true for the spatial distribution and diversity parameters in the ESU since these will require a broader look than is possible watershed by watershed.

Technical Assessments of Habitat Factors at the Watershed Scale

Detailed technical analyses of the habitat factors affecting Puget Sound Chinook and other fish species are contained in the following reports and spatial information:

Salmon and Steelhead Habitat Inventory and Assessment Program: Since 1995, this cooperative project between the Northwest Indian Fisheries Commission and WDFW has characterized salmon habitat conditions and the distribution of salmonid stocks in Washington. The spatial data system is designed to utilize comprehensive, consistent data with sophisticated analytical tools to provide a variety of digital products and maps for regulatory and conservation efforts related to salmon in Washington. For each basin SSHIAP has information such as:

- Basin summary
- Land use relief map
- Escapement levels and stock status
- Limiting factors summary
- Map and list of impaired water bodies from the Clean Water Act 303(d)
- Surface water appropriation status
- Man-made blockages
- SRFB projects implemented

The SSHIAP program information is available on the website of the Northwest Indian Fisheries Commission [www.nwifc.org]. A sample of the products that are available through the SSHIAP program for the Nooksack basin are contained on the following pages.